EB2000

# Silviculture for Washington Family Forests

DEPARTMENT OF NATURAL RESOURCES & WASHINGTON STATE UNIVERSITY EXTENSION

Washington State University Extension

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**EB2000**

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***This bulletin is a stand-alone publication, but we recommend that you read the companion bulletin,* Forest Ecology in Washington *(EB1943)[1] first, to make the information in this bulletin more easily understood.***

# Introduction

The purpose of the bulletin is to provide the family forest owner with a primer of silviculture and a framework to allow you to use when making important decisions about your forest. It will not tell you what to do nor suggest alternatives. Silvicultural education leads to landowner empowerment; conversely, silvicultural ignorance often leads to poor practices, lost opportunity, and lost income.

Many landowners will be working with professional resource managers and loggers in the development and implementation of silvicultural prescriptions and forest stewardship plans. This bulletin will help the landowner understand the language of forestry, which in turn will foster better communications and the attainment of landowner goals.

# Silviculture as Applied Ecology

## Silviculture Defined

Silviculture, which literally means *forest culture*, is the art and science of growing and tending forests for the production of wood and other benefits. Silviculture developed in Europe as a collection of practices for maintaining an adequate supply of fuel wood and construction timber from a decreasing forestland base. The primary goal of silviculture is the creation and maintenance of the kind of forest that will best suit the owner's objectives. The Society of American Foresters' Dictionary of Forestry defines silviculture as, "the art and science of controlling the establishment, growth, composition, health, and quality of forests to meet the diverse needs and values of landowners and society on a sustainable basis."[2]

While silviculture is often equated with wood production, silvicultural techniques can be used to produce other benefits such as clean water for municipalities, game animals for sport hunters, or improved habitat for songbirds and other non-game wildlife species. Silviculture can be used to prevent or mitigate insect and disease outbreaks or protect forests from catastrophic fires. Silviculture can also be used to increase production of mushrooms, beargrass, evergreen boughs, and other non-timber commodities. Essentially, silviculture is a set of treatments applied to forest stands or management units to enhance the development of a desirable future forest structure and species composition. In a nutshell, silviculture is tending your forest.[3]

## Vegetation Development

Vegetation development is the processes of change that occur in forest stands and landscapes over time. In the absence of disturbance, changes in the species composition of a forest are slow but continuous. The process of continual change is referred to as succession. Silviculture is based on the fact that the *direction* of forest succession is predictable and controllable. "Direction" refers to the gradual order of species replacement from shade-intolerant to shade-tolerant. The rate at which succession proceeds can be increased or decreased by altering the species composition and density of species in the forest. Disturbances influence rate and direction of succession. Forestry practices mimic natural disturbances, but with greater control and for a specific purpose. Thinning small trees in the understory mimics ground fires or natural mortality in a stand. Harvesting the dominant and co-dominant trees in a stand can have similar results to a windstorm that removes the overstory (Figure 1). Done with purpose, the results of planned practices can help achieve the benefits of forest changes and reduce potential harms.

