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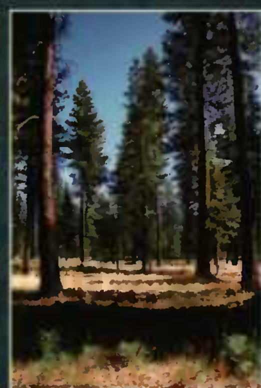

A COMPREHENSIVE MANUAL FOR FOREST MANAGERS

Oregon State UNIVERSITY | Extension Service

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Introduction

The forests of eastern Oregon are diverse—varying from pure stands of ponderosa or lodgepole pine to mixtures of the pines with Douglas-fir, larch, and grand and subalpine fir—and they have many values including clean water, recreation, wildlife habitat, livestock range, and timber.

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.

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. Chapters 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. A glossary, Appendix 1, defines many of the specialized terms used throughout the publication.

William H. Emmingham
May 2005

CHAPTER 1

Understanding eastside forest types

William H. Emmingham

This chapter will help you understand the general ecology and management of eastern Oregon forests and help you decide which forest type(s) you have. 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, and forest products you desire.

Geology and ecology of eastern Oregon forests

A basic understanding of the geology 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 what management strategy is likely to work best. The forests discussed here include those on the eastern slopes of the Cascade Mountains and on the Ochoco, Strawberry, and Blue mountains (Figure 1.1).

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

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 glaciations 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 Cascade Mountains were formed as active volcanos erupted violently and covered the surface with various forms of volcanic ash or molten lava.

Figure 1.2. A Wallowa Mountains landscape with a wide variety of forest types.

Less than 7,000 years ago, the violent eruption of Mt. Mazama formed Crater Lake. Coarse pumice deposits covered thousands of acres near the mountain, and fine ash layers were deposited across northeastern Oregon and beyond. Posteruption winds sometimes stripped fine ash from south slopes and deposited it on north slopes, or ash washed or sloughed off steep slopes and was deposited in valleys. All these geologic processes created variation in landforms and soils which, combined with slope, aspect, and elevation, created big differences in plant growth 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," forcing moisture from clouds before they arrive east of the mountains.

During summer, 3 to 5 months pass with insignificant amounts of rain, creating very stressful drought conditions for trees 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 tree stands. Coarse, gravelly deposits on hot, south slopes can create droughty sites with low productivity.

The net effect on the landscape is a complex pattern of forest types and growth conditions. All this variation means that management actions must be tailored to the changing 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 mixed-conifer, or cool mixed-conifer. A "forest type" indicates the potential for that soil and site to produce certain kinds of forest stands (see Figure 1.2). Before you make management decisions, it is important to know which type you have; with a little practice, it is possible to determine that (Table 1.1, opposite page).

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 mixed-conifer	Ponderosa or lodgepole pine, larch, Douglas-fir, grand fir, or species mixture
Subalpine or grand fir, lodgepole, Engelmann spruce, and larch, with or without other species	Cool mixed-conifer	Lodgepole pine, larch, or species mixture

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 be there. Historically, fire visited this type at short intervals, keeping stocking levels low. This is the climax pine type because ponderosa pine regenerates beneath itself. Pine regeneration is often poor or nonexistent due to long summer droughts, and productivity is low. The presence of a few Douglas-fir or grand fir in the understory indicates more moisture and puts the site into the warm mixed-conifer forest type.

Figure 1.4. Lodgepole pine stand with a pine overstory and a subalpine understory, indicating that this is a cool 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, and on high-elevation plateaus. A primary climate factor for lodgepole pine types is heavy frost during spring and summer, when seedlings are growing. Of the common tree species, lodgepole pine is the most tolerant of frost. Its ability to escape 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 in 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 (Figure 1.4).

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 eastern Oregon that are not limited by drought and spring or summer frost. Historically, fire visited these types sporadically at longer intervals than the ponderosa type, and fire intensity varied from light to intense depending on fuel accumulation. The mixed-conifer forests can be divided into two subtypes based on temperature and moisture conditions.

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

The **warm mixed-conifer type** occupies the warmer and drier end of the spectrum. 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. 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 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 (Figures 1.4, page 3, and 1.6). Typically, lodgepole pine or larch dominates the early successional stages, 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 where cold air drainage and deep frost eliminate the other species.

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 mixed-conifer type. Engelmann spruce or subalpine fir are key indicators of the cool mixed-conifer type. The pines, larch, and Douglas-fir can be found in either type.

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

Exceptions to the simple rules for determining forest type occur where fire or logging and reforestation have modified species distribution. For example, you may find mostly pine instead of a mix of pine, 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, reference 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 mixed-conifer. Productive potential drops again at the cold end of the cool mixed-conifer type, mainly because of the short, cool growing seasons. Site index is a measure of site potential based on how fast trees grow to a certain height; see Chapter 2, page 28, 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 mixed-conifer types, it is especially desirable to keep a substantial component of ponderosa pine and/or western larch because they resist defoliation by spruce budworm or Douglas-fir tussock moth. 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. Several Extension publications will help you understand more fully how to manage eastern Oregon forest types. They include *Thinning: An Important Timber Management Tool,* PNW 184; *Using Precommercial Thinning to Enhance Woodland Productivity,* EC 1189; and *Forest Health in Eastern Oregon,* EC 1413 (see Appendix 4, pages 203–204).

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 well, 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 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 eleveation 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.

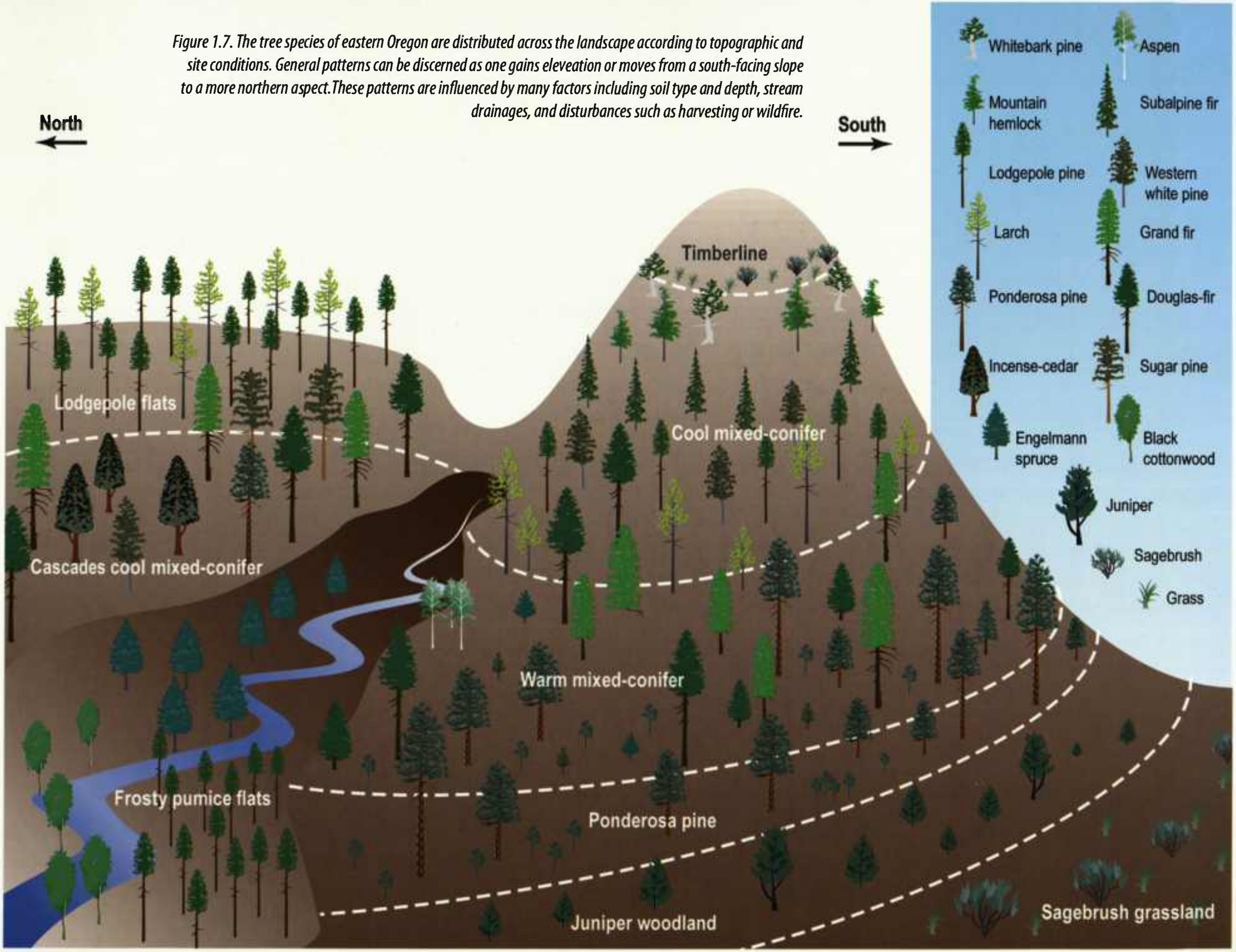


Figure 1.7, opposite page, and Table 1.2 show relative tolerances of each tree species. The numbers in Table 1.2 are not exact measures, but they show how each species performs *relative* to the other species in that tolerance category. The relative tolerances of different trees helps explain the current condition of many forest stands and is extremely important in making management decisions (see "How to use tree tolerances in your management"). For example, the shade tolerance of Douglas-fir and grand fir have allowed them to replace less-shade-tolerant lodgepole and ponderosa pine 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.

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.

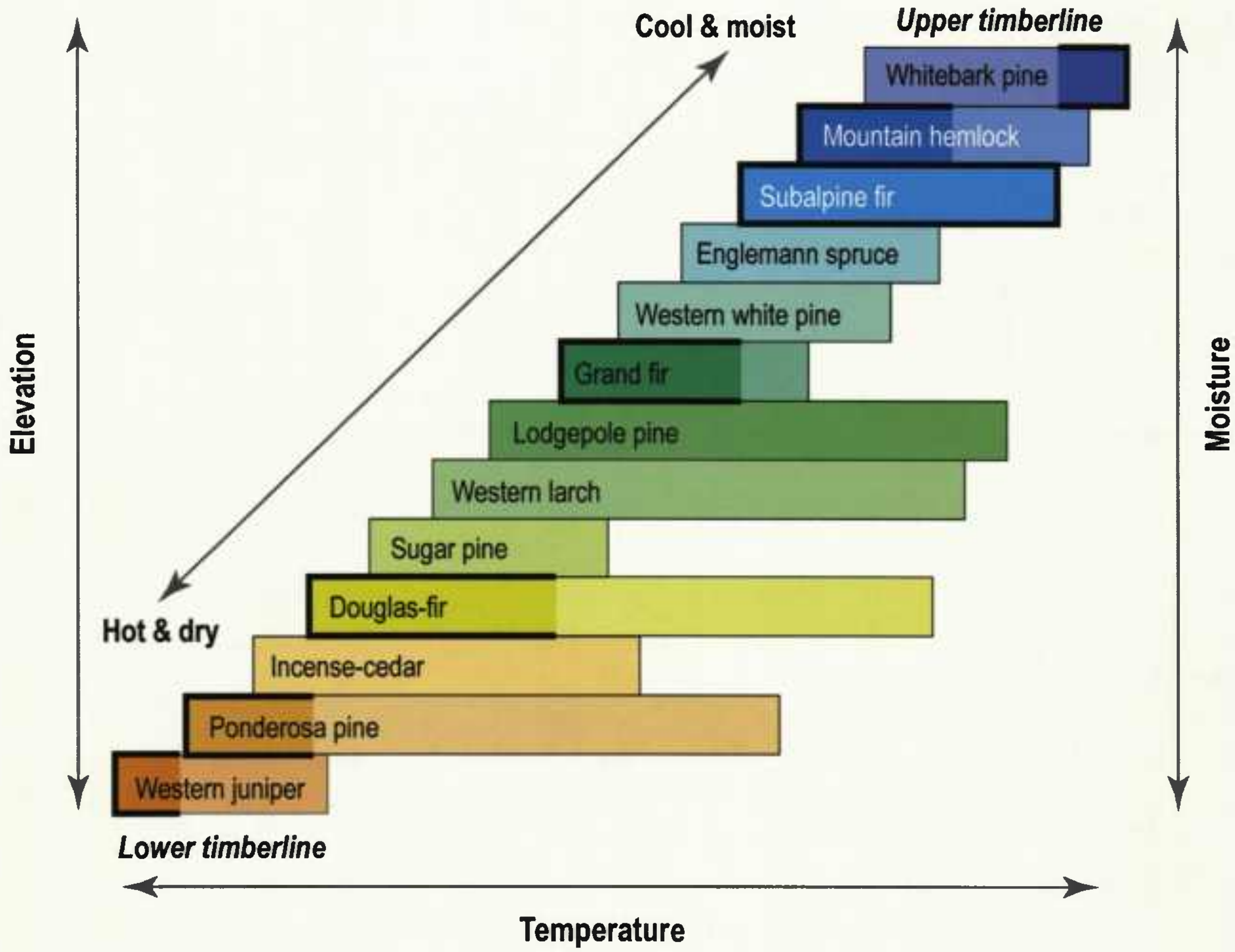


Figure 1.8. This diagram shows where each tree species is found in relation to other tree species in a general gradient of moisture and temperature from low to high elevation. It shows the distribution of coniferous trees in eastern Oregon from lower timberline (lower left) to upper timberline (upper 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 (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 that they grow, from warm, dry, low-elevation sites to cool, moist, high-elevation sites (see Figure 1.8, opposite page). Deciduous trees are listed separately. For help with tree identification, see *Trees to Know in Oregon,* EC 1450.

Ponderosa pine

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, has poor form and large branches, and has had limited commercial value as lumber, fuel for co-generation, or fence posts. Over the last century, juniper has expanded its cover over large areas but it reduces cover of grass, herbs, and shrubs important to some wildlife and grazing animals. It is resistant to pest damage but can be killed by prescribed fire to improve range values.

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 grows to large size, 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 overstocked, and in some areas it is badly infected by parasitic dwarf mistletoe.

Douglas-fir

Incense-cedar, where it grows on the east flank of the Cascade Mountains, 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.

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 many 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 defoliators, 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.

Western larch (the yellow trees)

Sugar pine is less drought tolerant and more shade tolerant than lodgepole and ponderosa pine. 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, it grows well in warm mixed-conifer forests and has high wood value, making it a welcome component where present.

Western larch is less drought tolerant than the pines and Douglas-fir. It is less shade tolerant than Douglas- and grand fir. Where it comes in after fire or clearcutting, it grows tall rapidly in the first decade of life but becomes 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


Lodgepole pine


Grand fir


Engelmann spruce

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.

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 wet meadows, or 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, that 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.

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 root disease and stem decay, is killed by bark beetles and fire, and like Douglas-fir is periodically defoliated. Defective trees are quite important for cavity-nesting species. Historically, its white wood was less valuable than ponderosa pine or Douglas-fir, but now it is sometimes preferred in Asian markets. By keeping grand fir stocking to less than a third of the stand's basal area, you can avoid many problems with defoliation.

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.

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 mixed-conifer forests in northern Idaho and western Montana. It may be a valuable addition to the relatively moist end of the warm mixed-conifer type because it is 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 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 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. 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 of spruce windfall.

Subalpine fir is a short-lived species (70 to 80 years) found at higher elevations in moist, cool, mixed-conifer types. It is sensitive to fire. It occasionally is attacked by balsam wooly aphid 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 or larch in the cool mixed-conifer forest type.


Subalpine fir

Mountain hemlock is found above or mixed with subalpine fir in the cool 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 probably 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. Like mountain hemlock and subalpine fir, it is found mostly in national forests.

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. 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 love to eat the high-protein leaves and twigs. Aspen is prone to stem decay and provides high-quality cavity-nester habitat thanks to cavities that woodpeckers excavate in decayed aspen.


Figure 1.9. Deciduaus species such as quaking aspen pravide impartant diversity values including habit far cavity-nesting birds and farage far big game animals. It alsa pravides a visual treat with its varied fall calors.

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. 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. Normally, during stem exclusion, 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.

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. A stand's tendency to stagnate depends on the tree species, type of stand, 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 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 has changed over the last century.

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 dry mixed-conifer types) had low-intensity fires at frequent intervals (5 to 20 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 bark grew thicker (Figure 1.10a, page 14). Most often, the low-intensity fires killed mostly smaller 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 cool mixed-conifer types, 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 invaded by shade-tolerant subalpine fir only gradually, after many decades of stand development.

Fire exclusion and suppression Soon after settlers arrived, they 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. Since about 1910, efforts to control fire have been increasingly effective (Figures 1.10b and 1.10d–f, pages 14–15). Thus, for almost a century, fire exclusion has allowed stands to become overdense, to the point of overstocking or stagnation. Fire-sensitive, shade-tolerant species seeded in, grew in more stands, and spread across the landscape. Timber harvest sometimes slowed the process of stand closure (Figure 1.10c).

Insects, diseases, and 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, however, 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 value when most trees succumb to either insect attack or wildfire. 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.

Grazing As European settlers moved into the region 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 (see Figures 8.8a–b, page 165).

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.

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." Harvest

Figures 1.10o–f. The historic photos below and on the opposite poge show successional trends, as Douglos-fir ond grand fir regenerated under ponderosa pine, and they show how horvest of timber occeleroted development of the fir understory.

increased the water and light available for the more shade tolerant Douglas- and grand fir growing in the understory, and they thrived (Figure 1.10f).

All these disturbances had three big implications for forest health.

1. The trend toward high stocking 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 grand and subalpine fir) 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).

3. Finally, the trend to higher stocking and multiple canopy layers (Figures 1.5 and 1.10e–f) led to stands that are prone to uncharacteristically destructive fires, and, because of large fuel accumulations, fires 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 *Forest Health in Eastern Oregon*, EC 1413).

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.

Historic and current conditions

Forest condition varies according to the forest's history of management and of fire, insect, and disease attack, and the prevalence of mistletoe. On the negative side, many private forests are overstocked and subject to bark beetle attack. 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 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 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, selective logging 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 protection.

Your forest may have been degraded by or may have benefited from events in the past. 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. Recently, higher timber values and the realization that many areas are in poor condition have encouraged more careful, intensive management to control stand composition and stocking levels and to promote more stable forests. Thinning forest stands, managing fuels, and better managing riparian areas are needed to correct current conditions. Such management would help prevent destruction by insects, disease, or fire and would make the yield of values (e.g., wildlife habitat, timber, or grazing) more predictable.

Even when current stand conditions are good, 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. When commercial timber is an objective, these controls are important because they allow the owner to sell timber at a time of his or her 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.

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

(continued next page)

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) is critical in keeping the next fire on the ground and out of the forest canopy.

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). 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.

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 and *Wildlife on Private Woodlands,* EC 1122, and *Managing Wildlife Habitats in Forested Ecosystems,* EC 1470, for information about wildlife management.) Finally, the landscape perspective reminds us that planning and cooperation with neighboring landowners can help attain a more fire-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

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

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 thick, mixed-conifer stand where beetles have 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.

Summary

This chapter is intended only to get you started on matching 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. In much of the area, you cannot choose which tree species to manage because only one will grow there. In such cases, thinning is your main tool for maintaining a healthy forest.

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.

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 gives you more management options and helps avoid wildfire, insect, and disease problems. Combining control of species composition, stocking levels, and fuel loading (Figure 1.12) 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.

CHAPTER 2

Silvicultural systems for eastside forests

Stephen A. Fitzgerald, William H. Emmingham, Paul T. Oester

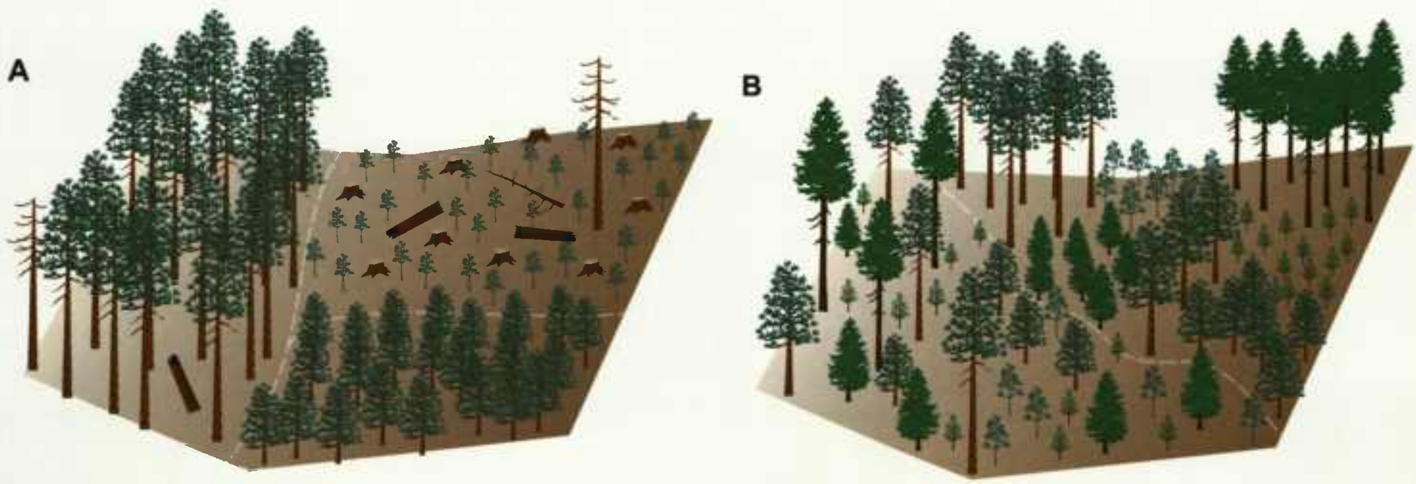
You have many choices for "designing" your forest—how it looks and what it produces—using a variety of long-term management strategies called silvicultural systems. You'll carry out your long-term strategies in operations such as planting and vegetation management, thinning, pruning, fertilizing, and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

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).



stands are clearcut, shelterwood cutting, and seed tree cutting. Regenerating uneven-aged stands uses individual tree selection (ITS) and group selection harvest methods. Both these approaches require active monitoring and management to guide stand structure, stand density, and forest health.

Which silvicultural system you choose depends on:

- Your long- and short-term objectives
- Current stand conditions; e.g., is the stand already even- or uneven-aged?
- Site factors; e.g., is it a dry, ponderosa pine type of site or a cool, moist, mixed-conifer type?
- 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 (silviculture systems) and how site and stand conditions influence the management operations needed to achieve your objectives.

Even-aged regeneration methods

Clearcutting

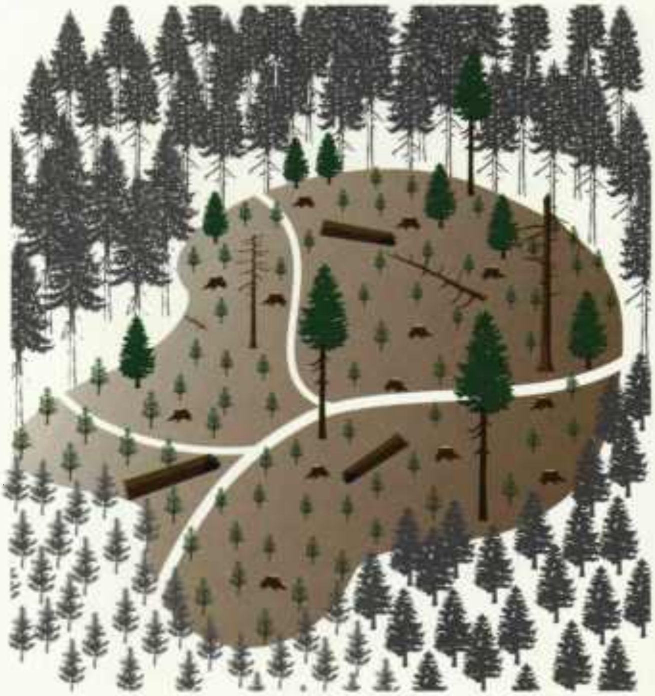
Clearcutting has been used very successfully to produce young, even-aged stands on mixed-conifer, lodgepole, and some ponderosa pine sites. A typical reason to clearcut is to convert lodgepole or ponderosa pine stands that have been heavily damaged by insects, disease, mistletoe, or wind or that have had all the good or high-value trees removed in a high-grade harvest. 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 6 years. Reforestation (see Chapter 6) can be by planting seedlings or by allowing seed from surrounding stands to naturally regenerate the site. Where natural regeneration is uncertain or slow, planting helps you meet the 6-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 has re-established.

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 kept in check.

Soften the harsh look of a clearcut by using irregular boundaries 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.

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 (Figure 2.3). 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 are likely to keep regeneration below legal requirements.

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. Typically, trees with these attributes are windfirm, resistant to insects, and capable of producing shade and abundant seed for natural regeneration.

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.

Overstory shelter or seed trees may be harvested to release the understory seedlings or may be left to create a two-story stand. If you harvest the overstory, do so after planted or natural regeneration is well established (3 to 6 years) but before seedlings are 2 to 3 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:

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

Figure 2.4. Windthrow in a shelterwood.

Windthrow of leave trees can be a problem (Figure 2.4). 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 very densely and then were opened up in one operation. The better approach is first to thin dense stands to improve windfirmness and cone production, then make a shelterwood cutting a decade or more later. A systematic thinning program throughout the life of a stand helps grow good shelter trees.

Uneven-aged regeneration methods

Individual tree selection

Figure 2.5. A hypothetical stand maintained by the ITS method, in which trees in all size/age classes are thinned periodically.

The individual tree selection (ITS) harvesting method is used to create and maintain uneven-aged stands having trees of three or more sizes mixed together with more small and medium-size trees and fewer large trees (Figure 2.5) The mix of tree sizes includes both merchantable and nonmerchantable 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 2.6 and 2.7). Using ITS may 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 thin the stand every decade or two, and you have to be careful to preserve understory trees. Stands that already have three or more size classes as a result of past harvesting, windthrow, insects, or other disturbances are good candidates for ITS. Stands that have two size classes can be converted to uneven-aged stands in a relatively short time (e.g., 10 to 20 years) with thinning and reforestation. It takes much longer to convert single-story, even-aged stands using ITS.

ITS is applied by lightly thinning every decade or two in the various size classes across each acre (see "Managing stocking in ITS," opposite). With each thinning, 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 thinned to a specified spacing based on species, site productivity, and time until the next thinning (Figure 2.6) to keep overall stand densities, including 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 pages 28–29) in order to promote the growth of 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 harvests to ensure continued recruitment of trees into larger age classes over time.

A common mistake is to maintain uneven-aged stands at too high a density or to delay needed thinning. 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 understory 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 thinned, even trees not of commercial size, leaving the best formed and most vigorous trees to grow. Thus, during each cutting cycle, thinning may be both commercial and precommercial. Although the two types of thinning can be done at the same time, they usually are separate operations for work efficiency or contract reasons.

Most tree species regenerate well from seed on a mineral soil. However, if cone and seed production are poor (typical of larch) or competion 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.

MANAGING STOCKING IN ITS

Management of ITS stands involves periodic thinning 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 or thinning, to estimate the number of trees per acre (tpa) in each size class. Figure 2.6 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 2.7 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.

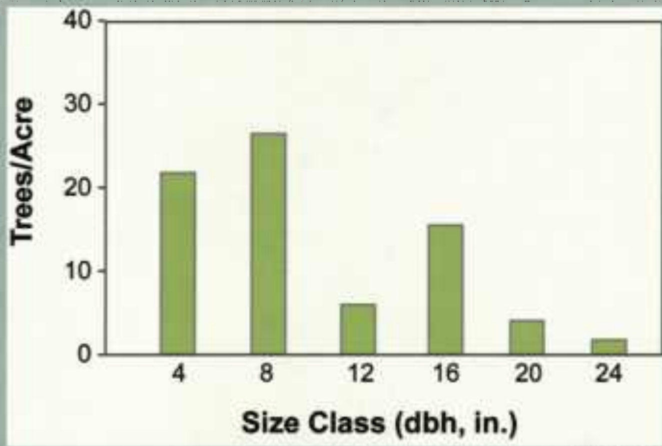


Figure 2.6

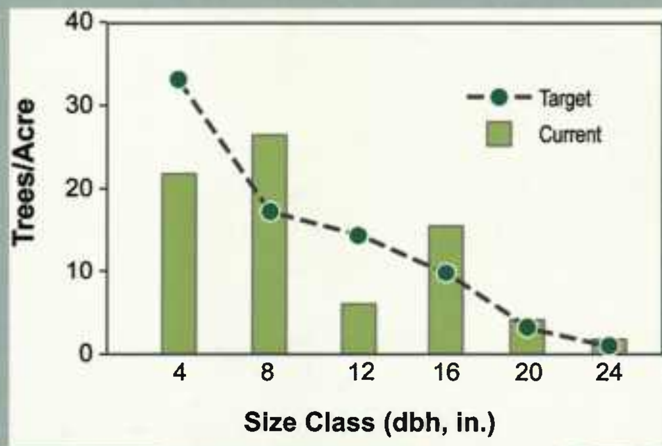
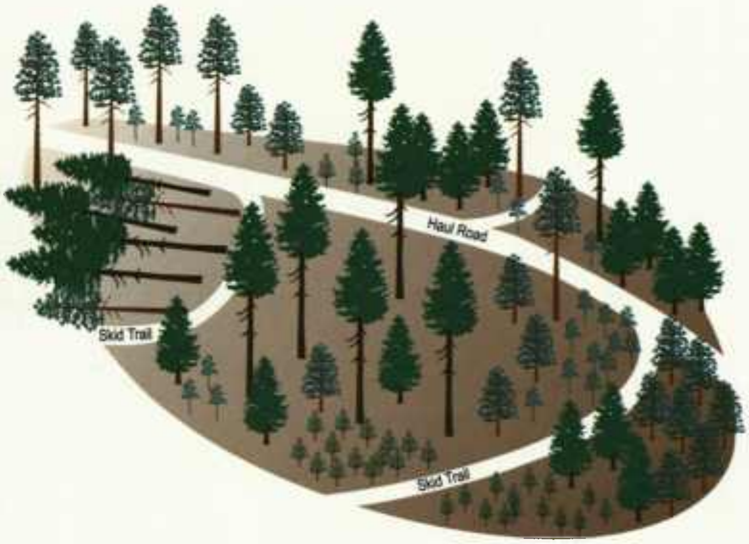


Figure 2.7

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.