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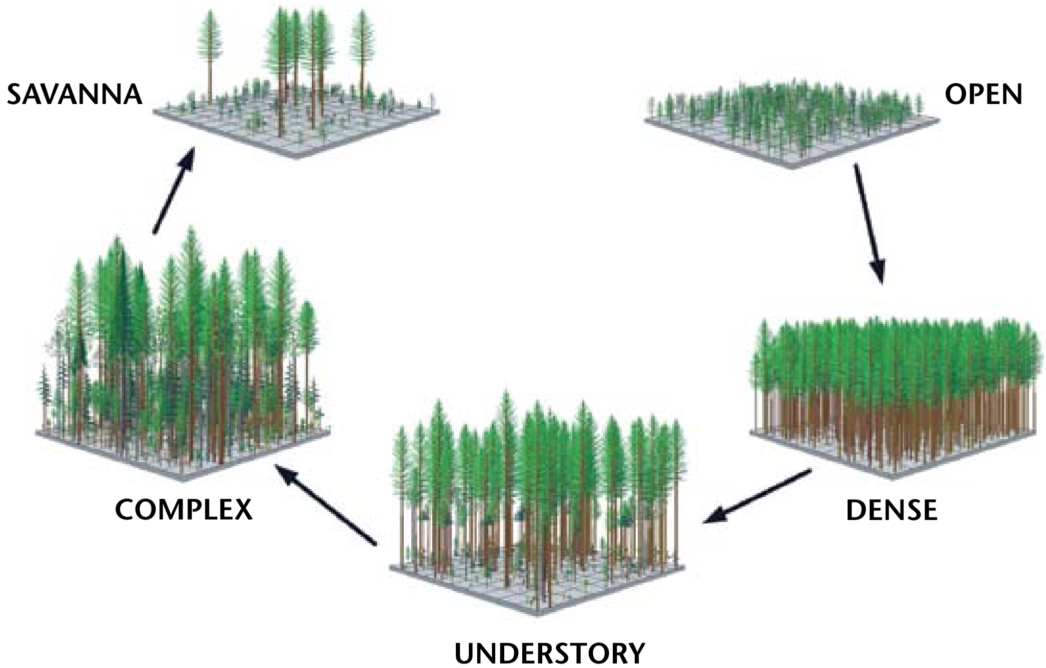
[1] *Forest Ecology in Washington* and many other forestry titles are available for free via the Internet as PDF files at *ext.nrs.wsu.edu*, or for a nominal charge a copy will be mailed to your address from WSU Extension publications.

[2] *The Dictionary of Forestry*, 1998, John A. Helms, editor. The Society of American Foresters, Bethesda, MD, 210p.

[3] See glossary at end of this publication for selected technical terms.

**Traditional Stand Development Theory:**
Forests grow into stable "old-growth" over time.




**Modern Stand Development Theory:**
Forests are dynamic and change by growth and disturbance, resulting in many structures.

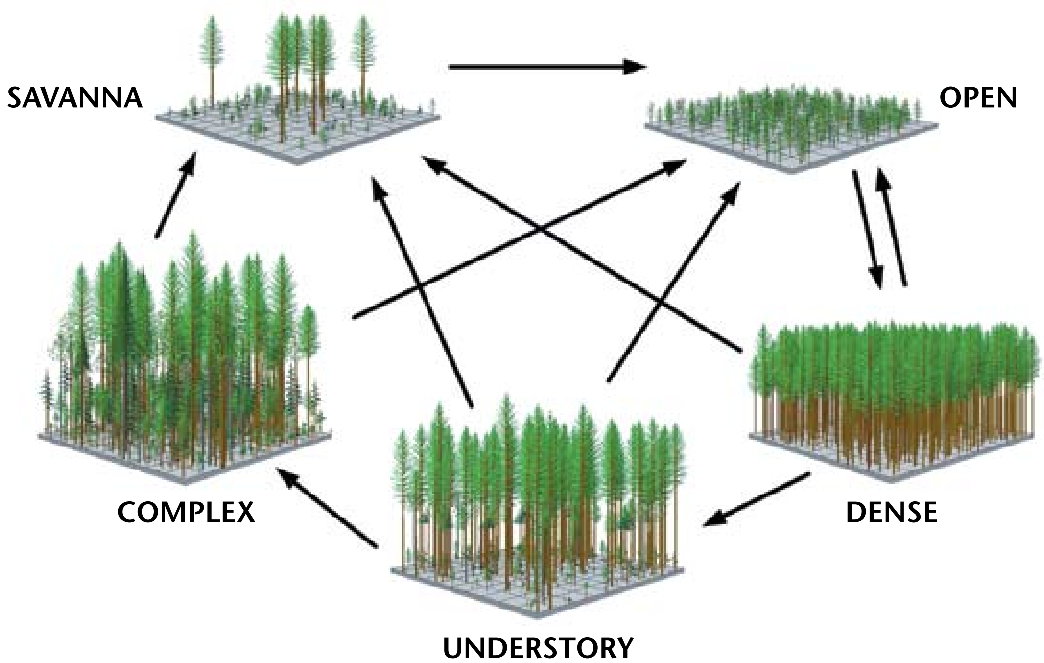



**Figure 1.** Stand Development Theory: the traditional approach (above) and influence of natural and man-made disturbances (below).