To prevent injuring seedlings, saplings, and commercial-size trees during harvest, carefully design the logging system (Figure 2.8). It is important to plan and establish a permanent skid trail system that reuses skid trails, controls 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 and thins trees in small groups, from about 0.25 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 the upper right of Figure 2.1b, page 21). Group selection cuts are made so that 10 to 25 percent of the stand area is harvested and regenerated in mini-clearcuts 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 stands 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). Such patches urgently need thinning to improve tree growth, vigor, and resistance to bark beetles. If trees within these groups have mistletoe infections, the trees should be removed.

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.

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 size classes. In other parts of the stand, trees may be clumpy; group selection either would thin some clumps to promote tree growth or would harvest all trees in mature groups to initiate regeneration. Group openings also can be created by making a miniclearcut 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 very diverse forest over time.

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.

Tree health and stand stability depend on stand stocking

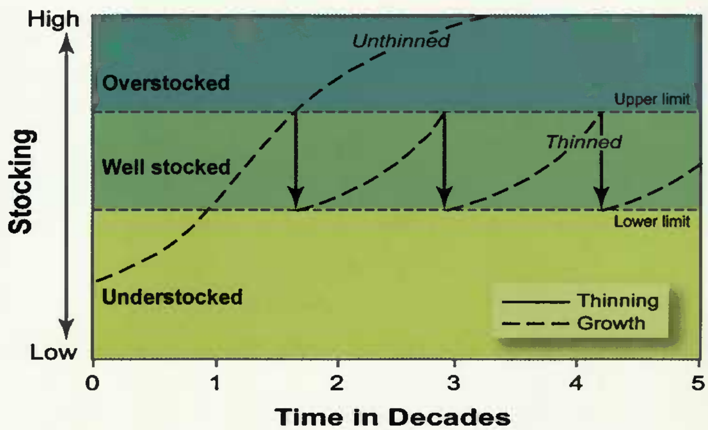
Maintaining proper stand density and stocking are the keys to maintaining healthy, stable forests that reliably produce the forest values you set in your objectives.

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. For any given site productivity there are stocking limits, which can be defined in terms of trees per acre and tree size or by basal area. 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. 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," page 28.

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. By periodic thinning, stocking levels can be maintained within the "well stocked" zone, where the trees and stands are resistant to beetle attack.



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 56–57). **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.

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).

Stocking level control for even-aged stands

In relatively pure even-aged stands, each species has its own stocking limits which depend on tree spacing and site indexes. For example, Table 4.4 (page 72), provides stocking guidelines for lodgepole pine stands with an average diameter of 6 to 18 inches. Each diameter class (e.g., 6, 8, and 10 inches) has a recommended spacing and 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.

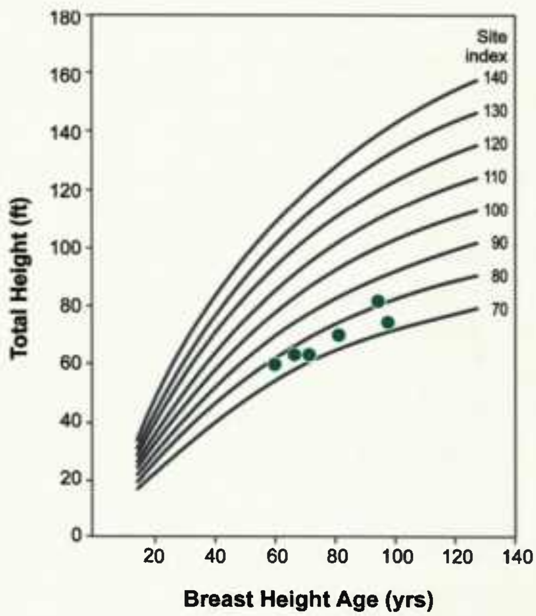


Figure 2.11. Site index curves (100-year basis) for managed, even-aged ponderosa pine stands in central and eastern Oregon. Heights are for the tallest trees in the stand (from Barrett 1978).

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 on pages 56–57 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 thinning, within the even-aged groups you can follow the guidelines above for even-aged stands. However, you might want higher stocking at the edges, where older groups adjoin younger groups, to foster windfirm edges.

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 thinning through ITS 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

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 *Stand Volume and Growth: Getting the Numbers*, EC 1190, to learn how to measure basal area. Each species has different basic rules for stocking based on basal area.

Radial growth is 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).

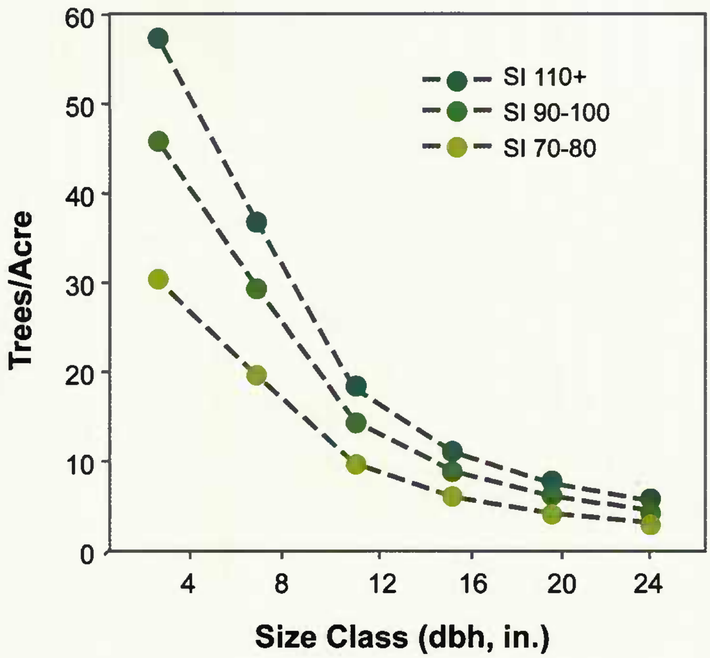


Figure 2.12. Stocking level targets in trees per acre (tpa) by diameter class for ponderosa pine stands on sites of low (SI 70–80), medium (SI 90–100), and high (SI 110 and above) productive potential.

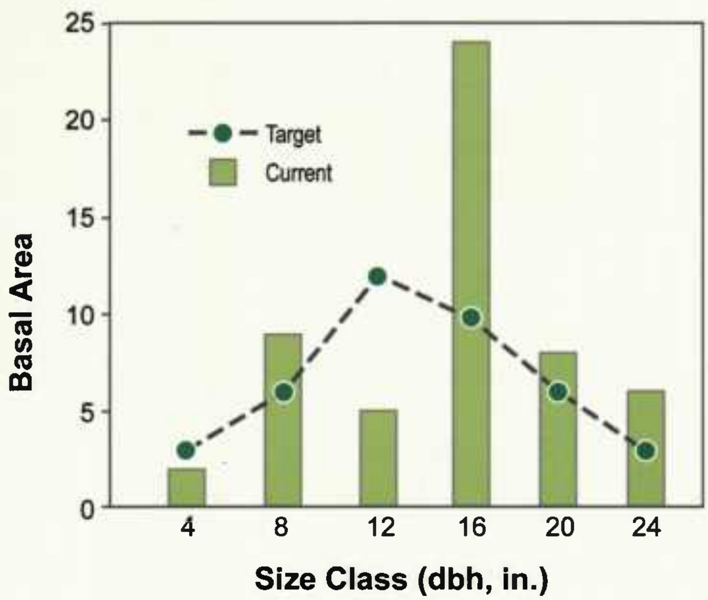


Figure 2.13. Stocking levels in basal area (bars) and target basal area by diameter class (dotted line) for an ITS stand. Thinning should remove trees in diameter classes whose basal area exceeds target levels.

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 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 diame-ter 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 54 square feet —which, by coincidence, is the 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 decide to leave the 8-inch diameter class to fill in the 12-inch class, and we decide 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 diameter 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 seed-lings 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 200 board feet or more per acre per year, you could thin the stand every 10 to 15 years and remove on average 2,000 to 3,000 board feet per acre. The cycle for harvest on less pro-ductive sites might be as long as 20 years.

Techniques for stand tending

In describing the silviculture approaches, we focused on management that would help shape the stand and secure regeneration. That is why we often refer to the silviculture 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.

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 that was common in that era. 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.

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

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 or concentrated fuels is that it can be done during wet weather to avoid danger of wildfire. The disadvantage is that burning only the concentrations of fuel may leave plenty of fuel to carry a 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. 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. For details, see *Using Precommercial Thinning to Enhance Woodland Productivity,* EC 1189.

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 burned during the wetter months. Contact your local ODF service forester for information on slash treatments (abatement) and fire laws in Oregon. When operating a chainsaw 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 $50 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 by killing the best trees. Cost-share assistance may be available to help defray a significant amount of PCT costs. For details, see *Incentive Programs for Resource Management and Conservation,* EC 1119, or contact your Oregon Department of Forestry service 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 wood 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

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 large 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 wildfire. Therefore, snags can be retained where they are surrounded by relatively fire-resistant conditions. Snags also can be isolated by removing duff and litter around them. For more about enhancing wildlife habitat, see Chapter 9.

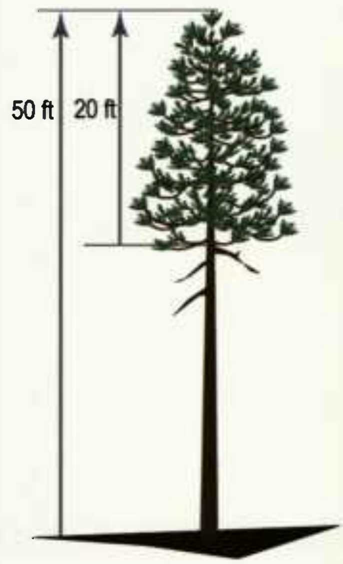


Figure 2.15. The live crown ratio compares the amount of tree bole with live branches to the total height of the tree. A 100-foot tree with live branches on its top 40 feet has a live crown ratio of 40 percent. Likewise, a tree that is 50 feet tall and has 20 feet of live crown, as shown here, has a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

beetle attacks. Thinning 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:

- 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
- Promote stand growth and succession to provide future wildlife habitat
- Provide periodic income, which increases over time as tree size and value increase
- Combine with fertilization or pruning to produce large, high-value trees

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.

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.

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 H:D ratios over 100. The stand has 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 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 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 stand should be light, to allow residual trees time to develop windfirmness (i.e., increase their height-to-diameter ratio). 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

(continued on page 38)

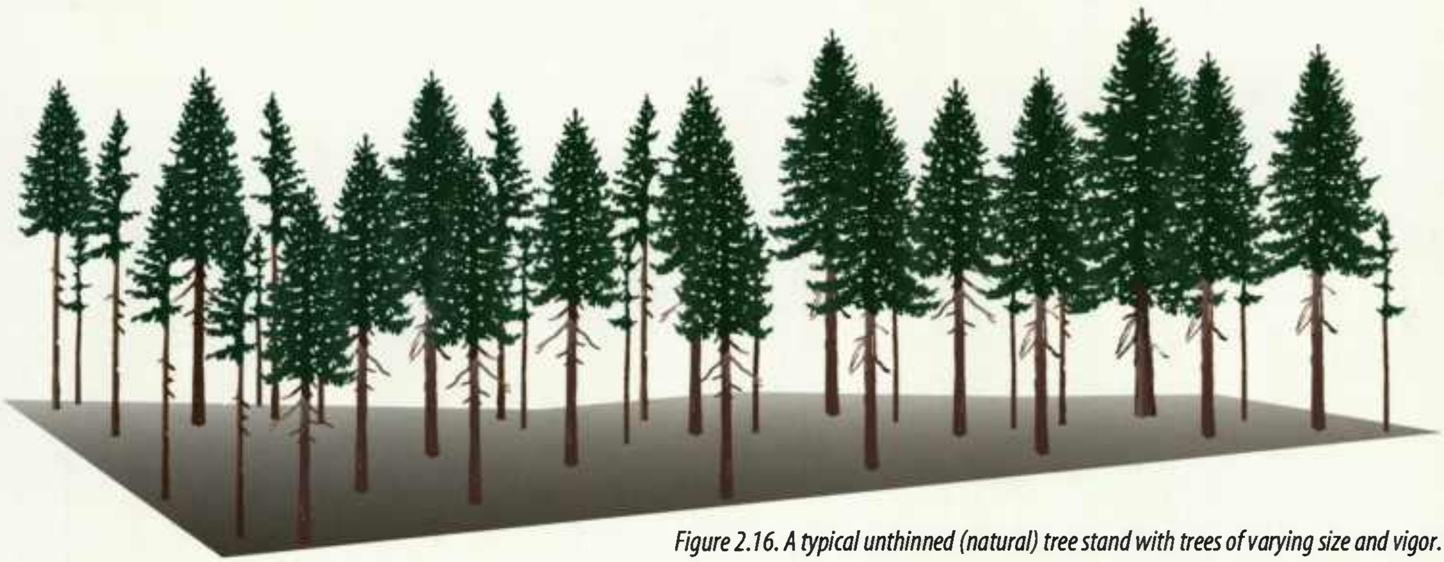


Figure 2.16. A typical unthinned (natural) tree stand with trees of varying size and vigor.

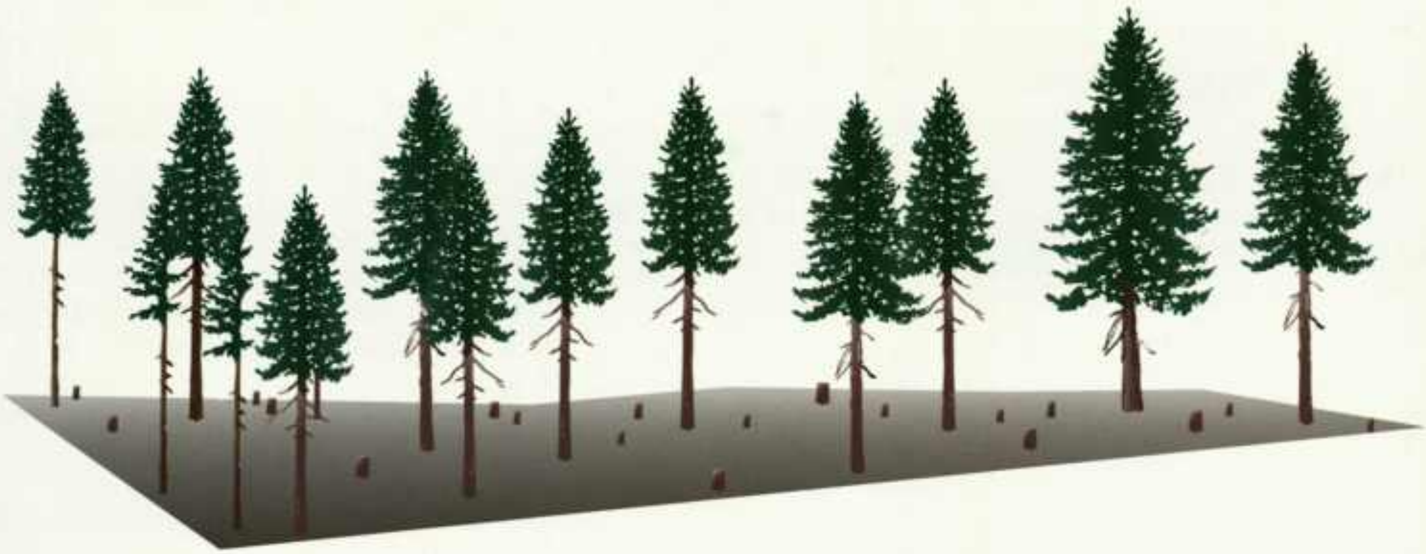


Figure 2.17. Low thinning, also called thinning from below, removes mostly smaller trees in the suppressed and intermediate crown classes, some in the co-dominant, and very few in the dominant crown classes. Low thinning releases better formed and faster growing dominant and co-dominant trees by removing 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.

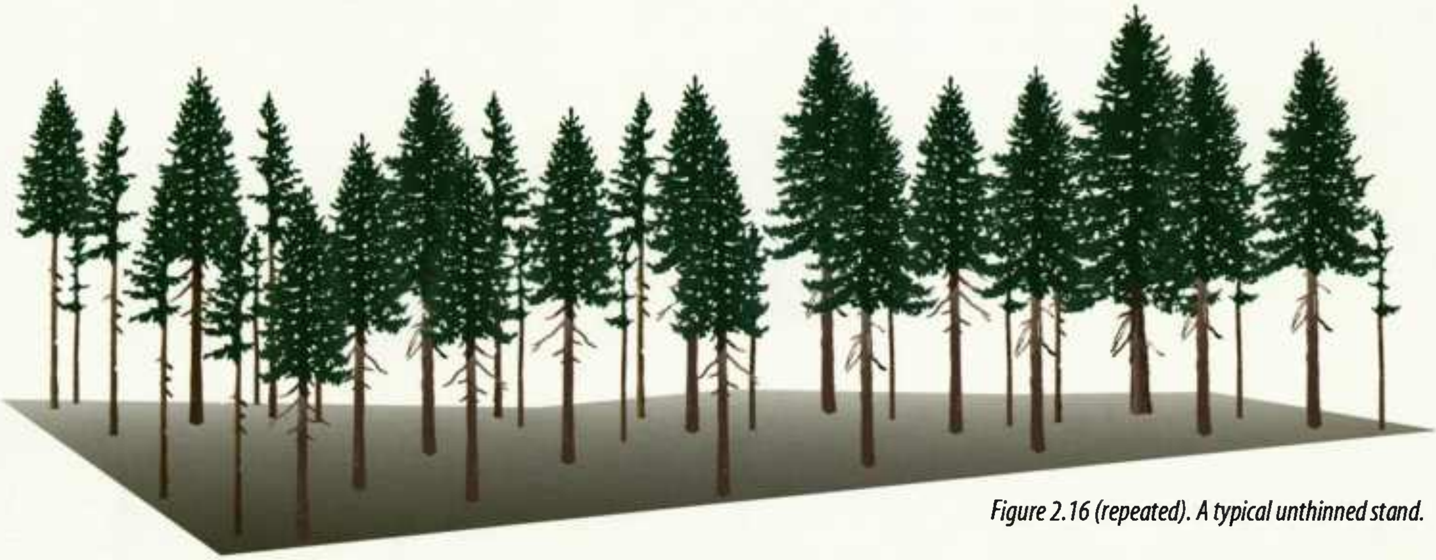


Figure 2.16 (repeated). A typical unthinned stand.

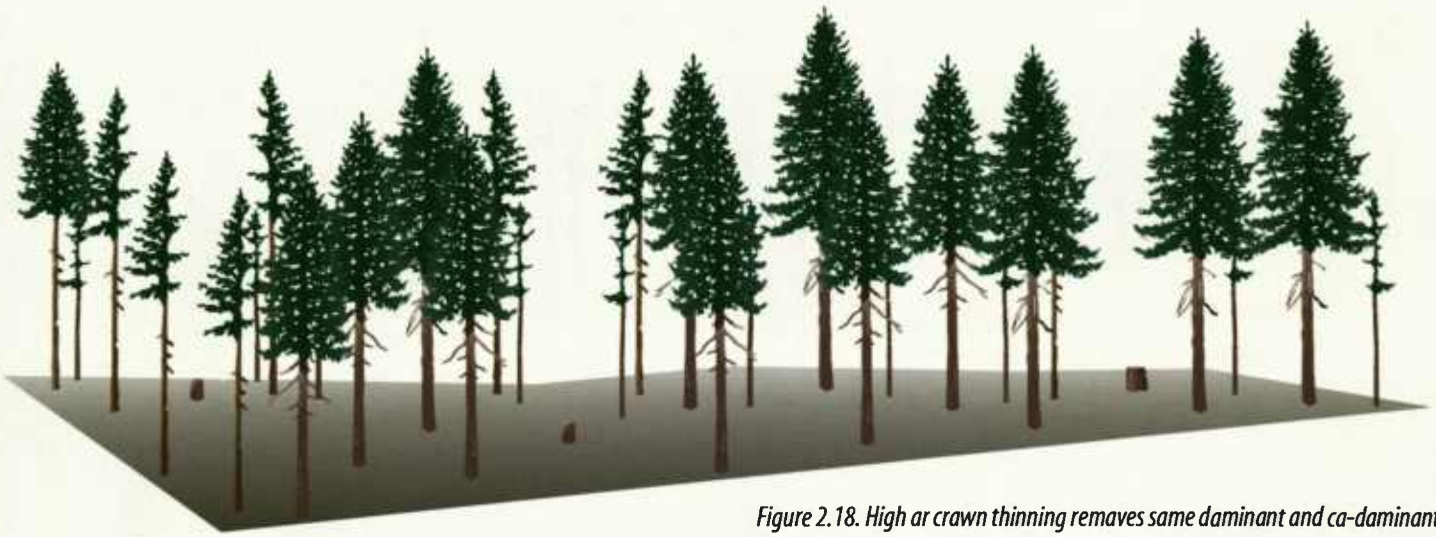


Figure 2.18. High ar crawn thinning remaves same daminant and ca-daminant trees in a stand ta free up grawing space far ather vigaraus ca-daminant and daminant trees. Because larger trees are remaved, lagging casts are lawer and prafits higher. A gaad time ta use high thinning is early in the life af an irregular, naturally regenerated stand ta remave raugh (i.e., large limbed), daminant trees that take excessive grawing space ta praduce law-quality lags. Avaid remaving taa many af the large trees, a practice knawn as high-grading, because that reduces the value and future grawth af the stand. A gaad way ta avaid high-grading is ta be sure that the stacking level target is filled with high-quality, well-farmed, daminant and ca-daminant trees.

Figure 2.19. Free thinning is o combinotion of both high ond low thinning. In mony coses, free thinning warks best in eastern Oregan stonds because af the variability in stand ond site conditions; however, this method requires more knowledge ond skill.

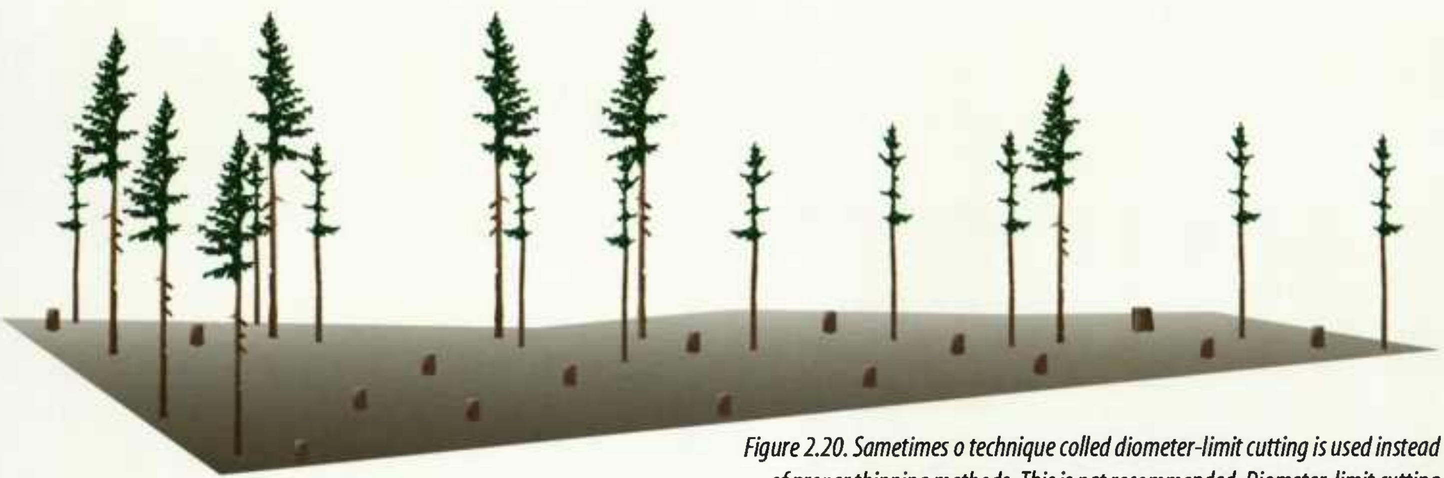


Figure 2.20. Sametimes o technique colled diometer-limit cutting is used instead of proper thinning methods. This is nat recommended. Diometer-limit cutting aften degrades genetic quolity, reduces diversity ond future growth, ond lowers future harvest tree quolity ond volue. Because it remaves all trees aver a certain diometer (aften the smollest merchantoble diometer, such as 10 ta 12 inches), it olmost olwoys results in leoving suppressed, poorly farmed, ar diseased trees thot will not grow well—ond are subject to windthraw and bark beetles. Ta reach defined gaals far yaur stands, be sure ta cleorly mork the trees ta be remaved according to the thinning methods described in this chapter.

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 and Christmas Tree Growers,* EC 1192.

Improvement cutting

As mentioned in Chapter 1, stands with certain species composition can create management problems in the long run. The main purpose of improvement cutting is to improve species composition, tree form, and tree vigor. Improvement cutting removes trees to release pole-size 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 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.

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.

Sanitation cutting markets or removes 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. Removing infested trees with the beetles in residence can "export" the problem from the site. 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 fire hazard and the buildup of insects so that they don't 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 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 to plant areas with low residual stocking.

Sanitation/salvage operations often become necessary in stands that weren't managed well in the past. Be aware, however, that sanitation/salvage cutting can increase the spread of Armillaria and Annosus root disease, so stands heavily invested with these root rots should be left alone or clearcut and managed for alternative species (see Table 7.4, page 145, 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 are 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 4 to 8 years. However, growth response on coarse soils in central Oregon is best when nitrogen is applied with phosphorous 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. Fertilizing unthinned pole-size trees often wastes money because fertilization accelerates mortality of intermediate and suppressed trees.

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 responds than those on granitic soils.

Approach fertilization cautiously. If neighboring lands have been successfully fertilized, you could start fertilizing on a modest scale and see whether it is a good investment for you.

For information about fertilizing tree seedlings at planting, see Chapter 6.

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 including:

- 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

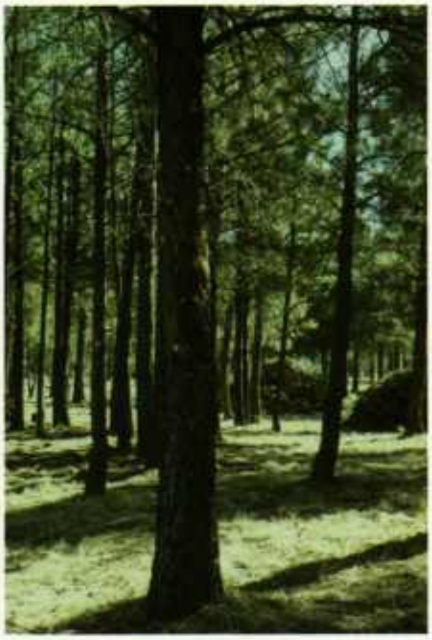


Figure 2.22. A stand of ponderosa pine recently pruned and thinned. Note that the thinning and pruning slash has been piled for burning at a later date to prevent beetle invasion.

Most conifers can be pruned, and procedures are similar for different species. Recent pruning studies of ponderosa pine and Douglas-fir on good sites show that the increase in clear wood lumber had enough market value to pay for the investment in pruning. However, future markets for clear wood are unknown, and there is no assurance that mills will pay a higher price for pruned trees. Therefore, approach pruning cautiously. If you aim to enhance timber value, make pruning a final addition to other intensive management practices.

Refer to *Pruning to Enhance Tree and Stand Value*, EC 1457, for more information about pruning.

CHAPTER 3

Managing ponderosa pine

Stephen A. Fitzgerald and William H. Emmingham

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. Today, 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. Harvesting the famed Matsutake or pine mushroom and other mushroom species has become a multimillion dollar industry in eastern Oregon forests. 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 (Figures 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" race 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 some sites. For information on managing valley pine, see *Establishing and Managing Ponderosa Pine in the Willamette Valley,* EM 8805.

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 7). 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. For more detail on the environment, soils, ground vegetation, range capability, and site productivity, refer to plant association guides listed in Appendix 4, page 204, "For more information."

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 may grow. Cheatgrass 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-stolen 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 (Figure 3.2). For detailed information, refer to plant association guides by Johnson and Hall (see Appendix 4, pages 204–205).

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 might be little ponderosa pine or Douglas-fir regeneration.

Stand initiation and development

Seed production and germination

Ponderosa pine can begin producing cones at age 7 to 10 years. However, good cone crops are not produced until trees are 80 years or older. Ponderosa pine cones take 2 years to mature, and cone crops are irregular, with heavy crops every 6 to 8 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 2 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 rain. 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 either 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 disturbance is light (e.g., spring understory fire) and many overstory trees survive, site resources available to 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.

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.

Once seedlings grow above competing herbs, grasses, and shrubs, they begin to capture most 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-size 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 (less productive), 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 in mixtures 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 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, pages 31–34).

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). Height growth increases with site productivity. Differences in site productivity affect volume growth per acre, usually 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 affects competing vegetation levels and decisions such as the timing and intensity of thinning.

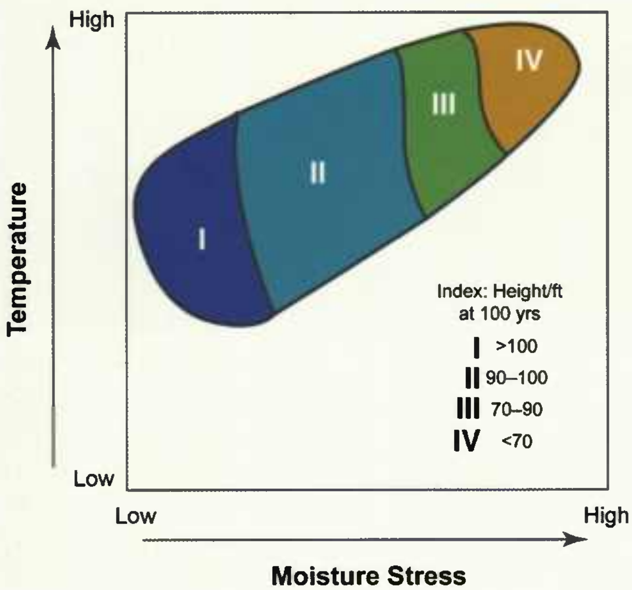


Figure 3.3. Effects of moisture and temperature on ponderosa pine productivity (adapted from Waring 1970).

Site productivity for ponderosa pine varies from a *site index* of 70 to 140 (see Chapter 2, page 28, 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.

Silviculture systems

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

- 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.

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

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. High-quality seedlings and shading are 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 3.4b. 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, page 23, 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. 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).

If you plan to use a shelterwood or seed tree approach to pine regeneration, it is a good idea to thin your stand frequently to promote development of trees that are vigorous, windfirm, and better able to produce cones.

Regeneration can be either from hand-planting seedlings, or 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 underplanting pine seedlings to meet minimum reforestation standards.

Uneven-aged management methods

Ponderosa pine forests often have uneven-aged structure with up to several *size 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 thinning is regular and reduces stocking to appropriate levels, uneven-aged stand structure will be lost.

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

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

Stocking-level curves for uneven-aged ponderosa pine stands for sites with site indexes of 70 to 110 are shown in Figure 2.12, page 30). Curves are approximately 50 percent of the recommended maximum stocking levels for even-aged stands (see Tables 3.3 and 3.4, pages 52–53) and represent the stocking level you should strive to have after thinning. These stocking levels should promote good growth in the smaller diameter classes.

To use these curves, first determine your stand's site index (see Chapter 2, page 28). Then, thin 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 thinning is necessary within that size class (see "Using uneven-aged stocking curves" on the opposite page).

Individual tree selection (ITS)

Ponderosa pine stands that already have three or more size classes are ideal for ITS (see Chapter 2, page 24). Often, a series of light thinnings 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 24 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 37), thinning 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.

Each 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 50) should be thinned promptly, especially on low-productivity sites, to avoid stagnation and reduce fire risk.

The time between 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

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).

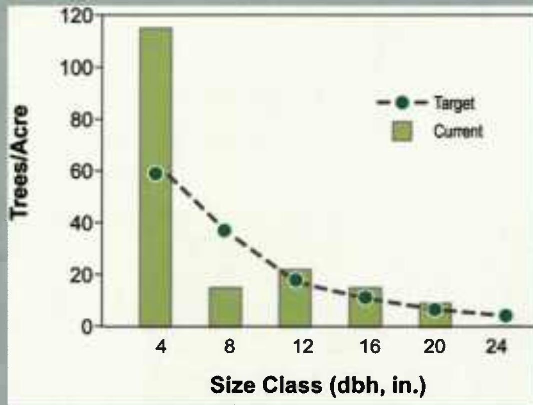


Figure 3.5. Stocking level curves for uneven-aged ponderosa pine.

You have excess trees in the 4-, 12-, 16-, and 20-inch size classes and deficits in the 8- and 24-inch classes. You want to thin 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 (thin) four tpa, leaving the most vigorous trees that are of commercial size.

16 inch An excess of four tpa in this class. Remove (thin) 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

more per acre per year, you could thin 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 48).

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.

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 0.25 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 53). Remove most, if not all, mistletoe-infected trees.

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, thinning 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 at least 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, page 27) 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 (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 now 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 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, page 101, 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.

Thinning methods Ponderosa pine stands can be commercial thinned using low, high, and free thinning methods (see Chapter 2, page 34). 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 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.

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 3.3, page 46, and Chapter 2, page 28). Tables 3.3 and 3.4 provide density and spacing guidelines for ponderosa pine stands in terms of trees per acre and dbh (Table 3.3) and basal area (Table 3.4). Guidelines apply only

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.

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 maintains good stand growth and reduces risk from bark beetles. A strategy for doing so is discussed in "Commercial thinning example" page 56.

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

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, page 33). However, in stagnated stands or clumps, even the best trees may have crown ratios 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 (i.e., decrease in height-to-diameter ratio). Given time and enough space, suppressed young ponderosa pine respond well to thinning.

Be cautious about diameter-limit cutting (see Chapter 2, page 37) in ponderosa pine stands. If you buy 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 6 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 cull.

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

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 4 to 8 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 phosphorous (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 is not a common practice. 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, page 33).

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.

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

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 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.

Figure 3.8. Prescribed burning in ponderosa pine to reduce accumulated fuels.

Commercial thinning example

You own a 10-acre stand of ponderosa pine that regenerated after a fire roughly 75 years ago. The stand is dense, and some larger trees died from a recent bark beetle attack. A professional forester recommends you thin the stand to improve tree vigor and tells you the market for small saw log material is good. You want to improve stand health, but you also are interested in future income from periodic thinning harvests. The stand has about 167 tpa with an average diameter of 12 inches. How many trees should you remove?

The first step is to determine the site index by sampling dominant trees for height and age (see Chapter 2, page 28). You determine that the site index is 90.

The next step is to determine the recommended minimum and maximum number of trees you should have in your stand given its characteristics. From Table 3.5, line A, you see that the recommended tpa is 96 to 143. You have 167 tpa, 24 more than the maximum recommended. Your stand is too dense and will benefit from thinning now.

How many trees should you remove? If you thin to 143 tpa (removing 24 tpa), your stand still would be at the upper limit. In only a short time, the stand would be susceptible to mortality. Clearly this is not enough thinning. On the other hand, if you thin the stand all the way down to 96 tpa—removing 71 tpa—you have a feeling the stand may be opened up too much and some trees may blow down. Because you anticipate thinning again, you decide to thin to 110 tpa, removing 57 tpa and leaving the more windfirm dominant and co-dominant trees. After marking the stand to remove the smaller trees (i.e., in a low thinning), you determine the average diameter of designated leave trees is 14 inches. Going back to Table 3.5 (line B), you discover that leaving 110 14-inch tpa still exceeds the 109 tpa upper stocking limit. Again, this is not thinning enough. To get below the upper stocking limit, you decide to mark another 24 tpa, leaving 86 tpa. Fortunately, that raises the leave-tree average dbh by only 0.5 inch.

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+
A 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)
B 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)
C 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.

You will need to come back when average dbh reaches 16 inches (Table 3.5, line C) because allowing the stand to grow larger than 16 inches with 86 tpa would increase the risk of bark beetle attack

How long will it take the stand to grow from 14.5 inches to 16 inches? At 86 tpa, you can expect the stand to grow 1 to 2 inches dbh per decade. So, it would take approximately 15 years to reach 16 inches dbh. Check diameter growth periodically. When the stand grows to 16 inches, you will need to thin again, to between 47 and 70 tpa, to allow the stand to grow to 18 inches with little risk from bark beetles.

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.

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.

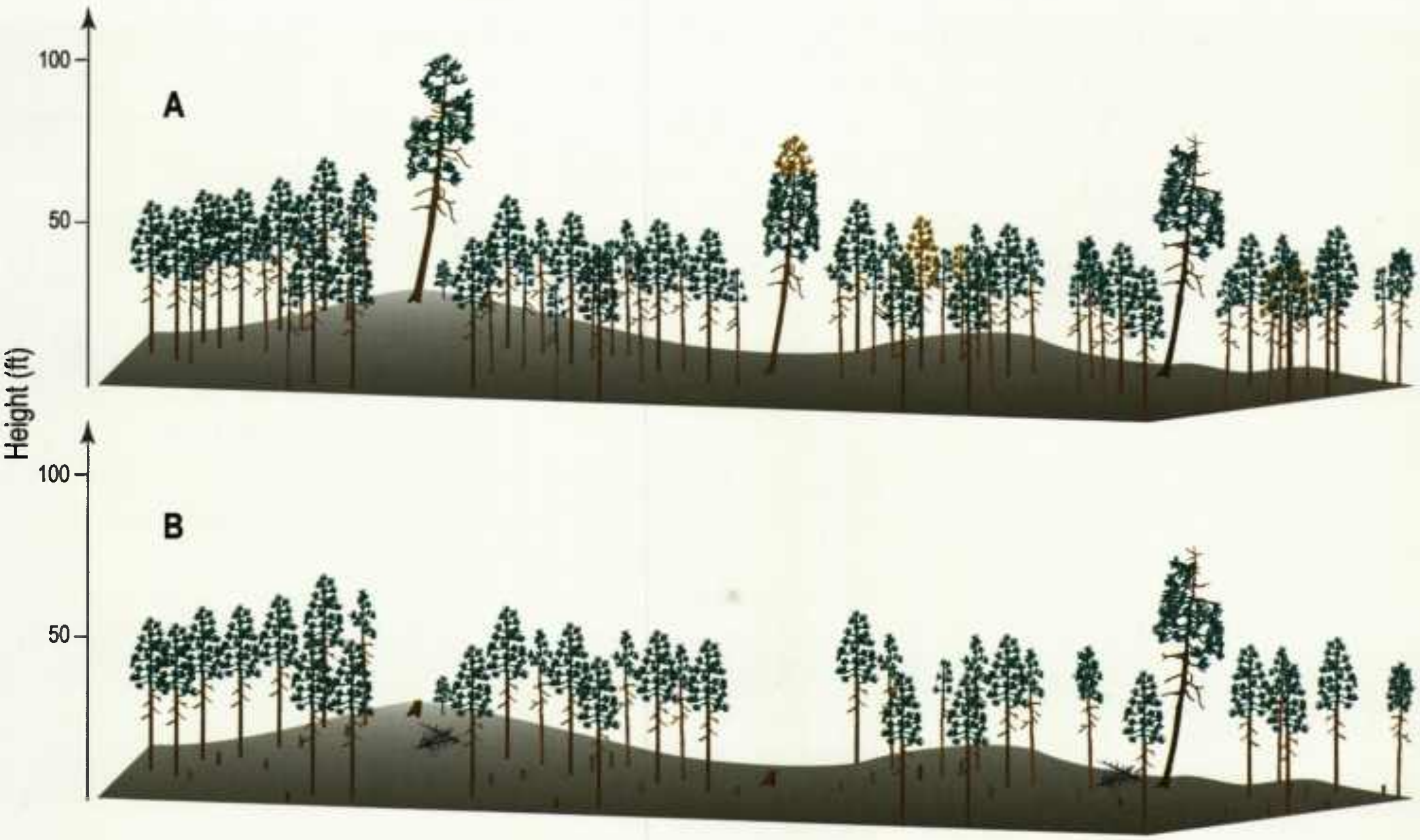
Scenario 1. Young, overdense stand

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-size 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 52), 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 through early spring. 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 thining, leaving 90 tpa. This will allow the stand to grow to 12 inches in diameter, when another commercial thinning can be planned (see Table 3.3, page 52).



Figures 3.9a–b. Management solution for pole-size ponderosa pine stand. (A) Stand condition before treatment. (B) Stand conditions after thinning.

Summary of Scenario 1 activity.

Timeline	Trees/acre	Avg. dbh	Activities
Current stand	500	6″	Precommercially thin in late summer from 500 to 125 tpa. Pile slash and burn in winter.
Future stand A	125	Grow to 10″	Commercially thin down to 90 tpa.
Future stand B	90	Grow to 12″	Commercially thin. The exact number of trees to remove will be determined at that time, depending on landowner objectives.

Scenario 2. Pole-size ponderosa pine stand.

Stand conditions (Figure 3.10a) and landowner objective

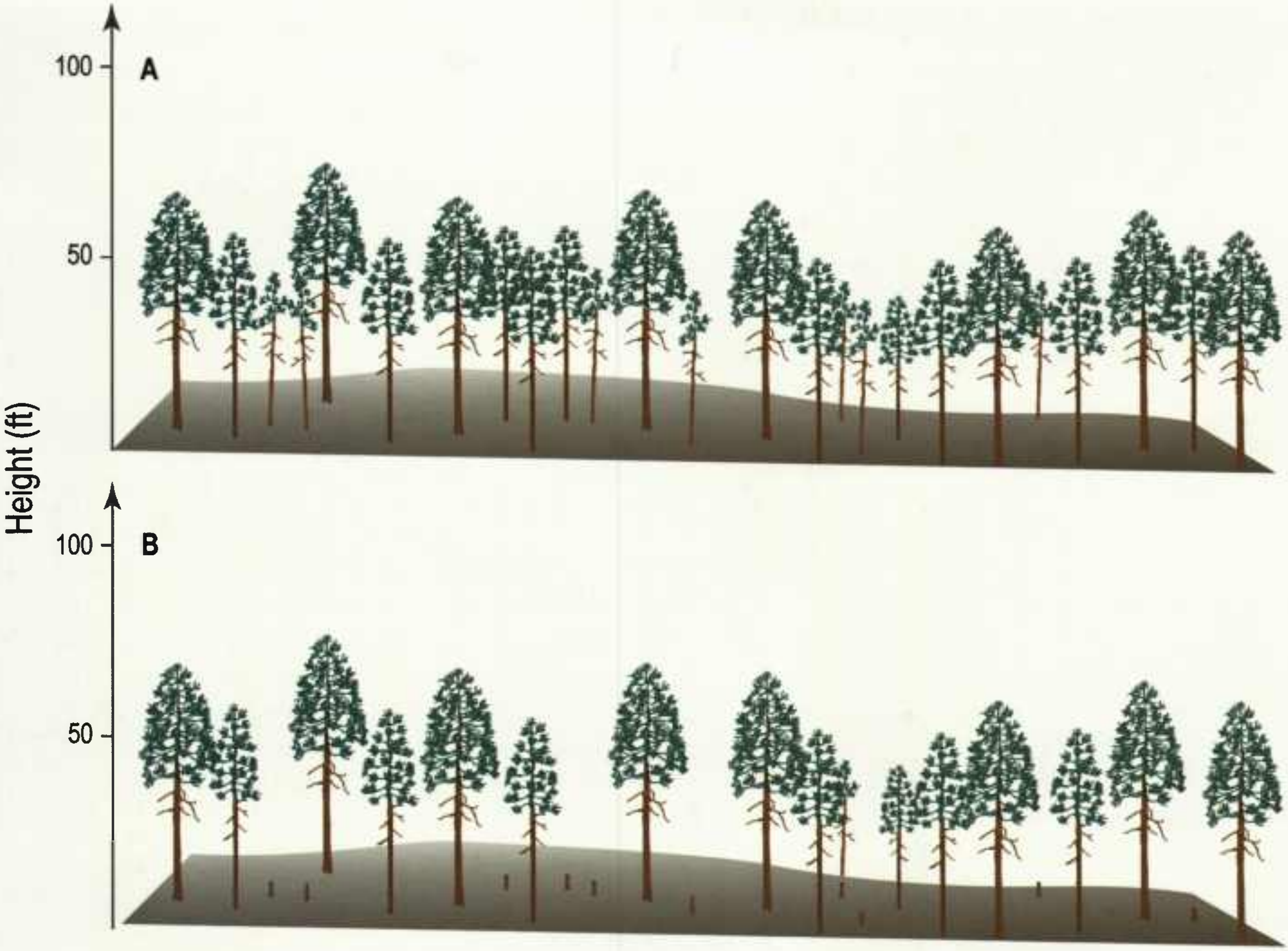
1. The stand has an average diameter of 10 inches, 210 tpa, and a site index of 90.
2. The landowner's main objective is long-term timber production and income.
3. Tree growth and vigor are declining, and the landowner is concerned about bark beetle attack.
4. The topography is relatively flat.

Solution (Figure 3.10b)

1. Using Table 3.3, page 52, 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 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 a 16-inch diameter. 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.

Summary of Scenario 2 activity.

Timeline	Trees/acre	Avg. dbh	Activities
Current stand	210	10″	Commercially thin from 210 to 145 tpa.
Future stand A	145	Grow to 12″	Commercially thin from 145 to 110 tpa.
Future stand B	110	Grow to 14″	Commercially thin from 110 to 85 tpa.
Future stand C	85	Grow to 16′	Commercially thin again, and so on.



Figures 3.10a–b. Management solution for pole-size ponderosa pine stand. (A) Stand condition before treatment. (B) Stand conditions after thinning.

Scenario 3. Multistory, multiage stand

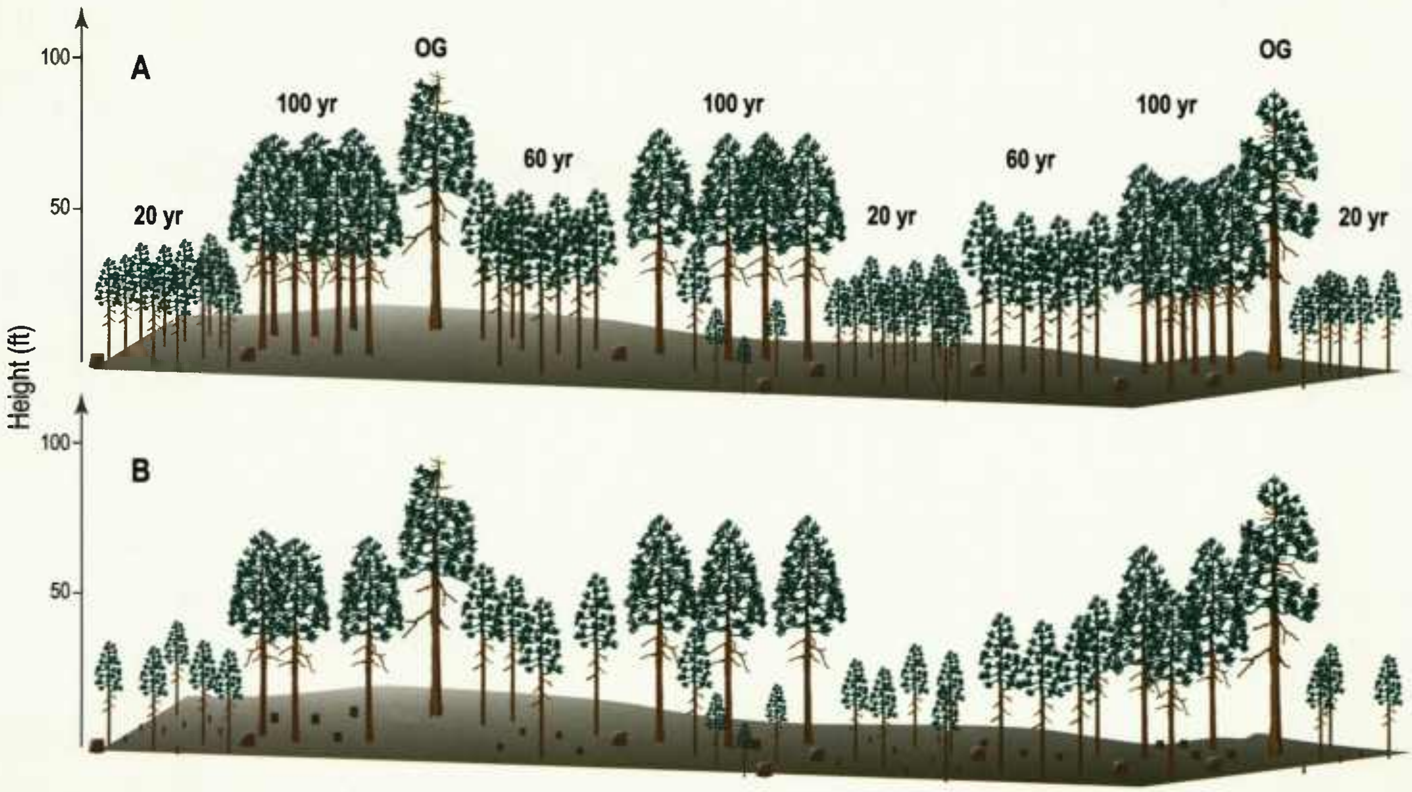
Stand conditions (Figure 3.11a) and landowner objectives

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. Below is a summary of current stand conditions.

Clump age (years)	Avg. tree diameter	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.

Figures 3.11a–b. Management solution for multi-aged ponderosa pine. (A) Stand condition before treatment. (B) Stand conditions after thinning.



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 52, 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 during 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 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, page 56).

   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.

3. 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.
4. If any openings in the stand are greater than 0.25 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 of Scenario 3 activity.

Current stand	Trees/acre	Avg. dbh	Action needed
4-inch clumps	450	4″	Precommercially thin from 450 down to 160 tpa (removing 290 tpa).
	160	Grow to 10″	Commercially thin. Residual spacing to be determined at that time.
8-inch clumps	255	8″	Precommercially thin from 255 down to 160 tpa (removing 95 tpa).
	160	Grow to 10″	Commercially thin. Residual spacing to be determined at that time.
14-inch clumps			
Clumps with regeneration	85	14″	Commercially thin from 85 to 70 tpa to release regeneration.
	70	grow to 16″	Assess growth of understory trees and thin again if necessary to maintain vigor of understory trees.
Dense clumps	125	14″	Commercially thin from 125 to 70 tpa (removing 55 tpa).
	70	grow to 16″	Commercially thin. Residual tree spacing to be determined at that time.
Scattered large trees	varies	20″+	Thin around the most vigorous in a "donut" fashion; leave others for wildlife. If some large trees are removed, reforest openings.

CHAPTER 4

Managing lodgepole pine

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). Lodgepole pine is recognized as a valuable species in many regions of the world. It is planted not only in North America but in Argentina, New Zealand, Scotland, Sweden, Ireland, and Iceland. In Sweden, lodgepole pine grows 70 percent more volume than native species.

In the Pacific Northwest, lodgepole pine sometimes has had a bad reputation for problems in management (or lack of management) including very slow growth due to overstocking, dwarf mistletoe, and bark beetles (Figure 4.2, following page; 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 under proper management.

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, 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, woody debris that improves aquatic habitat.

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.

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.

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

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 7). 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 or larch, perhaps for genetic reasons.

Climate, soils, and topography

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 Cascade Mountains, 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 6 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 crown fires. Such stand replacement fires resulted in the even-aged forests we have today. The catastrophic fires burned the existing lodgepole stands completely and in the process created 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 are 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 (see the plant association guides listed in Appendix 4, page 203.

In the Cascades

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 sedge; tailcup and silvery lupine; beargrass; squaw currant; snowbrush; greenleaf and pinemat manzanita; antelope bitterbrush; and big, dwarf, and grouse huckleberry. 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 low 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 huckleberry; 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 elevations and quaking aspen, mountain hemlock, or whitebark pine at the higher elevations.

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 mycorrhizae, 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. For more information on mushrooms as a crop, see *Harvesting and Marketing Edible Wild Mushrooms*, EC 1496.

Figure 4.3. Matsutake mushrooms.

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 collects. As elevation increases, lodgepole pine is replaced by Douglas-fir and grand fir. Mixed stands are more common in northeastern than in central or southern Oregon. In mixed stands, lodgepole pine grows with subalpine fir, grand fir, larch, spruce, and Douglas-fir.

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 1- to 3-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, or beetle attack.

The percentage of 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 or nearby shrubs.

Seedling development

Seedlings are poor competitors, especially against grass. Survival is best on disturbed mineral-soil seedbeds. 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 other pines and larch. Diameter growth rates of lodgepole pine are severely affected by stand density. For example, in northeastern Oregon unmanaged stands 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 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). Net yields for lodgepole pine by site index in Tables 4.1 and 4.2 are for pumice soils in central and southern Oregon.

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).

Age (years)	Site index 50 (height at age 50)				
	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).

Age (years)	Site index (height at age 50)				
	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

Silviculture systems

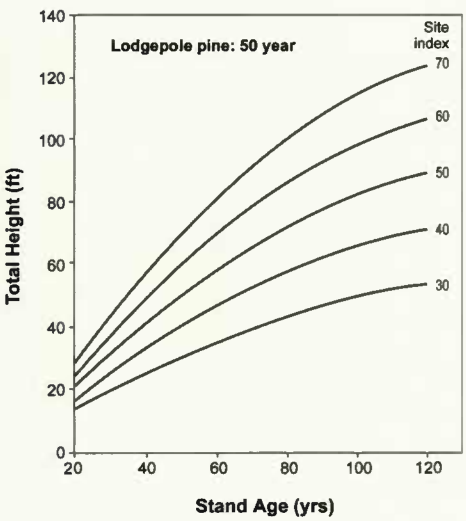
Three silvicultural methods produce even-aged stands of lodgepole pine: clearcutting, seed tree, and shelterwood systems (see Chapter 2). Managing for uneven-aged stands includes individual tree selection and group-selection methods. For information about reforestation, see Chapter 6.

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. 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. Clearcuts can be regenerated by planting or by natural seeding. Clearcutting in northeastern Oregon works well for regenerating lodgepole, whether in frost pockets or not. 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.

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



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 2.13, page 33) 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 seed tree or shelterwood trees is relatively small, leaving some or all of the lodgepole pine seed trees rather than harvesting them after successful seeding or shelter has occurred is a common practice to increase stand structure and diversity for wildlife. If you use mistletoe-infected trees as seed trees or shelterwood trees, 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 30 to 40 shelterwood trees to provide more shelter for seedlings. In this

Table 4.3. Silvicultural operations for managing lodgepole pine.

Age (years)	Stage	Method	Density (tpa)	Spacing (feet)
0	Regeneration	Natural	0–5,000+	n/a
		Planted	150–430	10 x 10 to 17 x 17
10–20	Early thinning (precommercial)	Thin from below	200–350	11 x 11 to 15 x 15
10–20	First pruning*	Leave 50% of live crown	50	30 x 30
20–30	Second pruning*	Leave 50% of live crown	50	30 x 30
30–40	Third pruning*	Leave 50% of live crown	50	30 x 30
50–90	Late thinning	Thin from below	50–100	21 x 21 to 30 x 30
91+	Harvest/regeneration	Clearcut	0	0
		Seed tree/shelterwood	10–40	33 x 33 to 66 x 66

*Pruning is a high-cost option.

case, remove most shelterwood trees later to avoid severe competition between the overstory and the seedlings. Trees should have no 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.

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, page 150).

Stand management

Thinning and improvement cutting

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. Thinning slash may need to be piled and burned, to reduce 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 percent live crown ratio. Thinning can significantly enhance growth, merchantable yield, and value, helps protect against bark beetles, and increases forage production by opening stands to light. In fact, many lodgepole stands 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 x 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 x 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 to keep the stump alive and competing for resources. Densities of less than 350 trees per acre have sufficient spacing (Table 4.3).

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

Commercial thinning Sometimes the first commercial thinning can be early, harvesting trees as small as 4 inches dbh for chip material. One strategy is to keep stands dense (more than 350 trees per acre) until average diameter is 4 to 5 inches, then commercially thin to 200 to 350 trees per acre (11 x 11 to 15 x 15 feet spacing; see Table 4.3).

Thin again when trees are 50 to 90 years old, leaving only 50 to 90 tpa (spacing of 22 x 22 to 30 x 30 feet). This significantly improves diameter growth, reduces likelihood of mortality from bark beetles, and 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 those 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 disease 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), or 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.

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

Sanitation cutting removes living trees that have mistletoe plants, thus reducing spread of mistletoe seeds to adjacent trees. Sanitation cutting also can remove trees recently attacked by mountain pine beetle while the beetles are still under the bark. Harvesting removes the beetles that would have flown and attacked other trees. Harvested trees probably would have died within the year; harvest saves wood value, which deteriorates after tree death.

Salvage cutting removes trees already killed by mountain pine beetle or mistletoe in order to capture wood value before it deteriorates further.

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

Tree spacing Thinning intensity is based on the stocking-level guidelines as 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 60–70) and the lower growth rates on poorer sites (SI 30–40). 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 (Peterson and Hibbs 1989).

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 slows, and trees die from bark beetles. Keeping your stands between low- and high-density range 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 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.

How many trees should you remove? If you thin to 250 trees per acre (the maximum recommended), the stand is still susceptible to some mortality. You decide to thin to 170 trees per acre, removing 330 trees per acre by free thinning (see Chapter 2, page 27). A sample marking of trees to remove shows that the average diameter of the residual stand will still be about 8 inches. Therefore, you don't have a marked "chain-saw" effect.