A key factor in succession is tolerance, the degree to which a species can successfully compete for site resources (light, moisture and nutrients). Tolerance is most often used with respect to light, and so, is often referred to as shade tolerance. Pioneer or early-successional species such as red alder, western larch, and ponderosa pine are often extremely intolerant of shade. They are not able to grow or reproduce in shaded conditions. Mid-tolerant or intermediate species can grow in partial shade, and late-successional species are able to grow and reproduce in heavy shade. As a result, unless interrupted by disturbances that remove all or part of the canopy, forest succession usually precedes toward more shade-tolerant species.

For example, Douglas-fir, western hemlock, and western redcedar occur together in many forest stands in west side forests. Of the three, Douglas-fir is the least tolerant of shade and will usually be found only in the overstory. Western hemlock and western redcedar are both very tolerant of shade and can exist in either the overstory or in the understory. As overstory trees die, cedars and hemlocks in the understory will grow into the overstory. If many years pass without fires or logging, the stand will increasingly be composed of western redcedar and western hemlock. In eastern Washington, western larch is a very shade-intolerant species that grows rapidly and may quickly dominate some forest stands following fires. More shade-tolerant species such as grand fir and subalpine fir are able to grow beneath the larch; however, larch will not grow in shade.

Two additional concepts provide a framework for understanding vegetation development patterns. These concepts are growing space and disturbance. Growing space refers to the availability of all the requirements that a plant needs to grow. The most important requirements—or growth factors—are light (for photosynthesis), water, and nutrients. Each tree in a forest uses these growth factors until one or more becomes unavailable. When that occurs, the growing space is essentially filled. New plants can't become established, and the plants already there must compete with each other to gain more growing space. Plants that out-compete their associates get more growing space and continue to grow. The losers often die. This competition is what ultimately drives forest succession.

The amount of growing space varies in time and in space. Light is most generally abundant for trees in the upper canopy, but may be extremely limited at the forest floor. Sometimes light at the forest floor is only 3% of that reaching the top of the canopy. Some species are able to tolerate growing conditions that are not adequate for other species, such as low light levels. Differences among species are not great, but can be enough to give some species a competitive advantage on a particular site. For instance, ponderosa pine needs more light to grow than does Douglas-fir. In the understory, then, Douglas-fir seedlings have a competitive advantage over ponderosa pine.

On very dry sites, forest succession results in stands of a single species, commonly ponderosa pine. In effect, forest succession ceases to occur. These forest types in eastern Washington are found primarily on poor soils, and on slopes that generally face south and southwest at lower elevations. Silvicultural manipulations on these extremely dry sites may require additional precautions and the advice of a professional resource manager.

## Planning is Important

Silviculture is used to manage change in forest stands to achieve desired results—overall forest health improvement, faster timber yields, high-quality timber, acceptable regeneration, improved wildlife habitat, and other goals. The basis for silviculture is our ability to predict the probable outcome of a silvicultural treatment. However, without clear objectives, silviculture may not help you achieve your goals.

Forest management and silviculture are not the same thing. Management objectives are guiding principles—statements about what is important to the landowner. Silvicultural prescriptions are specific to each stand, and recognize and support the management objectives by specifying treatments for desired outcomes. When management objectives are defined in very general terms, the choice of silvicultural prescriptions will be greater than if the objectives are more narrowly defined. For example, a forest owner may express a management objective to *protect habitat for bird species that use older forests*. The silvicultural strategy for this owner might be to retain selected large trees and snags past a normal rotation age. Other owners need to provide a return on the economic investment needed for periodic income as well as providing a base fund for retirement. These owners can achieve some financial goals through the appropriate silvicultural application of commercial thinning during their lifetimes.

A silvicultural prescription is a course of action that manages for change (disturbance) within a forest stand. A stand is an area in which the trees are similar in age, structure, and/or species composition.[4] Stand boundaries are the result of past harvests and natural disturbance histories or underlying soil types. Stands are often bounded by natural landforms, such as ridges, rivers, meadows, and the like.[5]

Silvicultural prescriptions include a wide range of practices intended to regenerate forests, make forests less susceptible to insect and disease outbreaks, or increase the growth rate, vigor, and value of trees for timber. In some instances, silvicultural prescriptions are used to regulate stream flow within a watershed or provide habitat for wildlife. Silvicultural prescriptions have been developed for improving existing stands and also for regenerating new stands. Common prescriptions include thinning, pruning, prescribed fire, and regeneration cutting.

Many factors determine the success of a silvicultural prescription: the biological capabilities of the stand, the current condition of the stand, owner objectives, weather events, and the skills of the forester and logger. Where market demands dictate prescriptions, the results can be less than desirable. Market-driven silviculture may fulfill some short-term financial objectives, but can result in long-term consequences that are both financially and ecologically undesirable, since markets change. In the past, demand for Douglas-fir caused many foresters to plant this species on cutover lands on the east side of the Cascades, where ponderosa pine or western larch would have been a better choice ecologically. On the west side, Douglas-fir was also planted in coastal regions, where western hemlock was better adapted. Many of these plantations failed on both sides of the state because site conditions did not favor Douglas-fir.

## Forest Management in a Landscape Context

Wise landowners understand and use ecological principles in forest management. A forest is more than the sum of all the stands within it. Landowners should consider individual stands, and the forest as a whole. For instance, if most stands in a particular forest were established after a single large disturbance event, they will mature at similar rates and will be ready for harvesting and regeneration at nearly the same time. While this might be "natural" there may be reasons not to harvest all stands within a short period. Such reasons may include ecological diversity, watershed considerations, and impact on personal income, with subsequent tax consequences.

Landowners should look at how adjacent lands are managed when making decisions on how best to manage their stands. In east side forests, fire suppression and cutting practices in the latter half of the 20th century created dense stands of Douglas-fir and grand fir in areas that previously supported ponderosa pine. These overcrowded stands of late successional species are at high risk for insects, diseases, and catastrophic fires. Landowners surrounded by such forests should manage their lands to reduce fire risk. In other words, they may want to maintain ponderosa pine or western larch and keep understory vegetation at a minimum. In west side forests, achieving diverse stands dominated by Douglas-fir, western redcedar, western hemlock, and red alder is a key to maintaining ecosystem sustainability.

> *The key to successful silvicultural manipulation is knowing how your forest develops and reacts to cultural treatments over time and using this knowledge to your advantage.*

## Silviculture and Forest Health Interactions

Silvicultural manipulations may be used to mitigate insect and disease conditions or to create favorable wildlife species habitats. Good forest health is defined as the condition of a forest when it is resilient to change and biologically diverse over a large area (e.g., has high

[4] Stand structure is the horizontal and vertical arrangement of ecosystem components, such as trees, logs, snags, etc.)

[5] See *Forest Ecology in Washington* (EB1943), available from WSU Extension Publications, for additional information.

landscape diversity), and is able to provide a sustained habitat for vegetation, fish, wildlife, and humans. A healthy forest is composed of trees and other organisms dependent on each other. The presence of a single or small group of unhealthy trees does not necessarily indicate an unhealthy forest. For example, small pockets of bark beetle infestation can actually promote forest structural diversity. A professional forester can help you determine the severity of a forest health concern.

Just as humans need a certain combination of food, water, and exercise to maintain physical health, forests and individual trees require certain inputs to maintain their health and growth. If one or more of these inputs is missing or insufficient, trees experience stress. Forest managers can influence these inputs through silvicultural practices.