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).

When will you need to thin again? With 170 tpa, thin again when 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 are removing 75 mostly smaller diameter trees in a low thinning. A sample marking shows that removing mostly small trees will increase the average diameter of residual trees to almost 12 inches. Thinning the stand from 170 to 75 tpa would allow the stand to grow to 16 inches dbh before another thinning is necessary.

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 (see *Pruning to Enhance Tree and Stand Value,* EC 1457). You can prune to remove branch infections of mistletoe or rust fungi.

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). 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. 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, lodgepole pine is very responsive to additions of 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. Consult with your Extension forester, a consulting forester, or an ODF 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 feet at 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.

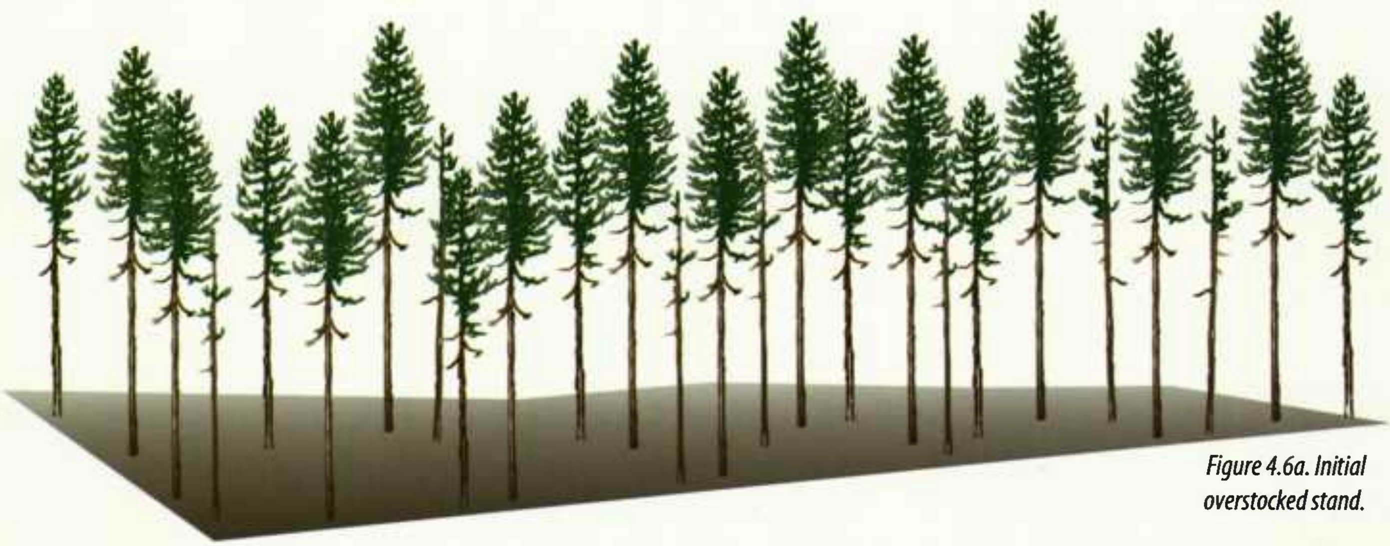


Figure 4.6a. Initial overstocked stand.

Solution (Figures 4.6b–c)

1. Commercially thin now to about 200 tpa (11 x 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.
2. In another 15 years, harvest the stand when it has a mean dbh of about 6 inches, and trees can be sold for chips or some sawlogs. Leave a light shelterwood of 10 trees per acre (65 x 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 and 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.

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.

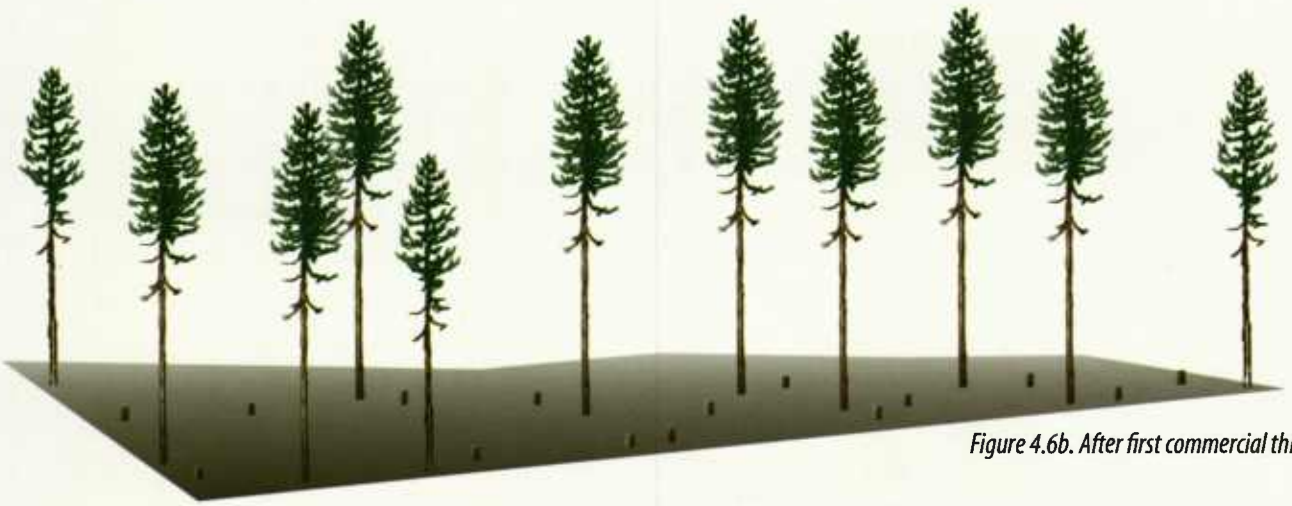


Figure 4.6b. After first commercial thinning.

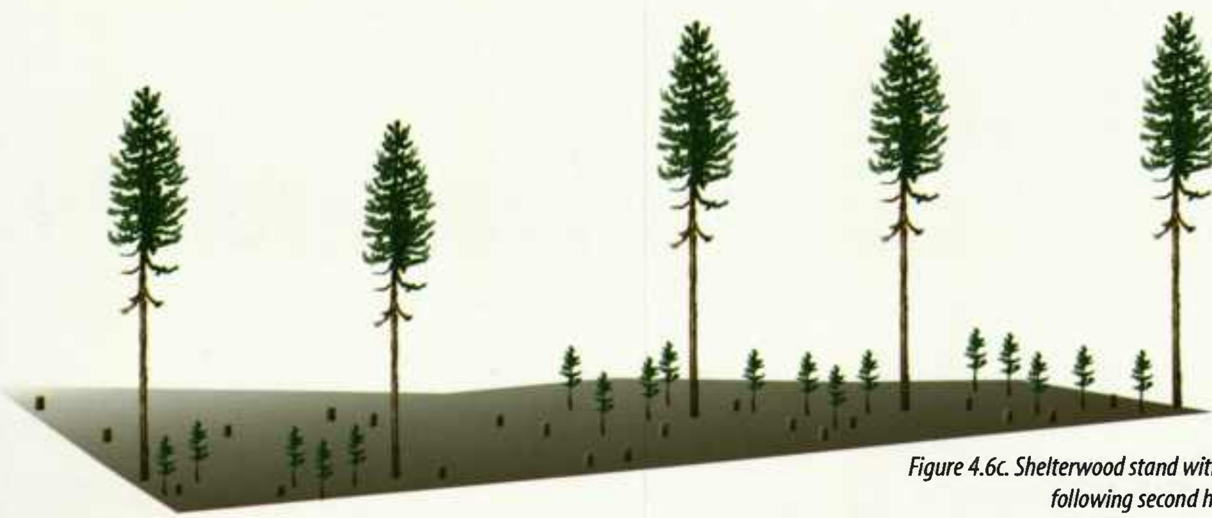


Figure 4.6c. Shelterwood stand with regeneration following second heavy thinning.

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 and 6 inches average dbh and has 700 tpa.
2. The stand is on a moderately productive site (site index 60 feet at 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 x 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. 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 Douglas-fir to increase biodiversity. Gradually the younger fir and pine trees will replace the old stand as periodic thinning continues.

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 Douglas-fir.

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 60 feet at 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 very slowly.
6. The main objective is future revenue from timber. Wildlife is secondary.

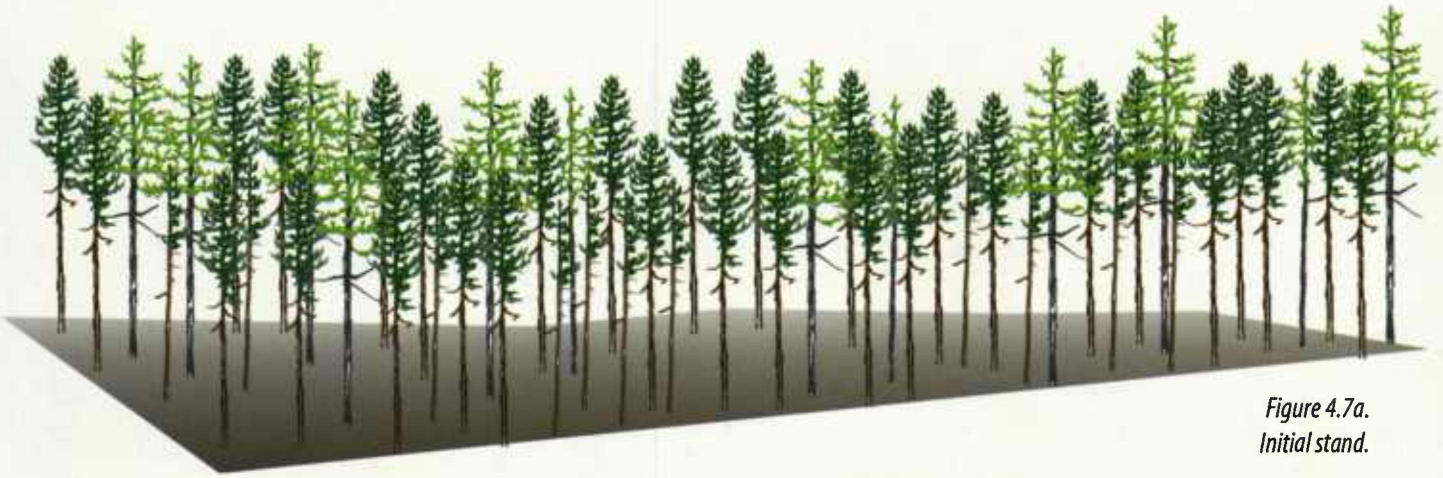


Figure 4.7a. Initial stand.

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). This thinning increases tree growth but still prevents invasion of new lodgepole seedlings at this age.
2. In 30 years, 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, the stand averages 14 inches dbh. Thin 65 tpa (retaining the 1-to-1 species mix), and sell the thinnings as sawlogs.
4. In another 20 years, 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 assure a good larch–pine mix for the future (Figure 4.7c). Harvest the other half of the stand, retaining 20 tpa for seed and wildlife shelter.

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

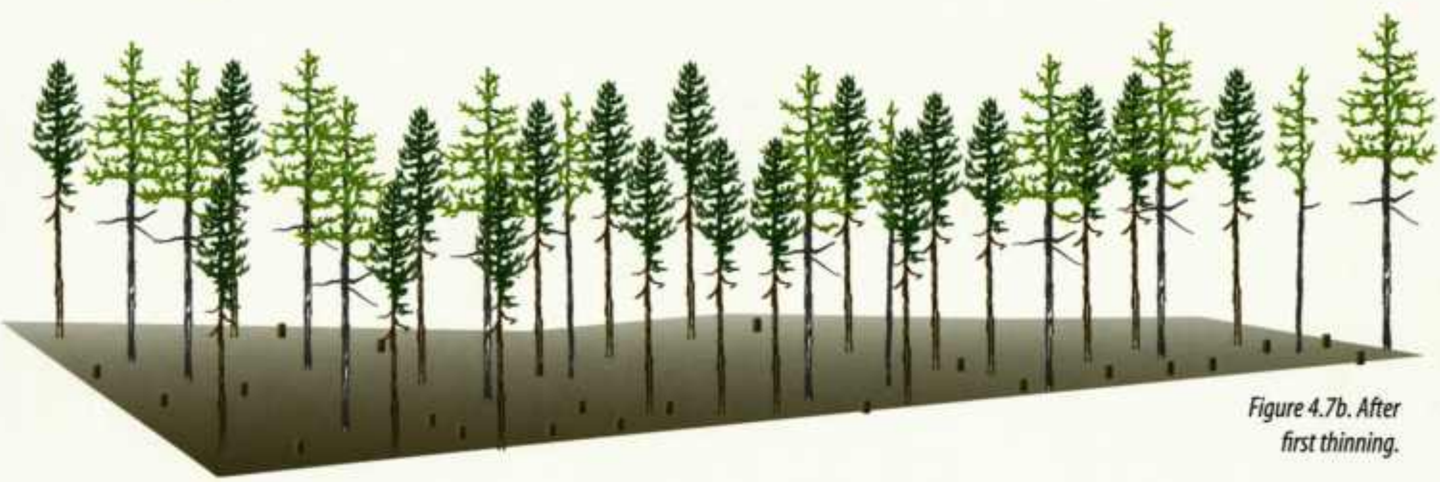


Figure 4.7b. After first thinning.

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

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 that 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 by:

- Using shelterwood systems on pumice soils to protect natural regeneration and thus reduce or avoid regeneration costs.
- Thinning overstocked stands to prevent stagnation, reduce fire risk, improve habitat, and increase value.
- Properly thinning stands with average dbh at or above 6 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

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Mixed-conifer forests of ponderosa pine, Douglas-fir, grand fir, western larch, lodgepole pine, and subalpine fir 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, Shasta red fir, sugar pine, and Engelmann spruce are sometimes 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. Also important, good management can improve forest health and assure that the benefits of mixed-conifer forests are available without interruption.

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 following page).

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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 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.

Because mixed-species forests span such a wide range of environments, we will divide them into two types: warm and dry, and cool and moist (see definitions in Chapter 1). The warm, dry mixed-conifer forest type is found at lower elevations, down to 800 feet in some cases. As elevation increases, conditions become favorable for 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. Generally, you'll find the mixed-conifer type within a 2,200- to 6,500-foot elevation zone, though elevation varies somewhat depending on location. Elevations lower than 2,200 feet and south slopes at moderate elevations may be too warm and dry for Douglas-fir and 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

Mixed-conifer forests grow over a wide range of climatic, soil, and topographic conditions. Climate varies widely depending on storm patterns and elevation. Most mixed-conifer sites receive 20 to 40 inches of moisture per year. Twenty 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 varies widely. The climate is typically a mixture of maritime and continental.

Mixed stands grow under warm, dry conditions where ponderosa pine usually seeds in after a disturbance. These sites were historically dominated by ponderosa pine because the species is well adapted to survive a low-intensity fire regime (see Chapters 1 and 2) every 8 to 20 years. Now, Douglas-fir or grand fir are *climax* species on warm, dry sites and make up about 70 percent of the mixed-conifer type (Fred Hall, personal communication).

The mixed-conifer forest type can be characterized as cool and moist where there is little ponderosa pine; instead, you'll find subalpine fir as well as Douglas-fir and grand fir in abundance. Western larch and lodgepole pine are common as pioneer species in mixtures on these sites. Western white pine and Engelmann spruce also grow in this cool, moist zone. On harsh, higher elevation sites, subalpine fir and Engelmann spruce grow in a cold forest zone. Subalpine fir also grows at timberline, often in conjunction with whitebark pine.

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 the warm mixed-conifer type in the Blue Mountains, they are primarily residual, developed from basalts and granitics. Ash soils are common, however, in both the warm, dry and the cool, moist forest types in the Blue Mountains. 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 relatively abundant precipitation. 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 within mixed stands.

Available soil moisture is extremely important in influencing site productivity and species distribution in these forests. Nutrient availability and cold in some areas may limit soil 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

Cascades region

Warm, dry forests On the east slopes of the Cascade Mountains, the common species are Douglas-fir, ponderosa pine, and grand fir; incense-cedar, sugar pine, and western larch are occasionally part of this mixture. In the understory, common 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 grand 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 forests On the east slope of the Cascades, Pacific silver fir, western hemlock, grand fir, subalpine fir, mountain hemlock, and Shasta red fir or noble fir are common tree species growing at mid to upper elevations. In general, the understory includes baldhip rose, gooseberry, big huckleberry, willow, twinflower, sedges, heartleaf arnica, lupine, and western hawkweed.

Blue Mountains region

Warm, dry forests Douglas-fir, ponderosa pine, 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 20 to 25 inches annually. In northeast Oregon, western larch is common in this type, and lodgepole pine is often present but plays a minor role. In the understory, mallow ninebark, common snowberry, spiraea, oceanspray, heartleaf arnica, baldhip rose, Columbia brome, Kentucky bluegrass, elk sedge, and pinegrass are widespread.

Figures 5.2a–b. At top, 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. Below, succession in a warm mixed-conifer forest, with grand fir and Douglas-fir regenerating under and growing up through a canopy of ponderosa pine.

What appear to be pure stands of ponderosa pine, western larch, or lodgepole pine can be found on these mixed-conifer sites. However, small numbers of the more shade-tolerant species generally grow there also, indicating the stands eventually will develop fir understories and become dominated, over time, by intermediate shade-tolerant Douglas-fir and/or the more shade-tolerant grand fir.

Cool, moist forests This forest type is found at higher elevations, generally between 4,500 and 6,500 feet, where precipitation levels are 25 inches or more and temperatures are colder.

The uppermost elevations of the Blue Mountains have almost pure stands of subalpine fir or grand fir mixed with mountain hemlock (rare), lodgepole pine, or whitebark pine. Here the understory is dominated by twinflower, queen's cup, and grouse huckleberry. As elevation drops, these understory species can be found growing with Douglas-fir, western larch, western white pine, and Engelmann spruce in a variety of mixes. The presence of subalpine fir generally indicates cool, moist, mixed-conifer forest types. Ponderosa pine may be present, 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), pine grass, and elk sedge.

Quaking aspen and black cottonwood Quaking aspen stands 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 probably more common. Suckering is stimulated by disturbance, and plenty of light is essential for growth of new shoots. Without disturbance from fire or other methods, quaking aspen stands may decline as older trees die from insects and disease and the stand is invaded by shade-tolerant grand fir and/or Douglas-fir. Many quaking aspen stands are in decline across eastern Oregon as a result of fire suppression 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.

Black cottonwood is the largest hardwood tree in the Pacific Northwest and is found in abundance along streams in eastern Oregon. This species provides shade along streams, cavities and structural diversity for wildlife, food for aquatic organisms, and bank stability (see *Cottonwood: Establishment, Survival, and Stand Characteristics*, EM 8800).

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 7.

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 have large seed crops about every 2 to 6 years but produce smaller crops more regularly. Larch seed is lighter than pine's and Douglas-fir's, and production is less frequent. Grand fir, subalpine fir, and Engelmann spruce produce large amounts of seed each year. Seed falls in late summer and early fall. Generally, collect cones in late summer when seed is mature but cones are still closed. Timing varies by species, elevation, aspect, and annual weather patterns.

Seed weight, wind patterns, tree height, and topography affect seed distribution. For example, western larch and mountain hemlock seed is light, at 136,000 to 114,000 seeds per pound, respectively. Given the same tree height, their seed will travel farther than ponderosa pine seed, which is relatively heavy, averaging 12,000 seeds per pound. Douglas-fir seed is somewhat lighter, at 49,000 seeds per pound. 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.

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. 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 limits establishment and growth of all mixed-conifer species, particularly on warm, dry sites. For more detailed information on natural regeneration and seed production differences among species, see Chapters 1 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 sites in the mixed-conifer zone, 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. Wildlife also take their toll on young seedlings. Look for browsing of the laterals and top (deer, elk), rubbing of the main stem (deer, elk), girdling damage 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 rates are moderate; and grand fir, subalpine fir, and Engelmann spruce typically have slow rates. Even though species with slower juvenile height growth can't keep up initially, some have higher shade tolerance (grand fir or 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 species composition of mixed-conifer forests. Ponderosa pine, western larch, and lodgepole pine are least tolerant to shade; grand fir, Engelmann spruce, and subalpine fir are most tolerant. Douglas-fir, incense-cedar, and western white pine are in between.

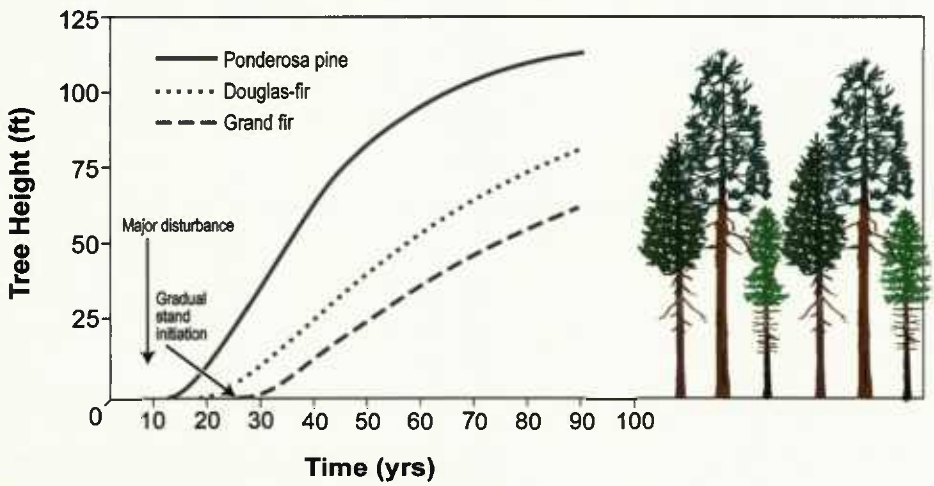


Figure 5.3. How mixed-conifer stands develop. In one model, a pioneer species such as ponderosa pine captures a site after a major disturbance. Over time, shade-tolerant species such as Douglas-fir and grand fir seed in under the pine, eventually growing up into the pine canopy and dominating the site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

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). 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.

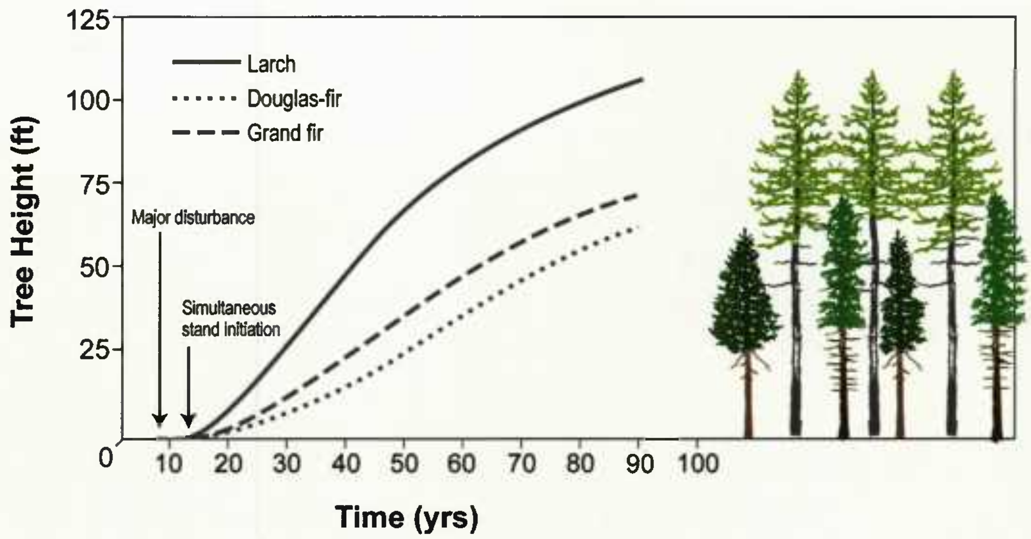


Figure 5.4. Simultaneous stand initiation. Here, several species get started at about the same time after a disturbance. Faster growing species such as larch surpass the more shade-tolerant species in the understory, which eventually grow up through the canopy to dominate the site (adapted from Oliver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

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 under-story. 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. In the second model, all trees are approximately the same age.

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 Forest Service silviculturalist 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, page 28, for how to measure and use site index.) Site index curves for managed stands of Douglas-fir, 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 16-inch diameters.

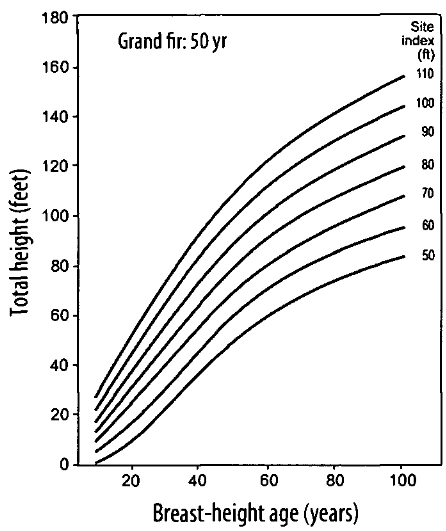


Figure 5.5. Site index curves for managed, even-aged stands of white or grand fir east of the Cascades in Oregon and Washington on a 50-year basis (Cochran 1979c).

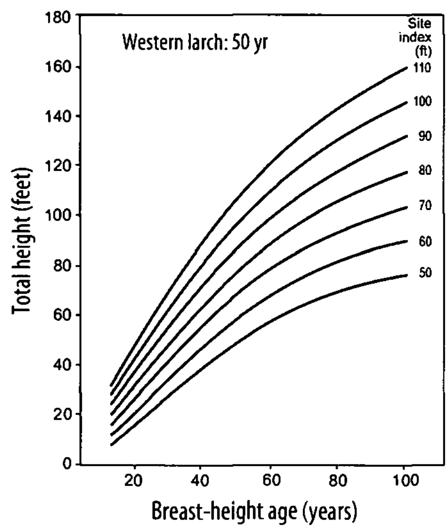


Figure 5.6. Site index curves for western larch on a 50-year basis (Cochran 1985).

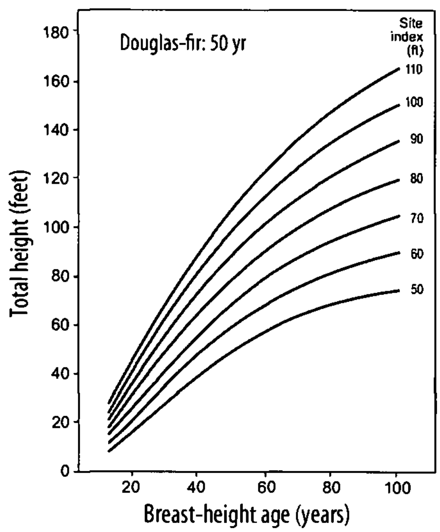


Figure 5.7. Site index curves for managed, even-aged stands of Douglas-fir east of the Cascades in Oregon and Washington on a 50-year basis (Cochran 1979b).

Cubic-foot and board-foot production

Tables 5.1 through 5.3 (below and on the next page) 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 80. 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 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 species.

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

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	1014	1371	1787	2262	2793
30	865	1311	1860	2507	3248	4081	5001
40	1263	1914	2701	3619	4660	5817	7085
50	1654	2496	3505	4670	5981	7428	9004
60	2030	3051	4264	5654	7208	8916	10,767
70	2391	3578	4978	6574	8350	10,294	12,392
80	2735	4076	5650	7436	9415	11,573	13,897
90	3065	4550	6285	8285	10,412	12,767	15,296
100	3378	5000	6885	9009	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	1073	1444	1838	2249	2671
30	1244	1879	2567	3285	4018	4757	5495
40	2142	3095	4019	5104	6118	7122	8111
50	3036	4268	5527	6787	8031	9250	10440
60	3892	5366	6851	8320	9757	11155	12511
70	4699	6387	8068	9716	11318	12867	14363
80	5458	7335	9188	10993	12737	14417	16033
90	6170	8217	10223	12166	14035	15830	17551
100	6839	9039	11183	13249	15230	17126	18940

deep soils and adequate moisture, at higher elevations and on north slopes), grand fir can provide 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, and grand fir density needs to be managed.

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 are not provided in this manual.

How can management influence timber yield? As a general rule of thumb, mixed-conifer forests grow between 150 and 300 board feet per acre per year for reasonably stocked stands of sawtimber; 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 for 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	1118	1443	1790	2157
40	999	1494	2040	2632	3265	3934
50	1433	2142	2926	3775	4682	5643
60	1823	2724	3721	4801	5955	7176
70	2164	3235	4419	5701	7071	8521
80	2462	3680	5026	6484	8043	9692
90	2721	4067	5555	7167	8890	10,714
100	2948	4407	6019	7765	9632	11,608
110	3148	4705	6427	8292	10,285	12,394
120	3325	4970	6788	8757	10,862	13,090
130	3482	5205	7109	9172	11,376	13,710
140	3623	5415	7397	9543	11,836	14,264

Silviculture systems

One of the first decisions to make about managing your mixed-conifer forest is which silviculture system to select. Even-aged and uneven-aged systems are two basic approaches (see Chapter 2). Because of past harvesting and fire suppression practices, many mixed-conifer forests in eastern Oregon have two to three age classes, making uneven-aged management an understandable choice. However, many stands have been *high-graded* and consist of too many shade-tolerant species (such as grand fir and Douglas-fir) that are susceptible to aggressive defoliators as well as bark beetles (Figures 5.8a–c). 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 right), to top kill (below left) to heavy mortality in the stand from defoliation and bark beetles (below right).

Even-aged regeneration methods

Clearcutting

Clearcutting (Figure 5.9) generally is reserved for converting damaged or endangered 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.

Replant all clearcut areas unless local knowledge indicates natural regeneration will be successful. The Oregon Forest Practices Rules set regeneration standards and regulates 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. Successful establishment of natural regeneration varies on both types of mixed-conifer sites. Even if present, the regeneration may not be a desirable species for the site and may be delayed. 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.

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. Ponderosa pine does better than other species on south or southwest exposures. Plant 1-1 ponderosa pine and control competing vegetation for best results.

Figure 5.9. Small cleorcuts or patch cuts in mixed-conifer forests con meet o variety of gools including converting a stond infested with dwarf mistletoe or root disease to o more healthy condition.

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 grows well; however, Douglas-fir does better with some shade on these sites.

Western larch grows well in 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 for both forest types where moisture stress and sun exposure are high.

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

Plan to plant or 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 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). 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

Natural regeneration across most mixed-conifer sites has been good with shelterwood cuts. 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 (25 to 50 square feet of basal area) per acre to provide seed and cover for regeneration. Natural regeneration success can be improved by creating a favorable seedbed. Shade-intolerant species germinate better on mineral soils. Logging disturbance, mechanical scarification, or prescribed burning are three ways to create that seedbed. 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 at higher elevations in the cool, moist type. Dense stands may need to be cut in two or three stages because of windthrow concerns.

BOYD WICKMAN

Figure 5.10. Shelterwaad horvests provide seed ond shelter from temperoture extremes. It's important that the shelterwood system be apen enough to ollow for the sunlight needs of pine ond larch, which are greater than fir species' need far sun. Refarestatian gaals can be met with naturol seeding, hand-plonting, ar o combinotion of both.

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. 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, plan on planting it. On warm, dry mixed-conifer sites, favor ponderosa pine in the drier areas and larch where there's more moisture. In cool, moist forest types, focus on larch and lodgepole pine. For the warm, dry type, one option might be 40 percent ponderosa, 20 percent western larch, and 40 percent Douglas-fir. On cool, moist types, plan for 40 percent western larch, 20 percent for lodgepole pine and/or ponderosa pine, and 40 percent grand fir, Douglas-fir, subalpine fir, and Engelmann spruce.

Dense stands are vulnerable to windthrow after harvest. Thin trees in two or three stages to build windfirmness. Also, avoid harvesting on ridge tops, shallow or wet soils, and areas where winds funnel. Keep ponderosa pine, larch, and Douglas-fir because of their deep root systems.

Seed tree cuts are not as common as shelterwood cuttings in mixed-species forests because of the high windthrow potential and lack of consistent success in seed tree cuts. On cool, moist mixed-conifer sites, seed tree cuts are 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 2 to 4 years, plant seedlings.

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 fire.

Leave trees should be good seed producers, be the right species for the site conditions, harbor little or no dwarf mistletoe or other diseases, 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. Take care, when removing the overstory, to protect regeneration. Work with the operator during the planning phase so that they understand that retaining advanced regeneration is a priority. Designated skid trails and directional felling are two methods to consider. 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).

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

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).

Uneven-aged regeneration methods

Uneven-aged management in mixed-species stands requires considering two major factors: first, the different shade tolerances of the various species (Table 1.2, page 7); second, differences in growth among species on the same site. For example, if pole-size 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. 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.

Individual tree selection

Stands in the warm, dry and 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. You can avoid predisposing these stands to insect or disease pests by managing species composition 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, 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 in warm, dry mixed-conifer or lodgepole and/or larch on cool, moist sites can improve the species mix. However, openings must be 0.5 to 1 acre or larger to provide enough light for good survival and growth. Even 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 even 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 in the stand) and a mixture of species, which is visually pleasing (Figures 5.11a–b). Many mixed-species stands are adaptable to this system.

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.

Many mixed-conifer stands in eastern Oregon have been high-graded. How do you know whether yours has? Look for:

- Mostly grand fir and Douglas-fir in the overstory and big, old pine stumps
- A prevalence of root diseases
- 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 the stand

In a warm 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 0.5 to 1 acre. Encourage ponderosa pine and western larch where they occur, and protect them. Options will depend on stand condition. For example, if the stand is almost pure grand fir, removing the fir more intensively may be necessary to get the pine and larch to grow more vigorously. On the other hand, 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. Watch for root disease. Where you find it, plant resistant species (see Chapter 7).

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 a risk especially in warmer, dry forest types; root diseases are a greater risk on cool, moist, mixed-conifer sites. Multiple harvests and thinnings in stands dominated by true fir 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 ages below 100 years helps lower defects. 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 thinnings. In mixed-conifer forests, the cutting cycle depends partly on the site's productivity, timber type, and stocking (see Chapter 2). Generally, plan on a 5- to 20-year cutting cycle. In both mixed-conifer types, better sites with plenty of larger trees allow frequent, light commercial 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. Beware, however, of harvesting just 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 5.6–5.13, pages 115–118). This guideline is based on uneven-aged management in other parts of the world and has the goal of getting regeneration fast. For more detailed information about uneven-aged management stocking levels for sites with certain characteristics, consult Powell (1999).

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 to fir, instead of to root-disease-resistant pine and larch, and 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.

In mixed-species stands, manage slash by using one or a combination of:

- Whole-tree yarding (bole, limbs, and top are 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. 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. For pine, creating large piles has shown promise in keeping *Ips* beetle populations confined to slash; however, use caution because research is limited. 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. For more information, see *Designated Skid Trails Minimize Soil Compaction*, EC 1110.

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 less than 3 to 4 acres. 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. 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 precommercial and commercial thinning. 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 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 stand, you also might have an area dominated by true fir 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.

Figure 5.12. Group cuts in mixed-conifer stands are a good way ta create enough light ta the farest floor to regenerate pine and larch. Group cuts alsa wark well ta 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 ta minimize site damage, and plan well ahead to prepare the site and replant if natural seeding does not accur within a year or two.

Stand management

Strategies for managing mixed-conifer forests 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 mixed-conifer sites are in Tables 5.4 and 5.5 (below and following page). We emphasize that there is no single solution to management.

Table 5.4. Some management strategies for three management objectives in **warm** 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 300–350 tpa on drier sites; plant PP, WL, and DF on more 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 350–400 tpa. Control competing vegetation if necessary. Allow maximum density (for SI and species) of regeneration where screening is desired. Encourage clumps.	Plant PP at 150–200 tpa. Control competing vegetation if necessary. Seed less competitive grasses (non-sod-forming) at low rates after planting. Avoid, reduce, or manage grazing for 3–4 years until trees establish.
Young forests *Precommercial thinning*	At age 15–20 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 = 8 in.	Thin at age 20–25 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 and leave more DWD. First commercial thinning when average stand dbh = 8 in.	Thin to 200 tpa at age 15–20 yr or height 10–15 ft. First commercial thinning at 10 in dbh. Favor PP. Pile and bum slash or underbum and seed grasses.
Pruning	Begin when trees are 4 in dbh. Select 60 tpa, favoring PP. Select vigorous, dominant, well-spaced trees.	Begin when trees are 4 in dbh. Select 30 tpa.	Begin when trees are 4 in dbh. Select 50 tpa.
Commercial thinning and harvesting *Even-aged management*	Thin periodically to "beetle proof" stands. Thin from below. Retain most vigorous trees (CR above 30%). 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 and DWD. Seed, plant, or promote native shrubs, grasses, forbs. Develop ponds and enhance riparian areas. Fertilize understory or underburn to stimulate browse. Provide bird houses and platforms.	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 more 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 and DWD. Plant or promote native shrubs. Seed native grasses and forbs. Fertilize understory. Enhance riparian areas. Provide bird houses 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.

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, 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. Know what you have and clearly identify your objectives before developing a management strategy!

Table 5.5. Some management strategies for three management objectives in **cool** 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) and WL for a total of 350–400 tpa. On north slopes, add WWP and LPP. Control competing vegetation if necessary.	Plant PP, LPP, WL, DF, and WWP at 400 tpa. Control competing vegetation if necessary. Allow more tpa where visual screening desired. Encourage natural regeneration of all species. Encourage clumps.	Plant 60% PP (lower elevations and south slopes) and 40% WL at 200–250 tpa. Control competing vegetation if necessary. Seed less competitive 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 300 tpa. Favor PP, WL, and LPP. First commercial thinning when average stand dbh = 8 in. Lop and leave or pile and bum slash.	At age 15–20 yr or height 15–20 ft, thin to 350 tpa. Thin in two stages for stands over 10 acres. Create snags and leave more DWD. Favor species mixes. First commercial thinning when average stand dbh = 8 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, and LPP. First commercial thinning when average stand dbh = 10 in. Pile and burn slash or underburn it. Remove natural fir regeneration in thinning or underburning.
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. 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 and 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 extend entry intervals to 15–20 yr and thin more heavily at each entry. Seed grass on skid trails and landings. Allow only light grazing to minimize damage to natural regeneration.

*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

Thinning and improvement cuttings

Precommercial thinning

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

Using PCT in young mixed-conifer stands:

- 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

For a general discussion of thinning, see *Thinning: An Important Timber Management Tool,* PNW 184.

One rule of thumb is to PCT when you have over 130 percent of target stocking (tpa) that would grow to commercial size. If your goal for a ponderosa pine stand in the warm, dry mixed-conifer zone is an average 8-inch diameter, then thin when densities are greater than 300 trees per acre (tpa), to 200 to 225 tpa (Table 5.6, page 115). Thin early, when trees are 10 to 20 years old. For larch in a cool, moist mixed-conifer forest type, thin when densities exceed 540 tpa and thin down to 450 tpa. A good rule of thumb is to thin soon after *crown closure*, when trees have expressed their dominance, and before the live crown ratio is

Figures 5.13a–c. Thinning examples. Precommercially thin young, mixed-species stonds to estoblish eorly species composition ond density control. The stand at left is being thinned in stages ond will be ot o wider spacing when commercially thinned. Stocking level and species composition ore importont decisions when considering a commercial thinning; use Tobles 5.6–5.14, pages 115–120, to determine minimum ond moximum stocking levels for mixed-conifer sites such os those below.

reduced below 40 percent. Western larch needs to be thinned earlier, preferably when trees are 10 years old and 10 to 15 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 codominant positions, and of the appropriate species for the site.

Stocking levels for PCT depend on the species, site productivity, and the target diameter for the first commercial thinning. For instance, in the warm, dry forest type, keep trees close (say, 11 by 11 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 115). 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 116).

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 and other problems. To help you decide, and for PCT spacing guidelines, see *Precommercial Thinning for Enhanced Woodland Productivity*, EC 1189.

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. For example, 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 (Figure 5.13a, preceding page). 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. Tree diseases such as dwarf mistletoe also can be managed 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, trees should average about 10 inches dbh by 60 years on warm, dry sites and by 40 years on cool, moist sites. At this stage they're ready for a commercial thinning (Figures 5.13b–c, preceding page). 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.

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)

Use low thinning (see Chapter 2) for mixed-conifer stands when you intend to leave dominant and codominant 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.

High thinning is an option when you want to release vigorous and desirable smaller trees; for instance, when shade-intolerants are being outcompeted by tolerant species. In mixed-species stands, removing rough, dominant grand fir can release subordinate Douglas-fir or larch. Not all dominants and codominants are removed in these harvests; enough are left to meet the stocking level target.

Stocking guides

Stocking guides for even-aged stands (Tables 5.6–5.14, pages 115–120) are essential 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 more 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 (see Chapter 2).

Table 5.6 is a stocking guideline for warm, dry 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. The table reflects stocking levels as an average for each species and size class across many site conditions found within the warm, dry and cool, moist forest types.

Although the tables were developed for sites in northeast Oregon (Cochran et al. 1994), 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, page 29, for stocking guides based on radial growth. If you want more detailed information, refer to Powell (1999).

STOCKING GUIDE EXAMPLE

A warm 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, 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.

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. If thinning with mechanical equipment, do so in 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 (see *Managing Tree Wounds and Stem Decay in Oregon Forests,* EC 1519).

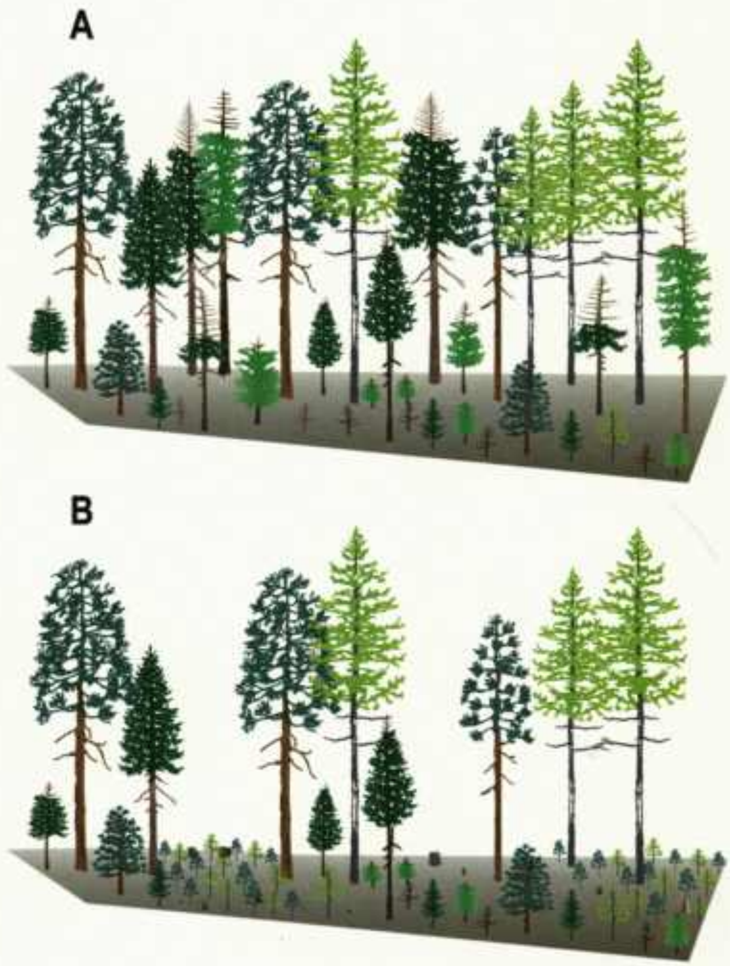
Sanitation, salvage, and improvement cuttings

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, below, and 5.15a–b, opposite). Remove:

- 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 fir (improvement; i.e, increasing resistance to defoliators and diseases by changing or balancing species composition)

Be sure to properly diagnose causes of poor forest health before you decide on an approach.

Figures 5.14a–b. Due to domoge by insects, diseose, weather, or other disturbonce, o mixed-species forest may have same tree species that are dead, dying, ar injured and athers that ore healthy. There may also be trees af poar vigor that are nat likely ta live until the next horvest (A). Given time, o sonitotion/solvoge/improvement aperotian will leove the forest with heolthier trees, proper spocing between trees, o good bolonce of species, ond the potentiol to regenerate the best species for the site (B). The wildlife value of stond B could be improved by leoving or creoting snags ond down logs.



W. T. ADAMS

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Figures 5.15o–b. An exomple of o sanitation/salvoge/improvement treotment shows (above left) o worm, dry, mixed-conifer stond that is overstocked, insect infested, ond diseose domoged. Retoining heolthy trees ond the lower risk pine and larch (above right) improves vigor ond species composition for a healthier long-term outlook.

Some disease problems, such as armillaria and annosus root rots, can get worse after an improperly planned cutting (see *Forest Health in Eastern Oregon,* EC 1413, and Chapters 2 and 7). Ask:

- 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?

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.

Pruning

The decision to prune your mixed-conifer forest 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 cut white pine blister rust mortality in 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 and *Pruning to Enhance Tree and Stand Value,* EC 1457). Prune only those trees you will retain the longest into the rotation, say, 50 to 75 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 is paramount to maintaining healthy pruned trees. Improperly pruned trees are more susceptible to pitch moths, stem defect, and heartrot.

Fertilization

Fertilizing mixed-conifer forests of eastern Oregon 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, page 39, 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, but total volume is greater than on poorer sites. Trees growing on volcanic ash cap and basalt-derived soils 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 response period. In mixed-conifer forests, fertilization will accelerate stand development, natural mortality, and the incidence of some pest-related damage. Vigilance is required to stay on top of density management and to capture increases in volume; if not, benefits of fertilization may be lost.

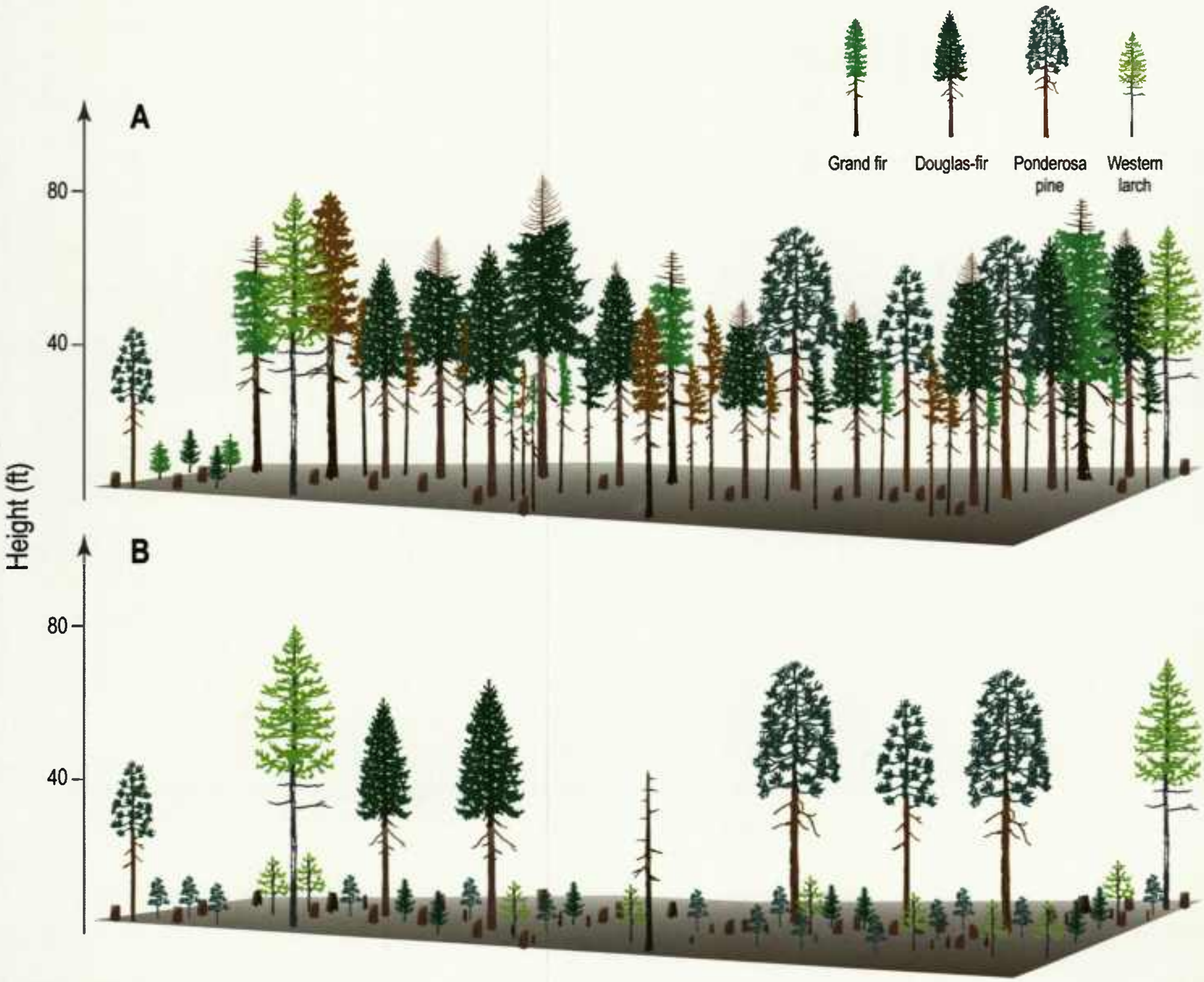
Mixed-conifer management options: Some examples

Scenario 1. Restoring a warm 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 is 80 percent grand fir and Douglas-fir, 10 percent ponderosa pine, and 10 percent western larch in the overstory. 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.

Figures 5.16a–b.



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. To reduce the fire hazard and make the stand more productive, the dead and top-killed trees must be removed as part of the treatment. 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 trees may moderate temperature extremes. 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 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 70 to 80 percent.

Control competing ground vegetation as part of planting. Some options follow; for details, see Chapter 6 and *Enhancing Reforestation Success in the Inland Northwest,* PNW 520.

- Apply herbicide the fall before or over dormant trees immediately after planting; apply to a 5- by 5-foot area centered on each tree. Use hexazinone (Velpar L or Pronone) for ponderosa pine; use sulfometuron (Oust) or glyphosate (Accord) for the larch. Do not apply hexazinone near larch! Before applying glyphosate, protect seedlings with a stove pipe or similar technique. Be aware that Oust can restrict Douglas-fir growth.
- Use 4- by 4-foot mulch mats around trees.
- Mechanically 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.
- By air, apply hexazinone to pine or sulfometuron to larch to the entire planting site. If both pine and larch are on the site, use only glyphosate (or glyphosate plus atrazine) as a site preparation tool before planting, or apply Oust to planted seedlings.

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 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 (see *Understanding and Controlling Deer Damage in Young Plantations*, EC 1201; *Controlling Pocket Gopher Damage to Conifer Seedlings*, EC 1255; and *Controlling Vole Damage to Conifer Seedlings*, EC 1256).

The fir will seed in, thereby increasing stocking levels, so plan for a precommercial thinning at age 10 to 15, thinning 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.

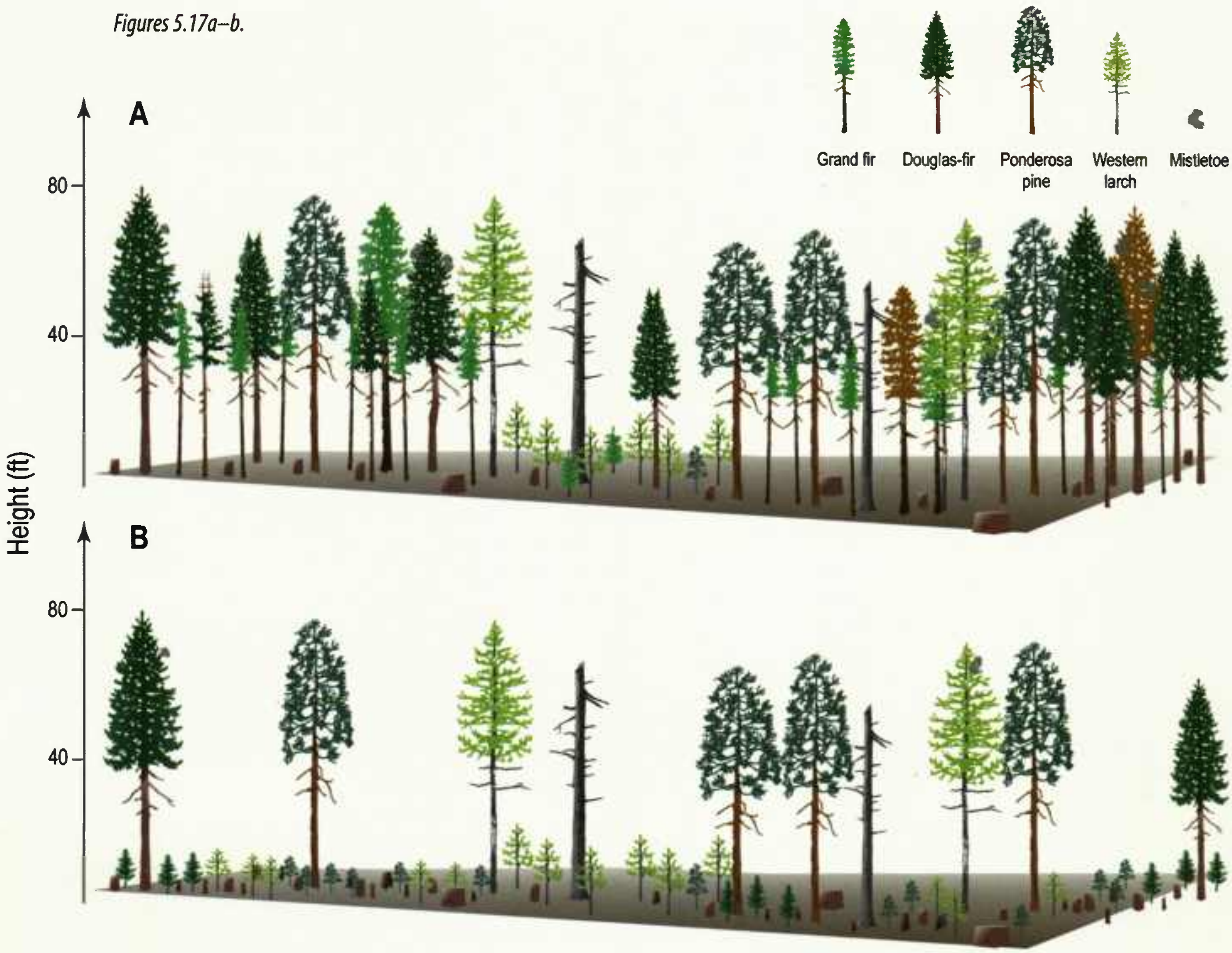
Scenario 2. Promoting the health and productivity of a warm, dry mixed-conifer stand

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 several times using *diameter-limit cuts*. Average tree diameter of sawtimber (trees 8 inches dbh and larger) is 12 inches; volume is 4,000 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, and root rot is killing the grand fir in a few pockets. 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.

Figures 5.17a–b.



Solution (Figure 5.17b)

Convert this stand to a pine- and larch-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) for shelter and seed; select mostly pine and larch and a little Douglas-fir. These should be dominant trees with good form and long crowns. 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. Remove the seedling and sapling Douglas-fir and grand fir less than 4 inches dbh to get pine and larch to regenerate.

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 2-0 ponderosa pine and 100 containerized larch per acre will hasten stand establishment and improve species composition. Control competing vegetation, as in Scenario 1, if necessary.

Once regeneration is 4 to 6 feet tall, remove overstory shelterwood trees in one or two stages. Because wildlife habitat is an objective, the overstory might be left to enhance vertical structure. However, leaving dwarf-mistletoe-infected overstory will increase the risk of infecting susceptible understory trees (larch and Douglas-fir). 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. Conversion to more pine and larch will decrease root disease problems on this site.

Leave a minimum of two snags per acre for cavity-nesting wildlife, or three to four snags per acre if wildlife is a high priority. Favor western larch and ponderosa pine snags or green trees 12 inches dbh or larger that have poor vigor and likely will die in a few years. Leave at least one to 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), anticipating a first commercial thinning when average tree diameter reaches 8 inches. For this first commercial entry, thin the stand to 84 tpa and let the stand grow to 14 inches (Table 5.6, page 115). Seed native or domestic grasses and forbs on skid trails and landings to reduce erosion and enhance forage for wildlife and domestic livestock. See Chapter 8 for seed mixtures, rates, and timing for domestic-grass seedings.

SUMMARY OF SCENARIO 2 ACTIVITY

1. Thin stand to shelterwood spacing of 20–30 tpa or 30–40 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 40–50 percent of the area and plant 50–100 2-0 ponderosa pine and 50–100 container larch (e.g., styro-5'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 or 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.