One of the major health concerns in Washington forests is stress caused by overstocking, i.e, having too many trees per acre. Overstocking causes tree stress because it forces trees to compete with greater numbers of surrounding trees for limited light, water, and nutrients over time. Many silvicultural practices are effective because they reduce the number of trees per acre and so reduce the competition for essential elements.

The first requirement for healthy tree growth is light. Plants manufacture their own food through photosynthesis by using the sun's energy to convert carbon dioxide and water to a usable food source. Heavy shade underneath the closed canopy of a forest limits energy for the smaller, less dominant trees to grow. Shade-intolerant species have great difficulty growing under these circumstances. These include larch, birch, aspen, cottonwood, red alder, and most pines. Other species, such as Engelmann spruce and east side Douglas-fir, are considered intermediate in shade tolerance and they can grow in partial shade. The tolerant species—grand fir, western hemlock, pacific yew, and western redcedar—can grow under conditions of moderate to heavy shade, although they will not grow very fast. Thinning can release slow-growing (suppressed) trees by providing more light and space, if accomplished before they loose so much vigor that they cannot respond to the improved conditions.

The second requirement for healthy tree growth is water. Tree species vary considerably in their water needs and drought tolerance. Shade-intolerant species commonly grow in hot, sunny areas and are often more drought resistant. Shade-tolerant species, on the other hand, grow naturally in the cool, moist forests. When drought occurs, which happens frequently in all western states, these shade-tolerant species are more stressed than shade-intolerant species. Thinning reduces the total number of trees competing for water and, thus, can relieve drought stress.

The third requirement for growth is a good nutrient supply. Trees take up minerals through their roots and incorporate them into developing cells. A basic determinant of potential tree growth is the level of nutrients available in the soil. Nutrient-poor soils will never produce large trees; however, even rich soils cannot produce large trees if the the site is overstocked. Some species, such as shore (lodgepole) pine, have such low nutrient requirements that they actually thrive in sandy, nutrient-poor coastal sites. A forest manager may thin a stand to reduce competition for nutrients. Although it is not always cost effective, using a fertilizer on forest soils can provide needed tree nutrients, and sometimes provide dramatic improvement in growth rate and health.

## Silviculture and Wildlife Interactions

With a little extra planning, forest management practices can be highly beneficial to wildlife. Here are some things to consider:

- **Timing—**The greatest disturbance to breeding bird populations, especially to migrant birds that rear young in Washington, is tree felling from April to June (into July at higher elevations). If you suspect harvesting may disturb breeding, ask a wildlife biologist for guidance.

- **Cavities—**Leave some trees and snags with cavities for wildlife species that use them for shelter. If existing cavities are scarce, leave poorly formed, non-merchantable trees and "top" them to hasten decay and snag formation.

- **Landings—**Seed in landings with the appropriate wildlife forage mix, to provide food and cover for many wildlife species.

- **Diversity—**Good structural and species diversity in forest stands will support more varied populations of wildlife than uniform single-species stands. Be aware, however, that structural diversity in some forests east of the Cascades may increase the risk of insects (defoliators and bark beetles), diseases (dwarf mistletoes), and catastrophic fires.

- **The big picture—**Improving forest habitat is often a matter of providing the missing piece of the puzzle in a larger landscape. Look at surrounding forest land: your stands could provide an element of habitat that may be missing over the larger area. More than anything else, this is the key to managing forest habitats for wildlife.

## Stand Characteristics

What is a forest stand? Moreover, why are stands important? A stand is simply a recognizable unit of the forest. Normally our forests exist with varied conditions across a landscape, so we break them up into manageable units called *stands*. Stands are defined in many ways: by the species present; by the ages of the trees present; or by a unique health-related feature. *You name a stand by common existing conditions*, such as western larch stand, a mixed conifer stand, or a root rot-infected stand. Another major category of stand nomenclature is based on age structure; even-aged, uneven-aged, and variable-retention.

### Even-aged Stands

Even-aged stands are stands composed of trees of generally the same age.[6] Not every tree in the stand must be exactly the same age and the key is how the stand became established. Even-aged stands are the result of *stand replacement disturbances*, such as wind, fire, logging, insects, or diseases. The tallest trees are called dominants, while the average tree is a co-dominant or intermediate in size. Trees that are lagging behind the rest (because of competition) are called suppressed. Since all the trees are generally the same age in these stands, there is a poor relationship between age and size. Commonly, shade-intolerant species are found in even-aged stands (Figure 2).

### Uneven-aged Stands

Uneven-aged stands contain trees of multiple ages. Stands of this type have usually been free of catastrophic disturbance for many years, and as a result, the trees have regenerated under the shade of older canopy trees. Uneven-aged stands also result from application of the selective harvest regeneration system over time. In uneven-aged stands, larger trees are usually older than smaller trees. Generally, shade-tolerant trees are more common in uneven-aged stands than in even-aged stands. Uneven-aged stands are rare in northwest forests (Figure 3). They do occur naturally at mid- to low-elevations east of the Cascades, but fire suppression and some harvest practices have created many uneven-aged stands in east side forests. Although these stands do have more species diversity most are subject to poor forest health and eventually to uncontrolled wildfires.

### Variable-Retention Aged Stands

Unlike even and uneven-aged stands, variable-retention is a new concept and is primarily applied to harvestable stands. This stand age situation comes about by retaining a few trees in a stand and harvesting the rest. The remaining trees form a two-tiered forest with the new regeneration. This stand type is new to the forester's tool box and as such may be more experimental in nature. We have observed in the short-term that this stand type creates a more diverse canopy. See the section on Variable-Retention Harvesting in this bulletin for more information (Figure 4).

## Harvest Regeneration Systems

A silvicultural system is a planned program of silvicultural treatments during one or more rotations. It is a long-term program of treatments designed to fit a specific set of owner objectives for their forest type and can evolve

[6] In some silviculture texts, stands with two age-classes are still considered "even-aged." Significant stand disturbances which have occurred twice result in this age class structure. Many two-aged stands exhibit the same characteristics of single-aged stands, except the age classes are often separated by canopy strata or by tree species. Management actions may be applied to trees in both age classes or individually by age class.