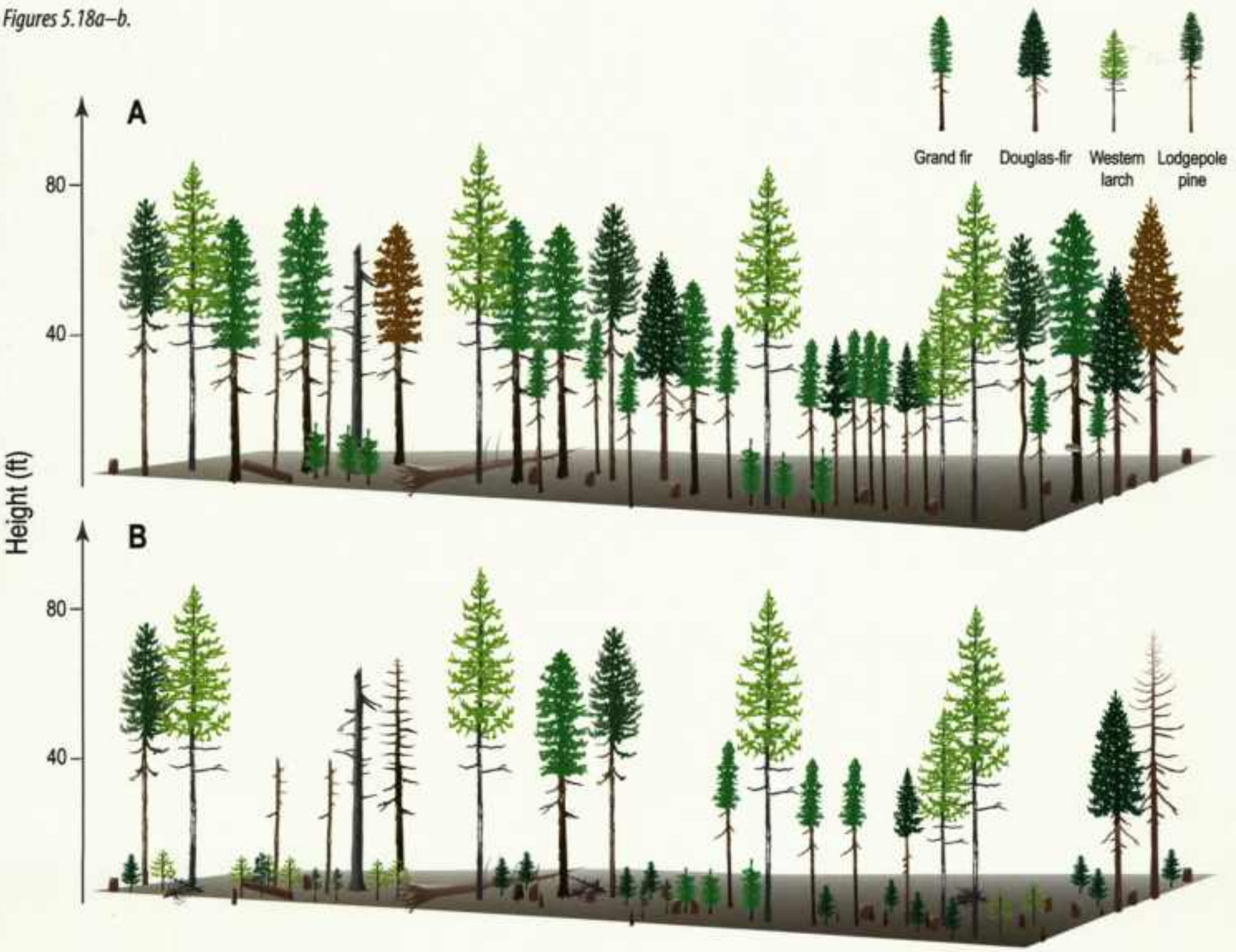
Scenario 3. Uneven-aged management of a mature cool mixed-conifer stand

Stand conditions (Figure 5.18a) and landowner objectives

This stand is on a cool, moist, north slope at 4,500 foot elevation. It is stocked at 8,000 board feet per acre with an average stand diameter of 14 inches dbh 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-size trees up to 7 inches dbh number 226 per acre (20 square feet of basal area); many of the grand fir are suppressed. New regeneration is sparse. Pest problems include scattered true fir and Douglas-fir killed by bark beetles, a few root disease pockets with dead and dying grand fir and subalpine 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 song birds and small mammals. The property also is used for family recreation, so maintaining aesthetic quality is important.

Figures 5.18a–b.



Solution (Figure 5.18b)

This stand is a candidate for uneven-aged management. Free-selection (see Chapter 2, page 27) harvests on a 10- to 15-year cycle will improve tree vigor, encourage regeneration, enhance stand quality, provide periodic income, and adjust species composition.

Thin clumps of commercial-size trees, using individual tree selection (ITS), down to 50 to 75 percent of the maximum stocking guide for even-aged stands. This is 56 to 83 tpa using the western larch stocking guide (Table 5.8, page 116; see also Chapter 2) and assuming an average 18-inch grow-to target diameter. After commercial logging, thin dense pockets of smaller understory trees to 300 tpa with the goal of a commercial cut when trees grow to 10 inches. Retain the most vigorous and best formed trees in all size classes during both cuts. Also, keep as much healthy larch and lodgepole pine as possible. Make group selections where there's root disease. Cut and pile the true fir in these pockets and plant styro-5 larch and lodgepole pine (or western white pine) at 300 tpa (12- x 12-foot spacing). To improve species mix outside the group cuts, plant these same species and stock-types in the middle of larger openings (at least 0.5 acre) at a 12- by 12-foot spacing.

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 true fir bole damage in grand fir 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 less) for aesthetic reasons.

Meet wildlife priorities by:

- Encouraging more pine and larch to increase species diversity
- Allowing two to three snags per acre
- Leaving two to 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
- 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. Thin clumps of commercial timber to 56–83 tpa. Remove poor-quality, dead, diseased, and insect-infested trees. Retain the good-quality larch and pine over the other species.
2. Healthy, vigorous lodgepole pine, larch, and Douglas-fir 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 lodgepole pine, western white pine (rust resistant), and containerized larch (styro-5s) for a total of 300 tpa.
4. Outside the group cuts, plant larch and lodgepole pine in openings at 50 tpa each to improve species mixes.
5. Precommercially thin young sapling trees to 300 tpa after commercial harvest.
6. Remove diseased grand fir, but retain 2–3 per acre for wildlife.
7. Minimize damage to the stand by using designated skid trails and rub trees.
8. Leave two to three down logs per acre, 8 inches and larger and at least 10 feet long for wildlife.
9. For wildlife objectives, encourage multiple canopy layers, provide bird boxes and platforms, seed forbs and grasses, and leave small slash piles.

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.

The key to effective management is to:

- Match species to site
- Strive for optimal species mixes
- Increase stocking of shade-intolerant species
- Address pest problems
- Manage stand density/stocking

In general, favor ponderosa pine on warm mixed-conifer sites and western larch, lodgepole pine, western white pine, and Douglas-fir on cool 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).

Avg. tree dbh (inches)	Minimum Trees/acre	Minimum Basal area/acre (square feet)	Minimum Spacing (feet)	Maximum Trees/acre	Maximum Basal area/acre (square feet)	Maximum 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.*

Avg. tree dbh (inches)	Minimum Trees/acre	Minimum Basal area/acre (square feet)	Minimum Spacing (feet)	Maximum Trees/acre	Maximum Basal area/acre (square feet)	Maximum 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. Averaged 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.

SPECIES Forest type Avg. dbh (inches)	Minimum Trees/ acre	Minimum Basal area/ acre (square feet)	Minimum Spacing (feet)	Maximum Trees/ acre	Maximum Basal area/ acre (square feet)	Maximum 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 avoids 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

Reforesting after harvest can be done by:

- 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*), or
- Taking advantage of seedlings and saplings that already are established in openings and beneath overstory trees (*advance regeneration*)

These three reforestation methods will be discussed in more detail in this chapter.

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

REFORESTATION LAWS

Oregon's Forest Practices Rules in most cases require reforestation if timber harvesting reduces stocking below certain minimum levels. (Exceptions are special cases of insect outbreaks or fire where the cost of salvage logging exceeds returns.) 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. Generally, 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 forest practices forester to find out the requirements for your situation.

Hand-planting nursery-grown seedlings

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

- Assures 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:

- 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.

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 very 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. Site preparation methods are discussed in more detail on pages 132–134.

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 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 in lots as small as 2,000 seedlings. Because it takes 2 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 ODF stewardship forester.

There are many seedling stock-types, each with characteristics that make it suitable for planting under certain site conditions (see Tables 6.2 and 6.3 on the next page). For most situations in eastern Oregon, the standard stock-type is 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 readily available for most seed zones and elevations in eastern Oregon. Other stock-types being used with success include 1+0, P+0 (plug), and

Table 6.1. Common seedling stock-type descriptions.*

Seedling stock-type description	Normal	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).

P+1 (plug plus 1 year growing in a transplant bed) seedlings, although they are not as widely available. 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 1 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 not been widely planted in eastern Oregon, but success has been good where they were used.

Plug ponderosa pine seedlings, particularly plugs greater than 10 cubic inches, are a good choice for 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.

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	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

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)	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

On cool and moist mixed-conifer sites, plant 2+0 bareroot or plug ponderosa pine, western larch, or Douglas-fir seedlings with a good balance between the roots and shoot. On dry mixed-conifer sites (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.

Where deer and elk browse, plant bareroot seedlings. Avoid planting plugs; the succulent plug seedlings often are heavily browsed. For more detailed information on seedling stock-types, see *Selecting and Buying Quality Seedlings*, EC 1196.

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.

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. 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. For more information, see *Seedling Care and Handling*, EC 1095.

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 may have begun to dry out already. This reduces survival and growth of newly planted seedlings.

Fall planting has had little success in central and eastern Oregon. Most soils 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. However, fall planting in northeastern Oregon may have potential because the region often gets sufficient early-fall moisture.

Planting tools

The tree spade (shovel), hoedad, and power auger are the most common planting tools (Figure 6.2). 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 sod is a problem, power augers work extremely 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.

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

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). For more detailed information, see *The Care and Planting of Tree Seedlings on Your Woodland*, EC 1504.

Selecting planting microsites

Improve planting success by selecting good *microsites*, especially on dry, harsh ponderosa pine sites but even on more moist mixed-conifer sites. 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, opposite) from mid- to late afternoon sun. Microsite planting may result in an uneven spacing, but it improves seedling survival.

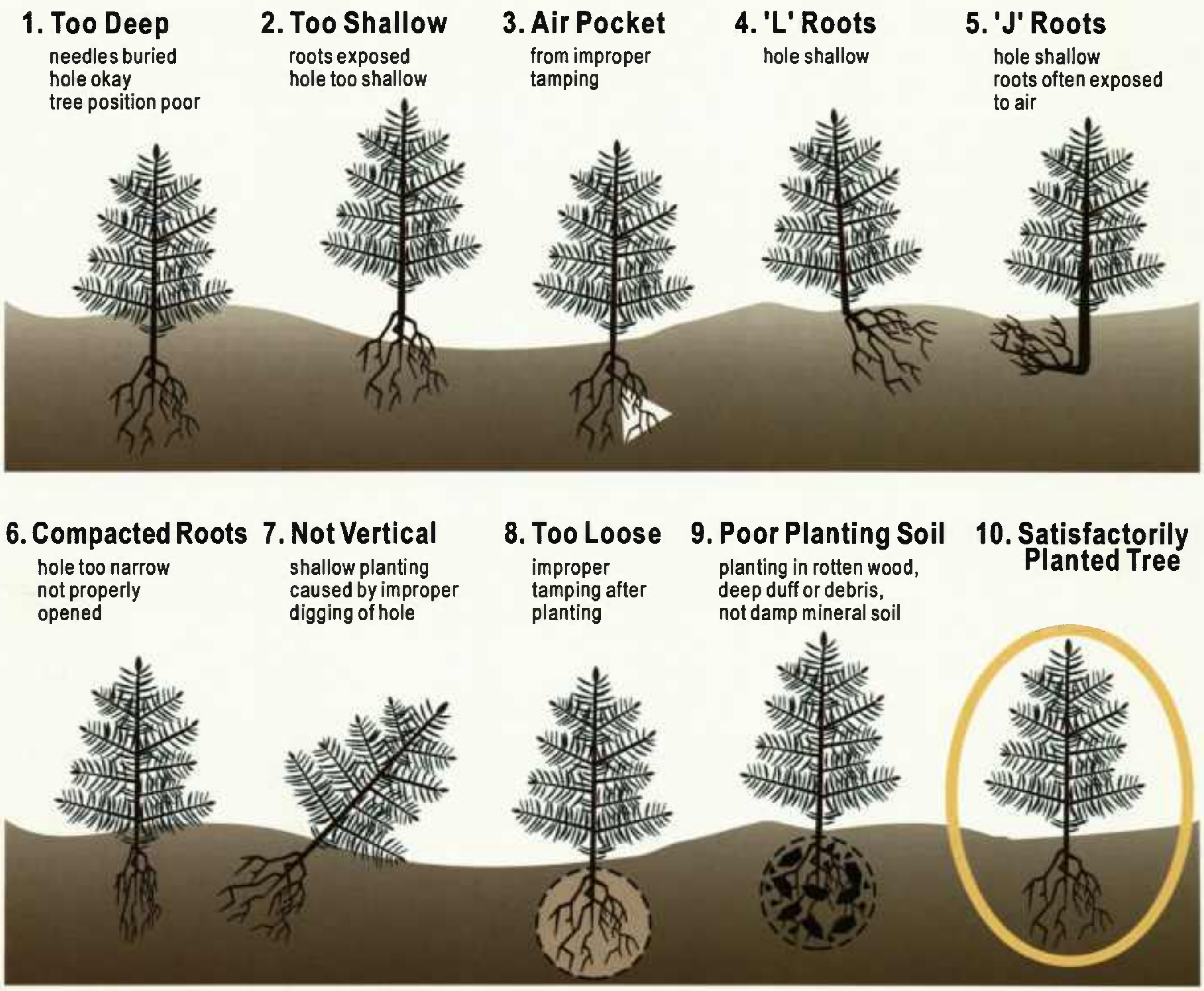


Figure 6.3. Proper and improper tree planting (adapted from Rose 1992).

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.

Figure 6.4. Microsite planting behind a stump.

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.

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

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

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

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), are effective but expensive and require follow-up maintenance the second year. Another deterrent is Big Game Repellent, a liquid that is sprayed on the terminal leader and has a strong odor (like rotten eggs) that deters browsing. Although it is effective, it requires retreatment within 2 months or so because it eventually washes off. For detailed information, see *Understanding and Controlling Deer Damage in Young Plantations*, EC 1201.

Pocket gophers that clip seedling roots are also a major problem on some sites and can cause complete reforestation failure in local areas. 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. See *Controlling Pocket Gopher Damage to Conifer Seedlings*, EC 1255, for more information.

Follow-up inspections

Plan follow-up inspections the first few years after planting, to identify potential problems with your seedlings. Signs to look for include:

- 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.

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, cone crops for ponderosa pine are good only every 2 to 5 years, and western larch can have intervals of 1 to 12 years between good cone crops (Table 6.4).

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.

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).

Several factors influence the success of natural regeneration including:

- 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 thinning or final harvest 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 2 years to ripen, but western larch, grand fir, and Douglas-fir cones mature in 1 year. If you need to harvest in a year when cone crops are poor, try delaying reforestation and site preparation a year or two until the next good cone crop, and then prepare the site just before seeds begin to fall in September.

Figure 6.6. Abundant natural regeneration beneath a shelterwood. The regeneration likely will require a precommercial thinning at age 20.

Natural regeneration can be achieved with *clearcutting* (in some cases), *seed tree* and *shelterwood* cutting (Figure 6.6), and with the uneven-aged system using *individual tree selection* and *group selection* cutting (see Chapter 2 for detailed 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 wind-blown seed. However, small openings 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 with 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 eight to twelve 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 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 25 to 45 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 what 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.

Advance regeneration

Seedlings often establish and grow in openings and under tree canopies (Figure 6.7). 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 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.

Figure 6.7. Excessive advance regeneration in a mixed-conifer stand.

On dry ponderosa pine and on 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 (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 the following.

Live-crown ratio Seedlings and saplings with long live crowns—greater than 50 percent of the seedling's or sapling's height—are the most desirable.

Height growth Consider the trees' growth during the 5 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 6.8).

Species 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. Also, wait until advance seedlings are 2 to 3 feet tall before removing the overstory, to minimize damage and mortality from logging.

Figure 6.8. Advance fir sapling with a good live crown ratio and an ability to respond to release.

REFORESTATION COSTS

The cost of reforestation after clearcutting, at the time of this printing, vary from $200 to $400 per acre. They should be considered long-term investments. Costs 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 (for example, the Forest Land Enhancement Program (FLEP)), the Oregon Forest Resource Trust, the Carbon Sequestration Program, and federal and state reforestation tax credits. Contact your local OSU Extension or Oregon Department of Forestry field offices for more information on these assistance programs; also see *Incentive Programs for Resource Management and Conservation*, EC 1119.

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.

Before planting, reduce competing vegetation with site preparation treatments. Tree seedlings may require an additional (release) treatment if competing vegetation reinvades quickly. For a general review of treatments, see *Site Preparation: An Introduction for the Woodland Owner*, EC 1188; *Enhancing Reforestation Success in the Inland Northwest*, PNW 520; and *Introduction to Conifer Release*, EC 1196.

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, but it exposes mineral soil to create plantable spots, enhance natural regeneration establishment, or remove habitat for tree-feeding wildlife. Controlling competing vegetation early 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, chemicals, 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 match 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, ODF stewardship forester, or forestry consultant.

To prepare sites with heavy grass and forb competition, use spot or broadcast applications of atrazine, hexazinone, or sulfometuron, depending on tree species, in the fall, before planting, or in 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, plant them slightly deeper and make sure soil has settled around base of the seedling. 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 other 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

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.

competitors, a mixture of hexazinone and glyphosate works well. See Table 6.5 for herbicide names and descriptions.

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 6.9). Scalping is very labor intensive and expensive 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.

Figure 6.9. Competing vegetation scalped away from a pine seedling.

Table 6.5. Common herbicides for controlling competing grasses, forbs, and shrubs in the inland Northwest.

Herbicide		Vegetation controlled	Application time	Mode of action
AAtrex 4L, AAtrex Nine-O	atrazine	Grasses	Early spring or late summer to early fall (August–September)	Root uptake
Accord	glyphosate	Grasses, forbs, and deciduous shrubs	Spring, summer, or fall	Absorbed through foliage
Arsenal	imazapyr	Forbs, grasses, 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	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, Pronone MG, Pronone 10G, Pronone 25G	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

Mulch mats are an effective alternative to either scalping or spot applications of herbicide. Mats are made of kraft paper, plastic, or a variety of woven plastic fabrics (Figure 6.10). 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.

Figure 6.10. A 3-foot vegetation mat around a pine seedling.

Sites occupied primarily by shrub species such as snowbrush ceanothus, mallow ninebark, black hawthorn, oceanspray, common snowberry, bitterbrush, and greenleaf manzanita can be treated using herbicides, mechanical scarification, prescribed fire, or combinations of those. 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 (see Table 6.5, preceding page). Mechanical scarification should be done when soil is dry; a brushblade does a good job of clearing site of shrubs, including roots. Mechanical scarification is a good way to gain access for planting and reduce competition on sites that shrubs have taken over, but a follow-up herbicide treatment may be needed to kill resprouting shrubs. Prescribed fire can also be used to reduce and kill competing shrubs. However, some shrub species can quickly resprout, and fire can stimulate dormant seeds of other shrub species (e.g., snowbrush ceanothus) to germinate and out-compete seedlings.

Release treatments

Grass, shrubs, and other vegetation may grow faster than newly established seedlings, reducing tree growth and increasing mortality. To ensure their survival, seedlings may need to be released from this competition using appropriate herbicides and/or manually cutting or scalping shrubs and grass. Even with good site preparation, some vegetation can be so aggressive that release treatments are necessary (Figure 6.11).

Figure 6.11. Using a backpack sprayer to kill weeds and release planted seedlings that are being overtopped by ceanothus and manzanita.

To release certain species' seedlings from grass or elk sedge, use hexazinone or atrazine in either a spot or broadcast application over seedlings in early spring or fall when seedlings are dormant. However, western larch, western white pine, and western redcedar are sensitive to hexazinone; instead, use Oust (Table 6.5, preceding page). 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 2,4-D, imazapyr, glyphosate, or triclopyr; herbicide selection, timing, and rates are critical to minimizing conifer damage. Herbicide combinations can be used if target vegetation in 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.

Individual clumps of competing hardwood trees and shrubs can be treated with a directed spray, tree injection, or basal bark applications 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.

Although more expensive and less effective than herbicides, manual cutting with a chainsaw 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.

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 vege-tation has overtaken and suppressed their growth (Figure 6.12). 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. For more information on release, see *Introduction to Conifer Release*, EC 1388.

Figure 6.12. Ceanothus has overtopped many seedling in this planting. Only a few seedlings have managed to stay above the vegetation. An earlier release treatment would have suppressed competing vegetation and allowed more seedlings to grow above the shrubs.

Summary

Reforestation is critical for achieving sustained benefits from your forests, and it is required by Oregon law. 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 develo 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

Gregory M. Filip and Paul T. Oester

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. This chapter briefly summarizes the major pests and management strategies for reducing damage. For more details, see *Forest Disease Ecology and Management in Oregon,* Manual 9; and *Forest Insect Ecology and Management in Oregon,* Manual 10.

Figures 7.1a–b. A laminated root rot center (below left) and an Armillaria root disease center (below). 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.

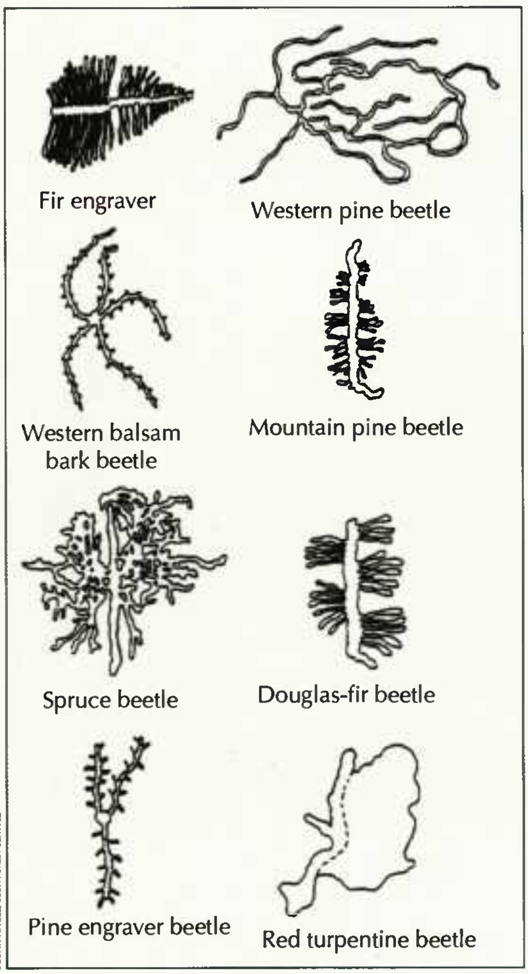
Figure 7.2. Lodgepole pine killed by mountain pine beetle in northeastern Oregon, 1975.

Bark beetles

Biology

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 fir, and the spruce beetle infests Engelmann spruce.

Most species of bark beetle attack trees that are relatively large (larger than 6 inches dbh) and old (more than 80 years), especially in dense stands. Engravers, however, can successfully breed in stems as small as 3 inches in diameter. Mountain pine beetle can kill entire landscapes of susceptible trees in only a few years. For example, in northeastern Oregon in the early 1970s, more than 1.5 million acres of lodgepole and ponderosa pine were killed (Figure 7.2); in central and southern Oregon in the 1980s, more than 1 million acres were affected. Although some dead timber was salvaged during these outbreaks, log prices fell as markets became flooded. These episodes represent the loss of millions of dollars in revenue to forest owners. For several forest management objectives, bark beetle outbreaks should be prevented.



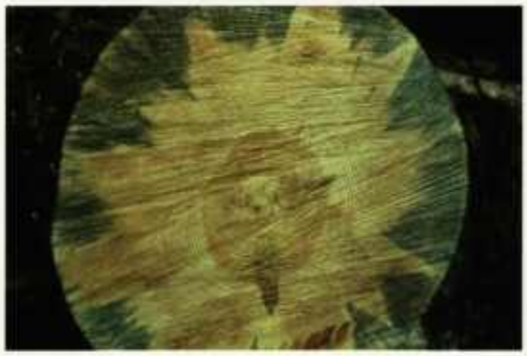
SUSAN HAGLE/USDA FOREST SERVICE

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-size pitch globs or tubes on the trunks of living trees (see Figure 4.2, page 66). 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, opposite page). Dry boring dust (like fine sawdust) also might appear in bark crevices below the pitch tubes. Tree species other than pines usually do not form pitch tubes, but instead the boring dust is often in the bark crevices.

Beetles do 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*. 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. By controlling tree density, trees and stands become less susceptible to beetle attack.

Management

All species of bark beetles prefer to attack and can kill trees that have been weakened by other causes, such as drought, defoliation, or root disease. The management strategy almost sure to prevent bark beetle attack is to maintain individual trees and stands in a vigorous condition through thinnings (Figure 7.5).

Figure 7.5. Ponderosa pine stand precommercially thinned to reduce bark beetle damage and Armillaria root disease.

Slash created from harvesting or precommercial thinning creates habitat (insect food source) for pine and fir engraver beetles, and that can result in beetle population increases and tree mortality. *Cull* logs and tops should be limbed, cut into short (3-foot) lengths, and left exposed to sunlight. That facilitates rapid drying and makes the material unsuitable for beetle reproduction. Limit harvests or thinnings to late summer and fall, and chip thinned material to keep engraver beetles in check. 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 usually species specific. 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.

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.

When mixing pine with other conifer species, follow the stand density guidelines (see Chapters 2, 3, 4, and 5) for pine. 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 before the next spring and windthrown spruce within 1 year to prevent buildups of Douglas-fir beetles and 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 logs with plastic to kill emerging beetles.

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, western larch	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 subalpine fir	Time production of slash and slash disposal. Manage root disease. Shift species to more pine and larch.
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*. 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 pine.

Figure 7.6. Grand fir defoliated by western spruce budworm in northeastern Oregon.

Western spruce budworm consumes new foliage of true firs, Engelmann spruce, and Douglas-fir, causing growth loss, top kill, and mortality (Figure 7.6). Epidemics occur every 12 to 20 years and usually persist for 5 to 10 years. 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 3 years, but damage can be severe. Outbreaks recur 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.

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	Emphasize pines in species mix.
Douglas-fir tussock moth	Douglas-fir; grand, white, and subalpine fir	Emphasize pines in species mix.
Pandora moth	Ponderosa, lodgepole, and sugar pine	Maintain high vigor.
Black pineleaf scale	Ponderosa and sugar pine	Maintain high vigor.
Larch casebearer	Western larch	Emphasize Douglas-fir and pines in mix.

Causes of defoliator outbreaks are complex and largely unknown, but outbreaks do require high stocking levels of host-tree species. Research by Torgerson et al. (1990) 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 of defoliating insects.

Management

Direct control measures for foliage-feeding insects traditionally have 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 *B.t.* (short for *Bacillus thuringiensis*), 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.

Shoot- and twig-feeding insects

Biology

Figure 7.7. Ponderosa pine showing a shortened infested terminal caused by the western pineshoot borer.

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 pineshoot borer, which attacks young stands of ponderosa pine. This moth lays eggs under *bud scales* on lateral or 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 current year's growth is dead (Figure 7.7). 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

Insecticide 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 include removing and burning the infected leaders or branches before insects emerge to overwinter in the fall. A disruptive *pheromone* for the western pineshoot borer 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. 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.

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 laminated root rot, Armillaria root disease, annosus root disease, and black stain root disease. Most infection is through root contact from infected to noninfected trees (Figure 7.8). Annosus 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.

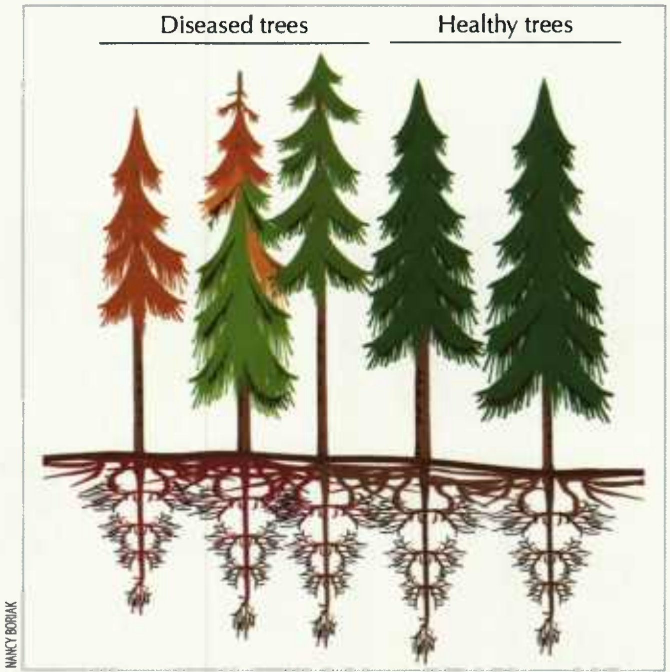


Figure 7.8. Root diseases spread from diseased trees to healthy trees via root contact.

Figure 7.9. Root-disease patch showing tree decline and mortality.

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). 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. Root disease often predisposes trees to attack from other pests, especially bark beetles.

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. 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 seed-tree, shelterwood, individual-tree, and group-selection systems (Figure 7.10; also Chapter 2).

Minimize black stain root disease by reducing site disturbance and tree injury and by favoring mixed-species stands. Also, stands thinned after beetle flight in July are less likely to be affected by black stain root disease.

Prevent annosus 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 done 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 true fir, probably will become infected and will spread infection to adjacent, residual trees. For more information about root diseases, see *Ecology, Identification, and Management of Forest Root Diseases in Oregon,* EC 1512.

Figure 7.10. Mixed-conifer stand thinned to reduce damage from root disease.

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	Thin only in August and September.
Annosus root disease	True firs and ponderosa pine	Preventive: avoid tree wounding. Treatment: apply boron to cut stumps.

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 fir. The fungus rots away the tree's central stem. It can be identified by the large horseshoe-shape fruiting bodies or *conks* on the outside of the trunk (Figure 7.11). 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).

Figure 7.11 (far left). 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.

Annosus stem decay is common 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. Trees less than 75 years old usually have very little decay even if wounded, whereas older trees can have considerable decay.

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	—
Indian paint fungus	True fir	Promote tree vigor.
Red-ring rot	Douglas-fir, true fir, hemlock, larch, spruce, and pines	—

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 (see *Pruning to Enhance Tree and Stand Value*, EC 1457). 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.

For more information on stem decays, see *Managing Tree Wounding and Stem Decay in Oregon Forests*, EC 1519.

Rust diseases

Biology

Important rust diseases of eastern Oregon conifers are western gall rust and comandra 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 7.13).

Figure 7.13. Gall caused by western gall rust on lodgepole pine.

Western gall rust, caused by a fungus, is probably the most common disease of lodgepole pine in Oregon. Severe infection causes round to pear-shape galls to form on stems and branches. This can lead to stem malformation, breakage, 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 white pine, sugar pine, and whitebark pine (Figure 7.14). Broom rusts form in true firs and spruce and create ideal habitat for many wildlife species.

Figure 7.14. 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. 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 or cause much tree growth loss.
- 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 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 1 year or more. Infected crowns usually refoliate, but repeated infection may cause growth loss.

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.

- 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.
- 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.

For more information on foliage diseases, see *Needle Diseases in Oregon Coast Range Conifers,* EC 1515.

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	—

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 7.15). 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 fir, ponderosa pine, and lodgepole pine.

Figure 7.15. Dwarf mistletoe plants on an infected ponderosa 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, opposite page). One variety of fir dwarf mistletoe infects only white and grand fir; another variety infects only Shasta red fir. Fir dwarf mistletoe is on true firs only in the Cascade Mountains; it is not in the Blue Mountains.

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 7.16, opposite page). If you wish to manage for timber, remove trees with severe dwarf mistletoe. On the other hand, the witches' brooms caused by mistletoe provide 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 very 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.

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.
- Prune lower branches with infections in trees with healthy upper crowns.
- Save a few infected trees for the wildlife.

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. Do not thin crop or leave trees for at least 5 years after removing the overstory, to allow enough time for *latent infections* to appear. After 5 years, thin out any trees that show infections.

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.

Figure 7.16. Witches' brooms caused by Douglas-fir dwarf mistletoe.

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.

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	—

CHAPTER 8

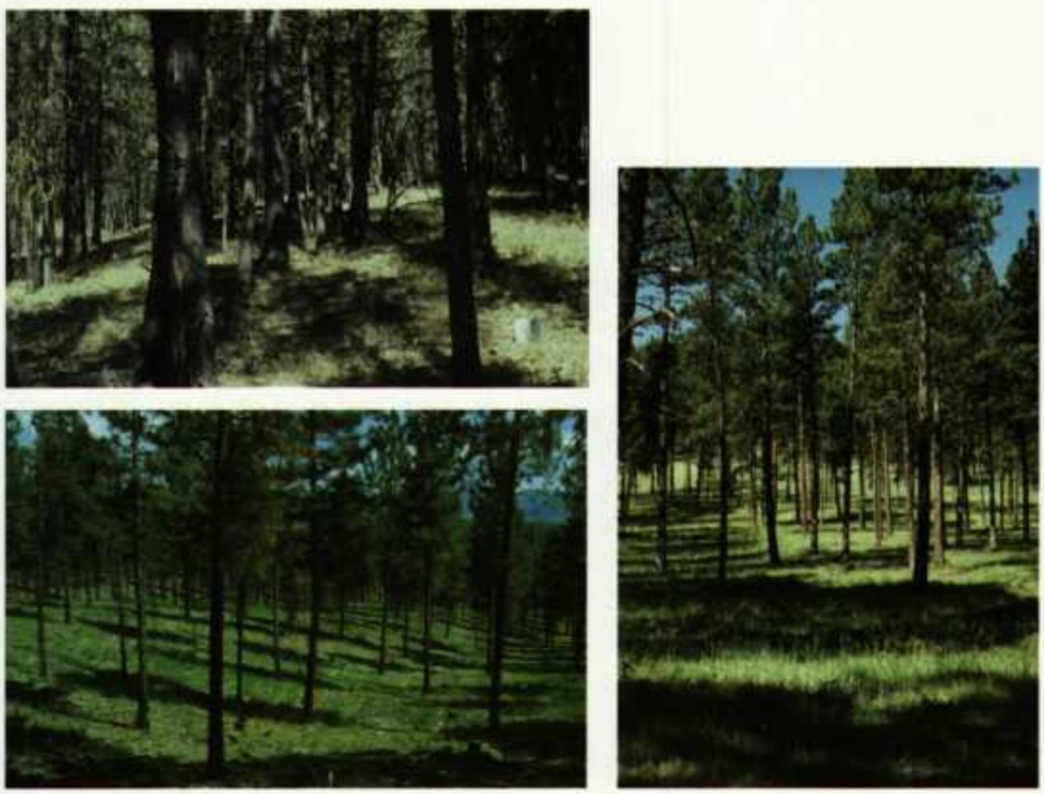
Managing forest range values

Paul T. Oester

There are many reasons to consider range 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 red meat production or wildlife forage (Figures 8.1a–c). Finally, finding strategies that best integrate resources (timber, range, wildlife, and water) can improve economic returns.

This chapter has three main purposes:

- Show how forest cover influences understory vegetation
- 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.

Range benefits

Forage production (the growth of grasses, forbs, and shrubs) and grazing in eastern Oregon forests can go hand in hand with timber production and wildlife habitats. Livestock graze on most forest types and ownerships in eastern Oregon, and there are abundant opportunities for enhancing range values. For example, thinning dense thickets usually can provide a two- to threefold increase in forage yields. Adding domestic grasses provides even greater increases. Livestock grazing combined with good silviculture gives owners a way to integrate operations. In fact, combining grazing and timber production might be more profitable than emphasizing one resource over the other (Clary et al. 1975).

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. For example:

- 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 2 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 beetween tree cover and forage
- Blending tree and forage production
- 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 a control plot. Understory production increased 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, mixed-conifer site, the percent com position of pinegrass plus elk sedge declined by almost 50 percent once tree conopy 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 accumulations, weather and climate, soils, past management, 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 tends to decline quickly at first and then levels off between moderate and high tree canopy coverage (Figure 8.2a).

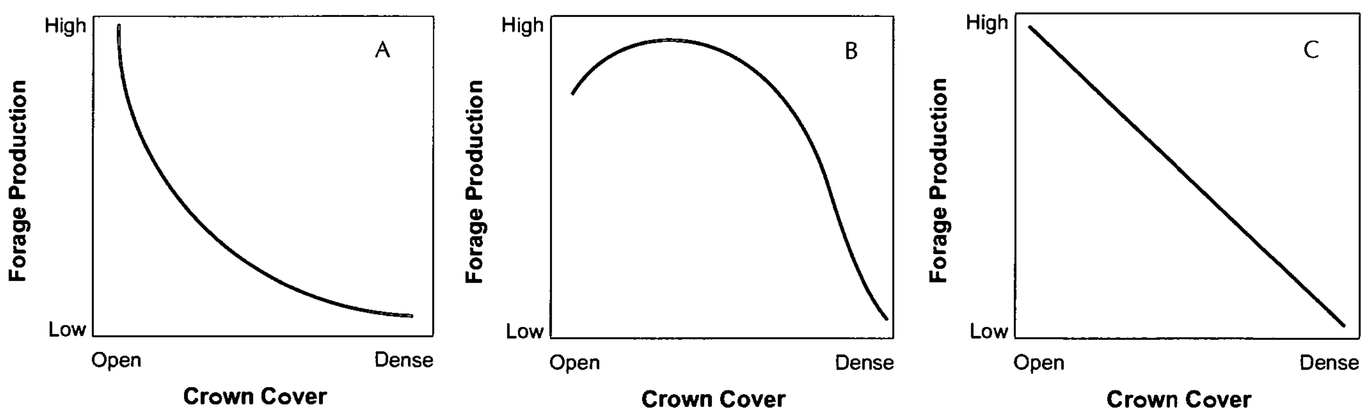
For more moist sites such as mixed-conifer with a high shrub component, some research has shown that light to moderate forest stocking levels tend to yield as much or more understory shrub cover as forest openings (Figure 8.2b). This suggests that if you are interested in forage production on these sites, 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 (Krueger 1981). 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 recolonize the site, the overstory–understory relationship returns to that of the original stand.

Preliminary findings from a recent study in the Blue Mountains (Delcarto 2005) show:

- Elk sedge represents more than 30 percent of available forage on ponderosa pine and warm mixed-conifer forests.
- Production appears high in ponderosa pine and warm mixed-conifer forests; these sites have large amounts of marginally palatable forages such as pinegrass and elk sedge.

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).



- 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 remained high up to the small sawlog stage; however, more moist sites showed a forage production decline after the sapling stage.
- In stands with more moisture and a high proportion of grand fir, forage production was higher in middle-age stands than younger or older stands.

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. Here are some general principles.

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, many less than 60 percent. Thus, these types should provide high levels of forage for wildlife and livestock.

Warm mixed-conifer stands will provide excellent grazing opportunities while managing ponderosa pine for good diameter growth. Seeding grasses such as orchardgrass will double production over native vegetation. Longer harvest cycles will cause declines in forage production, as native grasses will replace domestic seedings.

In cool mixed-conifer forest, invasion of grand and white fir has decreased herbage production. Optimum stocking levels for timber production should provide moderate forage production. Seeding after stand treatments should double forage production compared to native growth.

Where shrubs such as oceanspray, ninebark, snowberry, and spirea dominate in mixed-conifer forests, grazing will be limited. Expect low forage production, as shrub canopies hinder livestock in accessing forage and compete for limited resources (light, water, and nutrients) with grasses and forbs.

*Adapted from Hall 1988

Thinning

Thinning dense, stagnant stands can increase forage and individual tree growth. 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

Grazing can help reduce wildfire intensity and spread by removing fine fuels, particularly on more productive soils.

Seeding grasses

Seeding a mixture of domestic grasses can improve forage production and use. Species such as orchardgrass, Sherman big bluegrass, timothy, and intermediate wheatgrass potentially can increase carrying capacity, for they produce more pounds of forage per acre than native vegetation and they're 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 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 USDA Natural Resources

Conservation Service or OSU Extension Service 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).

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.

Native forages

Don't rule out the potential of native grasses, sedges, and shrubs. Pinegrass, Idaho fescue, bottlebrush squirreltail, and elk sedge are important to the foraging needs of ungulates, 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 domestic grasses. Elk sedge stays green throughout the year, providing important fall and winter forage for ungulates. Oceanspray, ninebark, ceanothus, bitterbrush, and common 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. Young shoots of willow, black cottonwood, and quaking aspen are hardwoods that grazing animals browse readily. Assess your situation and get professional advice before seeding grasses or other forage management activity in your forestland.

Table 8.2. Broadcast seeding recommendations for ponderosa pine, lodgepole pine, and mixed-conifer forest types.*

Forest type	Component of seeded grass mixture	Seeding rate (lb/acre)[1]	
		Component	Total mix
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.

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.

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). Seed grasses that will not form sod, such as orchardgrass, timothy, and Sherman big bluegrass. And, 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.

Grazing rotations

Time the grazing of various plant communities to coincide with the occurrence of green forage and maximum nutrient availability. 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 mixed-conifer types. Return to lower meadows in late August to capture regrowth, and then to higher-elevation, cool mixed-conifer and lodgepole pine forests in September. Recently thinned stands will lose forage quality earlier in the summer due to the more open canopy and should be used first. As a general rule, grazing should leave stubble 3 inches high.

Managed grazing

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 to tree seedlings. Some requirements are:

- 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 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.

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. Provide trace-mineralized salt to cattle to prevent cravings that might lead them to graze seedlings, especially terminal buds.

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 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 is significantly less. Also, having more Douglas-fir and grand fir increases the risk of defoliator damage and, if root disease is in the stand, lower yields from disease.

Wildlife

Wildlife and grazing are compatible goals. Thinned stands with good grass understories are excellent forage areas for deer and elk (Figure 8.4). Where grazing is a priority, encourage cavity-nesting birds, small mammals, song birds, deer, and elk by leaving extra snags, retaining a few slash piles, seeding grasses and forbs that attract wildlife (e.g., orchardgrass and small burnet), allowing brush and trees to grow together in thinnings, and promoting a diversity of tree species and multiple canopies.

Seeding guidelines

Table 8.2 (page 157) gives general broadcast seeding recommendations for ponderosa pine, lodgepole pine, and mixed-conifer forest types when range and wildlife objectives are prominent. Modify rates and species if the site is either drier or wetter or if your objectives are different.

In developing a seeding prescription, consider your objectives. For example, are you interested in soil stabilization (roadways, steep slopes on recent burns, waterways, and steep skid trails), or wildlife, or camp grounds, or interim forage for livestock? Also consider the site's productivity (soils and precipitation) and the cost of seeding.

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.

For example, to stabilize roads on moderately productive forest sites, sow about 30 pounds 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). If the objective is to attract animals to the road and lead them away from riparian areas, then orchardgrass, smooth brome, and timothy are good choices.

There is some variation in palatability among species, which can affect how seeding combinations are grazed. 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 to be grazed out, leaving the less palatable to dominate.

Seeding can be in the fall or spring. A common practice is to seed just before or at the beginning of winter snow accumulation. The action of the snow as it recedes the following spring helps move the seed into the soil. Try to seed on mineral soil for best results, or 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 by half so forage competition with young trees is kept manageable.

Usually, skid trails and landings should be seeded at higher rates to reduce soil erosion. In fact, on many mixed-conifer or lodgepole pine sites, you can use orchardgrass, timothy, and smooth brome on landings, skid trails, and access roads. This combination is more palatable and more productive as well as less competitive to 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 (see page 156) to compete on the site.

More about certain grasses, sedges, forbs, and legumes

Birdsfoot trefoil (Lotus corniculatus)

Long-lived, deep-rooted legume suited for erosion control, big game food, and beautification. Can grow under dryland conditions where the effective precipitation is 18 inches or more. Very winter hardy and useful at high elevations. Tolerant of poor drainage; quite vigorous.

Blue wildrye

Blue wildrye (Elymus glaucus)

Grows in 15 to 23-inch precipitation zone. Short-lived, perennial bunchgrass, 3 to 5 feet tall. Shade tolerant and widely adapted to favorable sites in timbered or brushy areas. A good forage, cover, and seed producer, becoming established easily under favorable management conditions such as rotation-deferred grazing. A self-seeder, thus good for areas needing cover for erosion control.

Elk sedge (Carex geyeri)

Grows chiefly in the ponderosa pine, lodgepole pine, and mixed-conifer forests of eastern Oregon. An evergreen sedge, usually keeping its semigreen leaves through the second growing season. Second-season leaves are brown from the tip down one- to two-thirds of the leaf length. Prefers well-drained sandy or gravelly soils at elevations from 1,000 to 10,000 feet. One of the earliest forage plants available at lower elevations in spring and remains green long into fall. Elk, deer, and cattle feed on elk sedge when other forage has dried up. Has a triangular stem with leaves branching off on all three sides (three ranked). A long-lived perennial, 6 to 20 inches tall. Spreads by seeds and underground rootstocks.

Elk sedge

Hard fescue (Festuca duriuscula)

A low- growing, long-lived competitive bunchgrass adapted to a wide range of climates and soils. Has a dense, voluminous root system, thus it gives excellent erosion control but is slow to establish. Even though it is a bunchgrass, it is highly competitive with tree seedlings. Less palatable than many domestic species. Utilization is most thorough under heavier grazing pressure.

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 texture soils, and shade are all characteristics of the type of site conditions common to Idaho fescue. Tends to occupy the drier forest sites, especially in the Blue Mountains, and is one of the more important native forages. A perennial bunchgrass, about 2 feet tall at maturity. Spreads entirely by seed. A good spring or early summer forage.

Kentucky bluegrass (Poa pratensis)

A sod-forming grass with fibrous and strongly rhizomatous roots that grows best in cooler, more moist sites. Although an excellent forage, it is very competitive with tree seedlings. Used primarily for lawns, parks, golf courses, and cemeteries. Also widespread throughout eastern Oregon, particularly in sunny, more exposed areas.

Intermediate wheatgrass (Agropyron intermedium)

A late-maturing, long-lived, mild sod-former suited for hay and pasture, alone or with alfalfa. Can be grown under irrigation or on dryland where effective precipitation is 15 inches or more. Requires good drainage and moderate to high fertility. Generally, recommended for erosion control on ponderosa pine and mixed-conifer sites.

Orchardgrass 'Hallmark', 'Potomac', and 'Latar' (Dactylis glomerata)

Long-lived, high-producing bunchgrasses adapted to well-drained soils. Grows under irrigation or on dryland where effective precipitation is 16 inches or more. Shade tolerant. Highly palatable and preferred over native species, such as pinegrass. In reforestation, more easily controlled because its bunching form allows easier removal with a hoedad or Pulaski during scalping. Suited for pasture and erosion control. Varieties refer to early, mid, and late season maturity. Late-season varieties are preferred in mixtures with alfalfa, especially in eastern Oregon. 'Latar' is preferred in mountainous areas.

Orchardgrass 'Paiute' (Dactylis glomerata)

Throughout the intermountain West, 'Paiute' has done well on well-drained basic and acidic soils. Performs well on soil textures ranging from clay to gravelly loams and on shallow to deep soils. Does not grow well in saline soils or in areas with high water tables. Selected for its ability to establish and persist in areas that receive as little as 11 inches of annual precipitation. Laboratory results indicate 'Paiute' has more drought tolerance than other orchardgrass varieties. Livestock, big game, and rabbits have shown a preference for 'Paiute'. In comparison to 'Fairway' or standard crested wheatgrass, 'Paiute' greens up 7 to 10 days earlier in the spring, remains green longer, and has better fall growth.

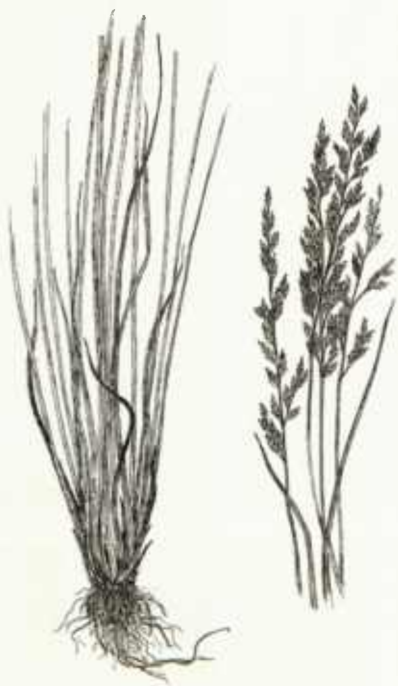
Pinegrass (Calamogrostis rubescens)

Found as a carpet under ponderosa pine and lodgepole pine and in warm mixed-conifer forest types, this native grass likes warm, well-drained soil and is not common on wet meadows or cold, north slopes at higher elevations. Stays green all summer and into fall, though protein content drops dramatically, as with other grasses, when seeds shatter. Requires approximately 3,500 pounds of water to produce 1 pound of forage, compared with bluebunch wheatgrass at 700 pounds of water and Kentucky bluegrass at about 1,200 pounds (Hall 2002). A long-lived and fire-resistant perennial. Has few seed heads, forms sod (highly competitive with regeneration), and spreads mainly by underground rootstocks.

Pubescent wheatgrass (Agropyron trichophorum)

A long-lived, aggressive sod-former adapted to low-fertility sites and fine-texture soils where effective precipitation is at least 12 inches annually. 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; use it to discourage livestock use, such as along busy roads.

Sherman big bluegrass



Sherman big bluegrass (Poa ampla)

A long-lived native bunchgrass. Well adapted for early spring grazing, it is as much as 4 weeks ahead of crested wheatgrass. Adapted where effective precipitation is at least 9 to 15 inches. Easily destroyed by overgrazing. Needs shallow, late fall or early spring seeding. Big bluegrass competes with winter annual weeds such as cheatgrass.

Small burnet 'Delar' (Sanguisorba minor)

Needs 12 inches or more of precipitation. Very palatable to livestock and game animals; excellent bee forage. Can grow up to 2 feet tall. Will establish and grow on soils with pH as high as 8.0. Very hardy but not adapted to poorly drained sites. Should not be grazed until second season. Establishes easily.

Smooth brome 'Manchar' (Bromus inermis)

Well suited to 15 to 18 inches of precipitation. Highly variable, cool-season, cross-pollinated, palatable, long-lived, sod-forming grass. Long grown for hay and pasture; also very useful in erosion control seedings. Adapted to fertile, well-drained soils.

Tall fescue 'Fawn' (Festuca arundinacea)

A long-lived, high-producing bunchgrass suited to a wide range of soils and climates. Tolerant of strongly acid to strongly alkaline conditions. Suited to irrigation, subirrigation, or moderately wet conditions as well as to dryland areas where effective precipitation is more than 18 inches. 'Alta' and 'Fawn' were developed for the Northwest and generally perform equally.

Timothy (Phleum pratense)

Perennial grass adapted to high elevations and where effective precipitation is 18 inches or more. Suited for forage and erosion control; especially valued in revegetating forested lands in eastern Oregon. A productive hay crop. Late maturity may be an advantage under certain conditions such as poorly drained soils. Highly attractive to gophers and should not be seeded where regeneration is a goal.

Yellow blossom sweet clover (Mililotus officinalis)

A tall, stemmy, annual or biennial legume. Only biennial forms of yellow sweet clover are commonly used. Suited to dryland where the effective precipitation is 15 inches or more. 'Madrid' has yellow flowers. Matures earlier—though less productive under optimum growing conditions—and more suited to sandy soils and drier conditions than white-flower sweet clovers.

Riparian areas and grazing

> *Livestock or big game can co-exist with or they can damage riparian systems. These responses are highly site-specific; no template for a grazing strategy can guarantee success. (George 1996)*

This section discusses how grazing management systems can be applied in different situations. 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 (Chaney et al. 1993). Strategies that manage grazing to protect, rehabilitate, and maintain riparian areas include:

- Alternative grazing strategies
- Excluding livestock
- Managing riparian zones as special-use pastures
- Implementing one or more grazing distribution systems

Alternative grazing strategies

If grazing is having a small or moderate impact on riparian zones (Figure 8.5), the following practices might suffice.

Livestock can be attracted away from riparian areas in several ways. Providing shade, salt, drinking water, or supplemental feed can reduce the time livestock spend in riparian zones. Seeding palatable forages (see Table 8.2, page 157) 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.

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.

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

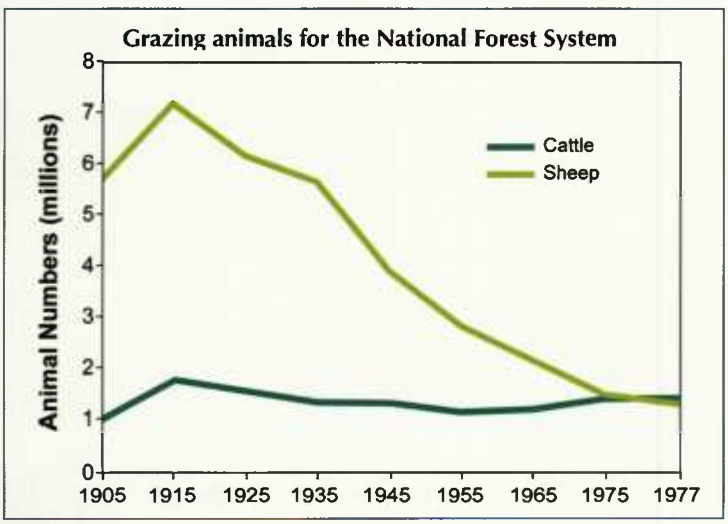
Several grazing management systems can control grazing intensity and/or timing. Compared to season-long use, which usually degrades streamside vegetation and streambanks, these systems can improve range productivity and use. In seasonal grazing, the objective is to avoid grazing when vegetation and streambanks are most vulnerable to damage. Rest–rotation grazing rotates seasons of use and 1-year rest periods among three, four, or more pastures. Or, consider other options (George 1996).

Economics of thinning and seeding forage

Seeding forages in conjunction with thinning or partial cutting can increase usable tree volume and livestock gains. 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. 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, below and on the following page).

The advantages of forage seeding and associated livestock grazing include:

- Greater usable forage in a shorter time
- Reduced fire hazard with grazing
- Improved aesthetics
- Enhanced watershed values because erosion is reduced
- Increased wildlife forage areas



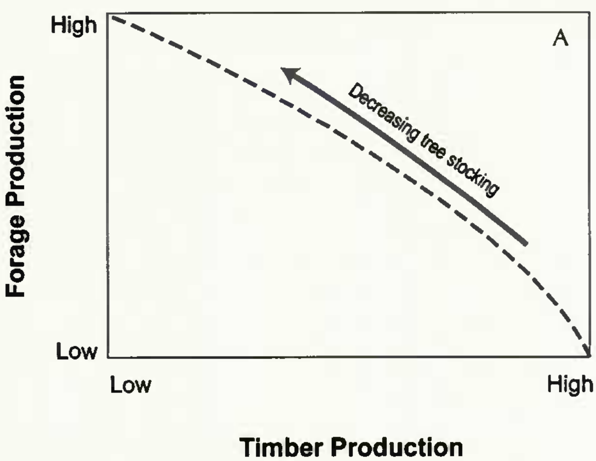
Figures 8.6a–c. Historically, livestock were heavily grazed throughout much of the inland West, damaging vegetation and soils in some areas (above left and right; Skovlin et al. 2001). However, sheep numbers have dropped dramatically from the early 1900s, and cattle numbers are generally lower (graph at left; Kosco and Bartolome 1981).

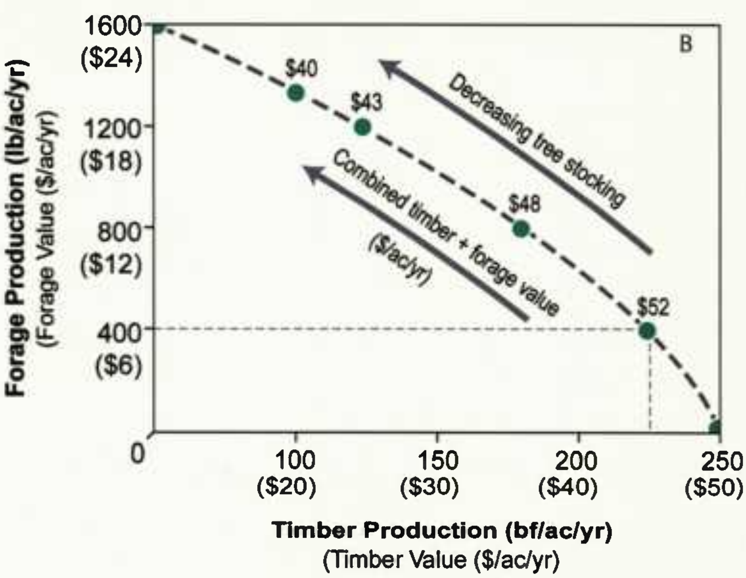
Figures 8.6d–e. Ranchers are using improved management practices with increasing success. For example, managing trees and forage by thinning and seeding potentially can enhance ranch income more than managing for either timber or forage alone (see Kosco and Bartolome 1981).

As a general rule, forage increases steadily as wood production declines (Figures 8.7a–b). However, at a point along this curve 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) and the values of forage and timber.

For example, if the value of forage is 1.5 cents per pound dry weight and timber is $200 per 1,000 board feet *stumpage* (the mill-delivered price minus costs of harvest, hauling, and taxes), then the value of forage ranges from zero to $24 and timber from zero to $50 (Figure 8.7a). In this case, 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. At this writing, timber prices are high compared to forage prices, and the best timber–forage option is when timber production is high and forage is low. Changes in price will change the optimum combination of timber and forage.

Figures 8.7a–b. Production possibilities for combining wood fiber and forage production (below left, adapted from Clary et al. 1975). Below right, an example using specific forage and timber values.





In addition to costs of a precommercial thinning, forage enhancement can incur additional costs. Slash treatments need to be thorough enough to provide access for livestock as well as provide space for forage to grow. Forage seeding, fencing, and water development are other costs. Each is a fixed cost incurred at the time of seeding. Forage seedings normally reach maximum production 3 years after sowing, then steadily decline over about a 20-year period as the tree canopy closes and native vegetation reestablishes. 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 both for trees and forages, altering nutrient and water cycling, decreasing wildlife habitat and food, and increasing soil erosion and stream sedimentation. They also adversely affect *biodiversity*. Here are some examples of invasive plant impacts (Parker 2003).

- 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 maculosa)* and leafy spurge *(Euphorbia esula)* can reduce grazing capacities as much as 65 percent.
- Introduced, invasive plants are increasing their foothold acreage an estimated 8 to12 percent per year.
- 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.
- Invasive weeds can alter hydrologic cycles in riparian areas, lower water tables in some cases, and reduce surface water.
- Plots dominated by spotted knapweed had 50 percent higher runoff and produced 300 percent more sediment in one study.
- The outdoor experience for many hunters and recreationists is jeopardized by the loss of habitat due to noxious weeds.
- 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 2005 *PNW Weed Management Handbook)*.

Prevention 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.

Use resources listed in Appendix 4, page 203, to identify and manage these alien invaders.

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 conditions to minimize their impacts.

CHAPTER 9

Managing wildlife values

Paul T. Oester and W. Daniel Edge

Many woodland property owners in eastern Oregon put a high priority on seeing wildlife on their land. Through active or passive decisions, woodland owners can affect wildlife habitat for better or worse. If profitability is a goal, then it will be important to find the combination of resources (timber, range, wildlife, water) with the best economic returns. This chapter provides an overview of managing woodland properties for wildlife. We review wildlife laws, explore important habitat components and structure as ways to enhance wildlife, and show how wildlife and forest management are compatible.

Wildlife opportunities

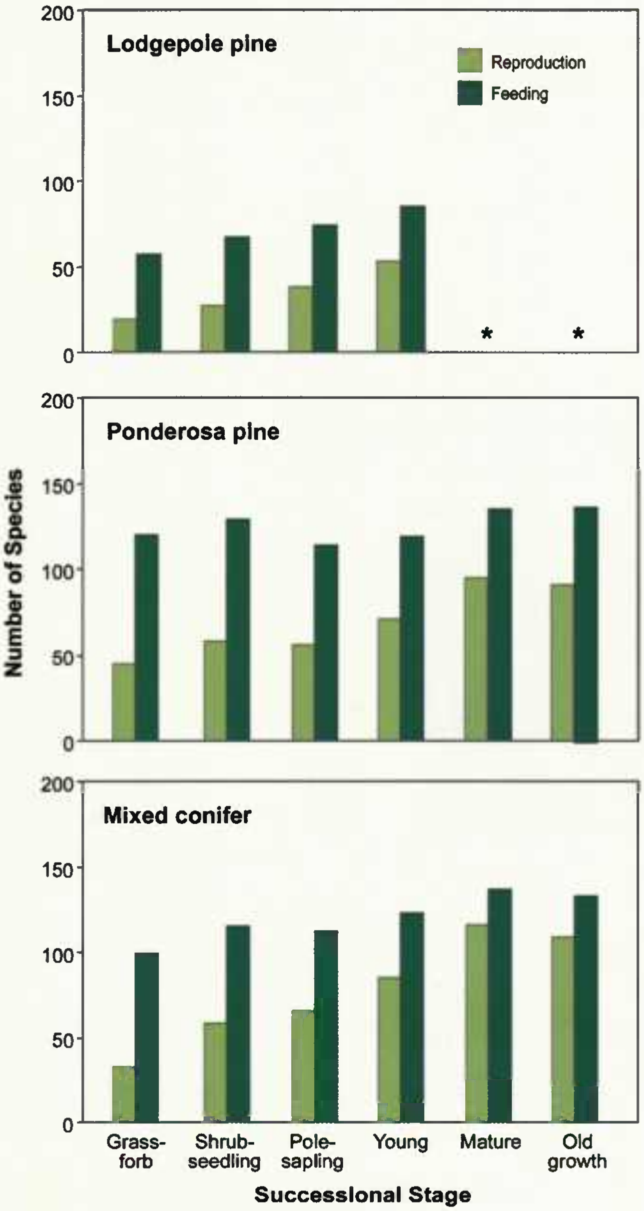
Eastern Oregon forests offer tremendous opportunities to manage for many wildlife species. For example, 159 species of amphibians, reptiles, birds, and mammals use mixed-conifer forests as primary habitat for feeding and/or reproduction (Table 9.1, page 171). Pure lodgepole pine forests have about 97 species. Ponderosa pine forests are similar to the mixed-conifer type in total number of species and diversity of life forms.

Figures 9.1 a–b. A fawn in forest cover (left) and an American kestrel are typical of wildilfe that use eastern Oregon forests.

Wildlife species use different stages of forest development—from openings to young forest to old growth—for feeding and reproduction. Frequency of use, however, varies by stage and forest type (Figures 9.2a–c).

One benefit of wildlife is the ability of some species to lower populations of forest pests. Bird predation on insect pests is an example. Thirty-five species of birds, including 24 *neotropical migrants*, feed on the western spruce budworm and the Douglas-fir tussock moth, two of the most destructive defoliating insects in eastern Oregon. Wildlife also provide viewing pleasure, promote nutrient cycles, support food chains, and might add profit to owners who offer fee hunting or wildlife viewing opportunities.

Figures 9.2a–c. Number of wildlife species reproducing and feeding by successional stages in lodgepole pine, ponderosa pine, and mixed-conifer forest types.



Legal status

All wildlife in Oregon has some protection under state or federal statutes. About 85 percent of the species are protected as "non-game" or watchable wildlife and cannot be harmed, except if they are doing damage (for example, destroying nursery stock in new plantations). The remaining species are classified as "game animals" or "furbearers" and 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). In eastern Oregon, the gray wolf (extirpated), bald eagle, Canada lynx, and northern spotted owl (central Oregon) are the only wildlife species currently listed under the ESA.

Table 9.1. Life forms using eastern Oregon forests as primary habitat for feeding and/or reproduction (Thomas 1979).

Life form	Ponderosa pine	Lodgepole pine	Mixed-conifer
Amphibians and reptiles	14	5	10
Waterfowl	5	2	4
Raptors	12	7	10
Upland game	4	3	3
Owls	7	4	9
Woodpeckers	6	3	7
Other birds	68	33	67
Mammals	45	40	49
Total	161	97	159

Oregon has an ESA with definitions very similar to the federal act. However, the state ESA allows listing of species that are rare within the state but might be common in other states. The state ESA affects management only on state lands, except that killing or harassing of 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.

Wildlife habitat needs

Wildlife has four basic needs: food, cover, water, and space. **Food** needs depend on the wildlife species. Predators prey on other animals, while herbivores feed on plants. Carnivores are food-quantity limited—they give little consideration to the quality of meat; the problem is getting enough. Herbivores are food-quality limited—quality varies by plant species, season, and by the plants' availability to wildlife (e.g., plants may be unavailable to wildlife if access is restricted by barriers such as snow or logs).

Cover used by wildlife is provided by vegetation, topography, and isolation. Wildlife use different types of cover for different purposes. Thermal cover protects wildlife from extremes of heat and cold; hiding cover enables wildlife to elude predators; and nesting cover is used to hide nests and rear young.

Sources of **water** for wildlife include metabolic water (a product of fat metabolism), preformed water (from foods high in water content), and free water, which is the most common (puddles, ponds, streams, etc).

All wildlife species need a certain amount of **space** in which to find the three other 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.

WAYS TO ENHANCE FORESTLAND WILDLIFE

Song birds

- Encourage multiple plant species and multiple canopy layers
- Plant native shrubs and trees that bear food for birds
- Install bird boxes

Raptors

- Provide nesting opportunities by maintaining or creating cavities, snags, and large trees
- Create or maintain *edges* between forest and openings for feeding and diversity of habitats
- Protect cliffs, *talus*, caves, and rimrocks for nesting and hunting opportunities
- Provide logs for prey habitat
- Create or maintain ponds, marshes, bogs, and streams for habitat for feeding opportunities

Small mammals

- Create brush piles and leave some slash piles to create habitat for species such as squirrels and mountain cottontail
- Seed 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)

- Seed grasses and legumes
- Leave some areas unthinned for hiding cover
- Thin thickets to allow more forage to grow
- Restrict access to roads

Species richness

- Create multiple canopy layers
- 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

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 is limited by the size of your property. 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 invite to your land.

Once you decide to make wildlife an objective, you need to decide what kinds of wildlife you want and what your land can sustain. For example, if you want more cavity-nesting birds (birds that nest in holes), then retain *snags* during harvest or create snags by topping some trees. 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.

A good way to start your planning is to look at the habitat you have and see what wildlife can be attracted to it. Inventory your current habitat (see Town and Mahoney 1996). Sketch a map to identify streams, forest stands, openings, and special habitat areas like talus slopes, rock outcroppings, bogs, *seeps,* and riparian areas (a good example of how to develop a map of wildlife habitat is in *Enhancing Wildlife on Private Lands,* EC 1122). This helps 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 is possible.

Important habitat components and structure

Woodland properties meet wildlife needs by providing specific habitat components. Although the specifics vary by species, several components appear to be universally important for meeting the needs of diverse wildlife communities. Snags, logs, and structural diversity are three habitat components that you can directly affect through your forest management.

Snags

Many species of plants, invertebrates, birds, and mammals use snags (Figure 9.3). Snag types are: dead, partly dead, sound wood or decayed wood, and short or tall (Figures 9.4 and 9.5a–b, following page). Each is uniquely suited for certain types of wildlife.

Snags in the open are home to one group of cavity users; snags in cover support 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.

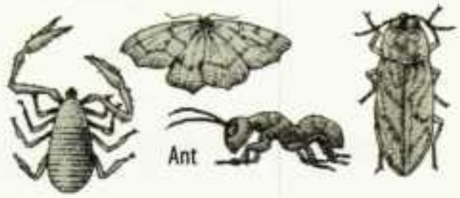
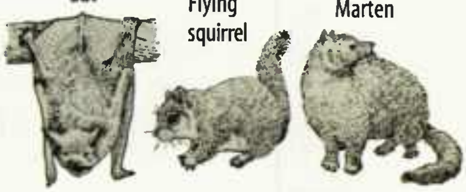
Life form	Use of snags	Examples
Fungi, mosses, and lichens	Decayed wood serves as a growth substrate.	Fungus, Moss, Lichen 
Invertebrates	Spaces under bark serve as cover and as places for feeding	Pseudoscorpion, Moth, Beetle, Ant 
Birds	Cavities are used for nesting or roosting. Snags are used as perches 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 9.3. Snags are used by many species of plants, invertebrates, birds and mammals (Thomas 1979).

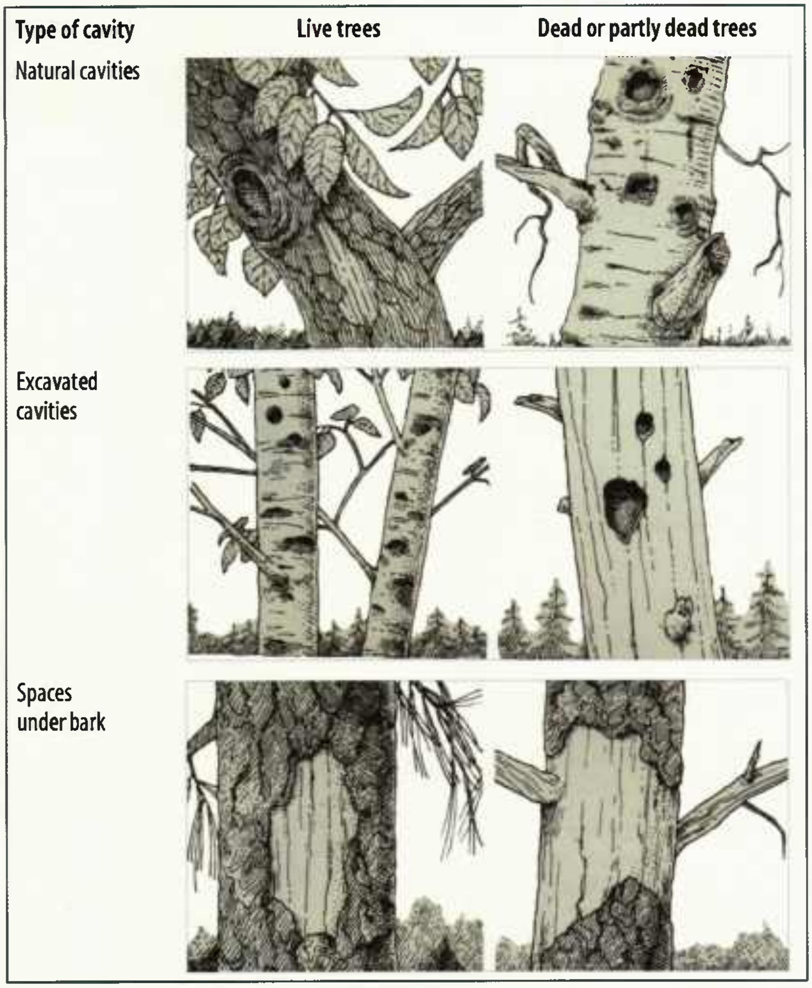


Figure 9.4. Wildlife habitat is provided by live trees and snags (Thomas 1979).

Consider the following snag recommendations from the U.S. 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 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 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. 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.

Figures 9.5a–b. Retain or create snags and retain defective trees to attract a wide variety of plants, invertebrates, birds, and mammals. Snags can be either short (at near right) or tall (far right). These habitats provide food, shelter, and nesting for wildlife.

STEVE CLEMENTS

STEVE CLEMENTS

For clearcut or partially cut areas 25 acres and larger on private lands where wildlife trees are required,* the Oregon Forest Practices Act (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 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. Remember that these snag-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 chainsaw 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. Purposely 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 produce desirable wildlife trees at less cost than killing trees to create snags (Bull et al. 1997).

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 the FPA's 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. Consult Logan (2002), pages 18–19, for more information.

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 clusters, 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 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.
- **Retaining existing snags and wildlife structures is the most cost effective and ecologically sound way to provide habitat,** compared to creating snags and wildlife structures.

*Adapted from Bull, Parks, and Torgersen 1997.

KEY FACTS ABOUT DECAYING LOGS*

- Size, species, and number of logs per acre determine whether log resources are suitable for wildlife.
- 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.

Down logs

Down logs (fallen dead tree trunks and roots) are another important wildlife resource (Figure 9.6). 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.

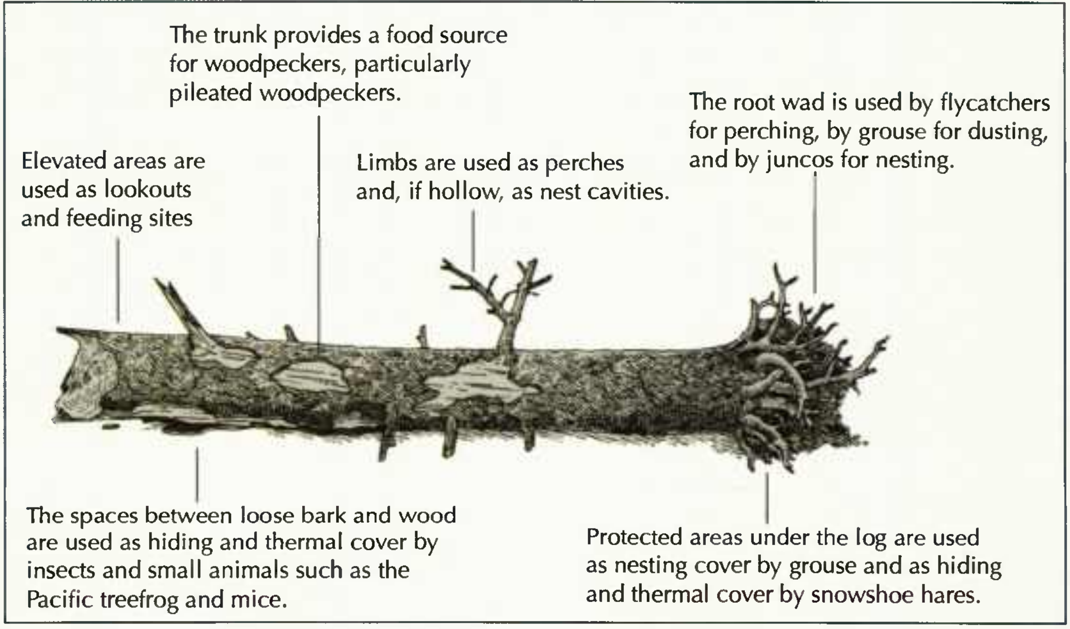
Recommendations for logs vary somewhat among land ownership (Figures 9.7a–c, opposite page). For example, federal land managers recommend:

- Ponderosa pine forests—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—at least 15 to 20 logs per acre, at least 8 inches in diameter and longer than 8 feet

On harvest type 2 and type 3 operations of more than 25 acres on private land (see footnote, preceding page), the Oregon FPA requires two down logs or trees per acre. At least 50 percent of these logs are to be conifers, and each should be at least 10 cubic feet gross volume and no less than 6 feet long. One down conifer or suitable hardwood log of at least 20 cubic feet 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, consult Bull, Parks, and Torgersen (1997); Parks, Bull, and Torgersen (1997); and Logan (2002). Generally, when deciding how many snags and down logs to leave, more probably is better. The trade-off, however, is higher fuel accumulations and, therefore, fire risk. Make this decision based on your objectives and comfort level.

Figure 9.6. Down logs provide many kinds of habitat for wildlife (Thomas 1979).



STEVE CLEMENTS

STEVE CLEMENTS

Figures 9.7a–c. Decaying logs on the forest floor are important habitat for many species of insects, amphibians, reptiles, birds, and mammals. The type of forest will determine management goals for the number of logs and their size. Generally, the cool mixed-conifer forest types (far left) or lodgepole pine type (near left) require a larger component of woody debris than warm mixed-conifer types (below).

Structural diversity

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 (Figures 9.8 and 9.9a–d, following page).

Patch cuts provide multiple age classes between stands, and individual tree selection silviculture (see Chapter 2) provides several age classes of trees within a stand. Leaving uncut patches of trees in thinnings 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 thinnings* (see Chapter 2).

Developing multiple age classes in a stand increases risk of crown fires, as layering of tree crowns up through the canopy creates a "ladder" for fire to move from the ground to tree crown levels. This risk can be moderated by isolating such clumps with fuel breaks. Increased 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. See Thomas (1979) for more information on diversity, *edge effects*, and the effects of forest succession on wildlife.

Figure 9.8. Gaps in the forest create edges and foraging areas for wildlife.

Figures 9.9a–d. Diverse forests that feature a mixture of species create conditions for diverse wildlife populations. At top left, multiple canopy layers; top right, a mixture of species; bottom right, different habitats such as cottonwood or aspen groves; and bottom left, forage and cover components.

Riparian areas

Wildlife use *riparian areas* more than any other type of habitat (Figure 9.10). 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 (Thomas 1979). 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 structurally diverse habitats on your property. Elk depend heavily on riparian areas. For example, although riparian areas make up only 7 percent of the area in northeast Oregon, elk use them 40 percent of the time.

Figure 9.10. Riparian areas are habitat magnets for many wildlife species.

Some management considerations are:

- Because riparian areas are so different from one another, it's important to consult both fishery and wildlife biologists when restoring or managing riparian areas.
- Road construction in riparian areas reduces the effectiveness of the zone 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.
- Extend protection from overgrazing to small or seasonal streams.
- Plant appropriate 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 regulates harvesting, road building, stream crossings, and pesticide applications in and near riparian areas. See Logan (2002) for a good overview of the rules.

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 the wildlife diversity and abundance on your property. For more information, talk to a stewardship forester in your local Oregon Department of Forestry office and read Logan (2002). For a discussion of grazing and riparian areas, see Chapter 8.

Special and unique habitats

Special or unique habitats might be on your property. If so, it's important to inventory and include them in your wildlife 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 lack of management. Two ways to help restore aspen are to convert older, decadent stands to young stands and to remove invading shade-tolerant conifers. One problem with converting older stands to young, vigorous ones is that big game and livestock will browse new sprouts. 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 (see *Cottonwood Establishment, Survival, and Stand Characteristics,* EM 8800). 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.

Cliffs, talus, and caves are small but important features for wildlife in eastern Oregon forests. 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.

Special habitats are important features on the landscape; some, such as cliffs, talus, and caves, are rare and fragile. If you have these areas on your property, carefully evaluate forest management activities and seek advice from wildlife professionals. For more information, see Thomas (1979).

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. See *Incentive Programs for Resource Management and Conservation*, EC 1119. For more information, also contact the Oregon departments of forestry and of fish and wildlife, the Oregon Watershed Enhancement Board, and the federal Farm Services Agency and the Natural Resources Conservation Service.

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 micro scale, 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-age, single-species stand of the same size.

Figure 9.11. Think beyond your property boundaries and consider how actions on your property might affect wildlife on a larger scale.

Diversity among stands, or landscape-level diversity, is important, too. Consider how your property relates to wildlife habitat conditions on a landscape level (Figure 9.11). 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.

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.

Combining wildlife and forest objectives

Timber production and wildlife 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 attempts to simplify the problem by providing examples that enhance the diversity of birds and animals in two common forest types: ponderosa pine, and lodgepole pine and mixed-conifer.

Ponderosa pine

- Leave at least two snags per acre, as large as possible, during harvest operations.
- Enhance forage by thinning and burning.
- Leave occasional brush piles.

MANAGEMENT STRATEGIES FOR OVERALL DIVERSITY

Diversity among stands

- Retain integrity of riparian areas versus upland areas
- Restore, promote, and protect minor 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

- Leave a few logs per acre, at least 8 inches dbh.
- Enhance the health of aspen and cottonwood habitats within this forest type.
- Leave occasional islands (groups of unthinned trees) for cover and snag habitat.
- Look for opportunities to create, protect or enhance water habitats, including constructing ponds.
- Protect special or unique wildlife habitats.

Mixed-conifer and lodgepole pine

- Leave four to six ponderosa pine or western larch 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 logs per acre, at least 8 inches in diameter.
- Enhance the health of aspen and cottonwood habitats within these forest types.
- Look for opportunities to create, protect, or enhance water habitats, including constructing ponds.
- Protect special or unique wildlife habitats.

Also consider how wildlife enhancement programs will affect your forestry objectives (Figures 9.12a–c, opposite page). Mule deer, whitetail deer, and elk can damage conifer seedlings (see *Understanding and Controlling Deer Damage in Young Plantations,* EC 1201). Managing to attract a higher population of these animals should not result in increased damage in most situations. However, habitat enhancement can increase populations of some animals, such as rabbits, pocket gophers, porcupines, and voles, to the level that they might begin to damage trees. For example, planting forage crops can increase the number of meadow voles and potentially lead to root damage and girdling of seedlings (see *Controlling Pocket Gopher Damage to Conifer Seedlings,* EC 1255, and *Controlling Vole Damage to Conifer Seedlings,* EC 1256). 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 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 foraging lowers timber yields if stocking is greatly reduced. Extending rotations for wildlife objectives decreases potential economic returns from timber because timber management financial investments 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 tree reproduction 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. Capitalizing on the potential of small, unused areas, areas with poor soil for timber, riparian zones, steep slopes, disease-prone areas, and similar places can provide wildlife habitats.

Figures 9.12a–c. Though wildlife and forestry objectives are compatible in many ways, wildlife can cause damage if populations become out of balance. Seedlings can be affected by several animals, including: (top left) roots destroyed by pocket gopher feeding; (top right) growth tips browsed by deer and elk, which can stunt and deform seedlings; and (below) seedling stem girdled by meadow voles living in grass communities.

Other ways to include wildlife needs in managing timber stands are:

- Thin to promote more understory development, particularly shrubs and herbs (realize, however, that increasing understory shrubs and herbs can increase shading and competition, which will create more competition for conifer regeneration and add to ladder fuels).
- Plant and retain native species that produce berries.
- Leave no-spray buffers if herbicides are to be used along wetlands or streams.
- Create patch-thin areas and/or small patch-clearcuts.
- Leave some snags and defective trees.
- Avoid or limit management activity during nesting, calving, and fawning time.

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 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.

Snags and down logs are important wildlife habitat components and structure. 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 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. Sometimes this results in tree damage. Be aware of potential conflicts and manage accordingly. Usually, conflicts are temporary, but they can be costly if not managed. Overall, forestry objectives and wildlife objectives are highly compatible, and forestland owners can enjoy a healthy forest and abundant wildlife.

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.

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 33.

Cull—A tree or log of merchantable size that is not merchantable as timber because of poor form, large limbs, rot, or other defects.

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 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 and 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.

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.

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.

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. See illustration, Figure 6.6, page 126.

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 3 to 5 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.

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 (0.5–4 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*.

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. 0.5–4 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.

(continued)

Regeneration methods (continued)

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*.

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*.

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.

Snag—A standing dead tree, usually unmerchantable.

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.

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.

APPENDIX 2

Tables and selected figures in this manual

Figures

Tables

Chapter 3. Managing ponderosa pine

Chapter 4. Managing lodgepole pine

Chapter 5. Managing mixed-conifer forests

Chapter 6. Reforestation methods and vegetation control

Chapter 7. Eastside conifer pests and their management

Chapter 8. Managing forest range values

Chapter 9. Managing wildlife values

APPENDIX 3

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*
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*
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*
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*
Snowberry	*Symphoricarpos albus*
Snowbrush ceanothus	*Ceanothus velutinus*
Spiraea	*Spiraea* sp.
Squaw current	*Ribes cereum cereum*
Twinflower	*Linnaea borealis*
Westernbog blueberry	*Vaccinium occidentale*

Forbs and herbs

Common name	*Scientific name*
Arrowleaf balsamroot	*Balsamorhiza sagittata*
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 trilium	*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

See *Forest Insect Ecology and Management in Oregon*, Manual 10.

Diseases

See *Forest Disease Ecology and Management in Oregon*, Manual 9.

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 4

For more information

Publications from Oregon State University Extension Service

Many of the following publications can be viewed online and downloaded from the OSU Extension website at http://extension.oregonstate.edu All can be ordered from:

Publication Orders
Extension & Station Communications
Oregon State University
422 Kerr Administration
Corvallis, OR 97331-2119
phone 541-737-2513; fax 541-737-0817
e-mail puborders@oregonstate.edu

For current availabilities and prices, visit the Extension website or contact the OSU Extension office that serves your county.

Abiotic Injury to Forest Trees in Oregon, EC 1501.

Care and Planting of Tree Seedlings on Your Woodland, EC 1504.

Contracts for Woodland Owners and Christmas Tree Growers, EC 1192.

Controlling Pocket Gopher Damage to Conifer Seedlings, EC 1255.

Controlling Vole Damage to Conifer Seedlings, EC 1256.

Cottonwood: Establishment, Survival, and Stand Characteristics, EM 8800.

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Ecology, Identification, and Management of Forest Root Diseases in Oregon, EC 1512.

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Fuelwood Management: Opportunities and Options, EC 1254

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Introduction to Conifer Release, EC 1388.

Introduction to Forest Protection, EC 1253.

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Needle Diseases in Oregon Coast Range Conifers, EC 1515.

PNW Weed Management Handbook (revised annually), WEED.

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Chapter 2, Silvicultural systems for eastside forests

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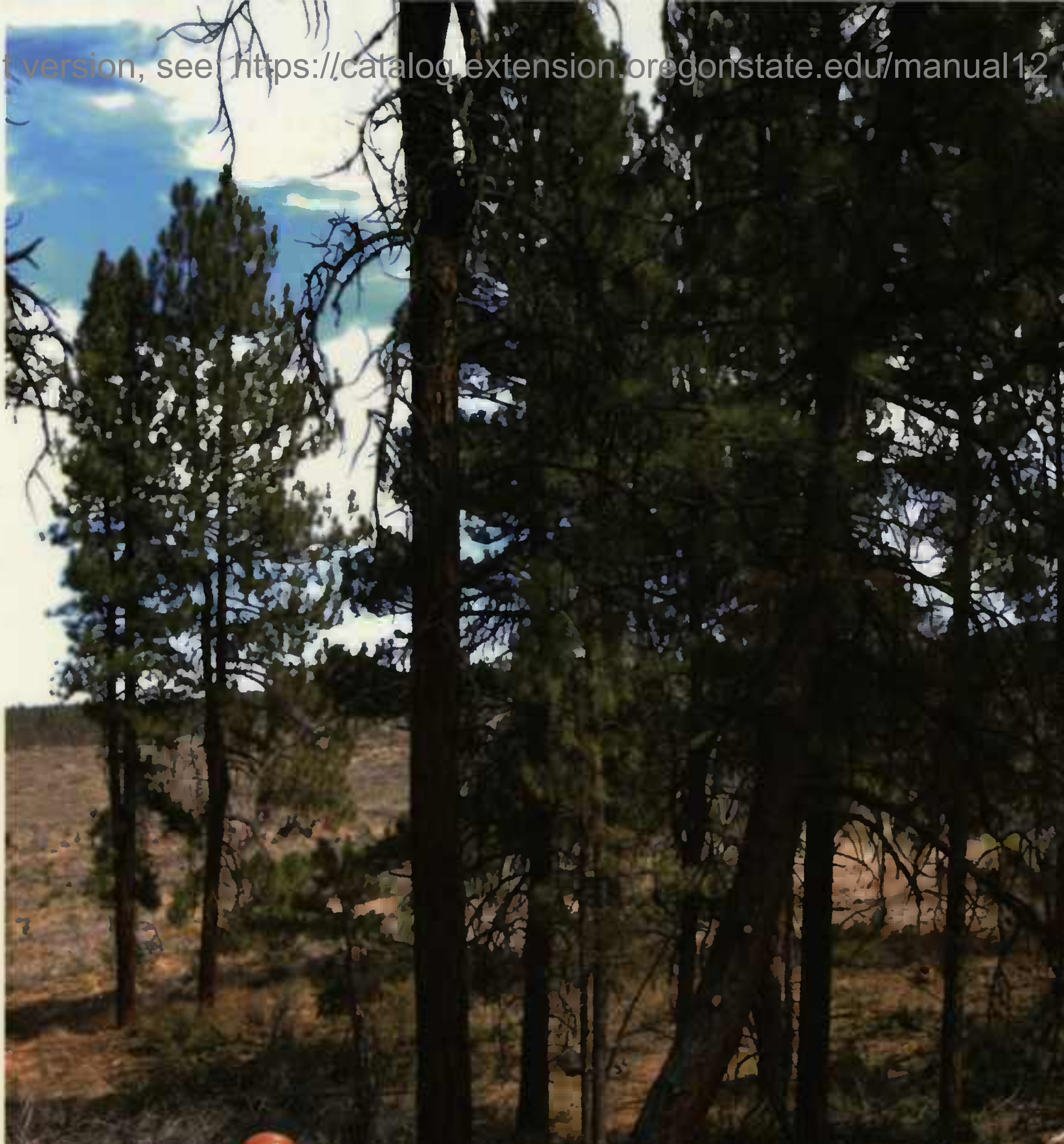

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