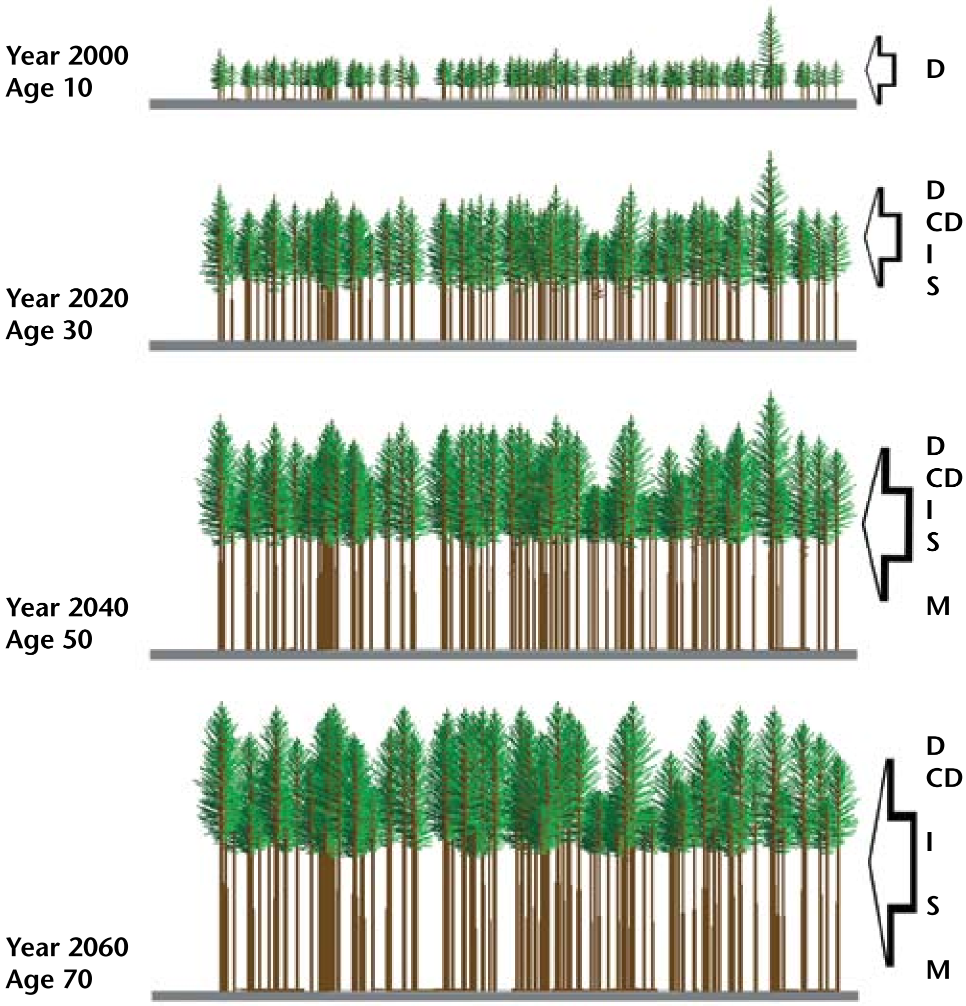



**Figure 2.** Stand development for an even-aged stand. Trees develop over time into dominant, co-dominant, intermediate, and suppressed trees as they compete for light, nutrients, and soil moisture.


**Figure 3.** Uneven-aged stands are composed of trees and shrubs of multiple ages. Uneven-aged stands are rare in eastern Washington and do not occur in western Washington.

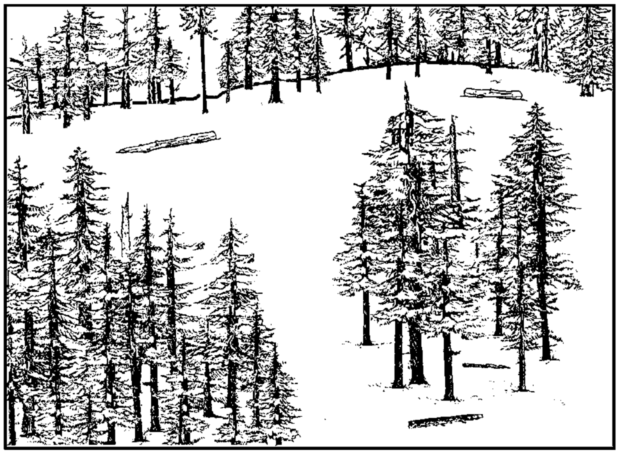


**Figure 4.** Variable retention-aged stands represent a new concept of commingling older trees with younger trees to improve biological diversity with the older trees serving as biological legacies. In this example, the older trees are left in clumps.

as circumstances change. According to Dr. David M. Smith, author of *The Practice of Silviculture*[7], a silvicultural system should satisfy the following objectives as much as is possible: 1) compatible with the goals and characteristics of ownership; 2) provision for regeneration; 3) efficient use of growing space and site productivity; 4) control of damaging agents; 5) provision for sustained yield of specific outputs (wood, wildlife, etc).; 6) optimum use of capital and growing stock; and, 7) concentration and efficient arrangement of operations. Depending on ownership, the importance of each objective will vary, and some objectives may even conflict.

Silvicultural systems are comprehensive programs of silvicultural treatments throughout an entire rotation. Each silvicultural system includes a reproduction method and subsequent intermediate treatments, such as thinning, pruning, fertilization, or prescribed burning. Reproduction methods are often referred to as silvicultural systems, but they are actually only one component of an actual system. Reproduction methods are the silvicultural procedures used to establish or regenerate a stand. Let's review some common methods of harvesting trees and regenerating a new stand (reproduction methods), and then some intermediate treatments and their results.

Reproduction methods are often defined by: 1) the method used to regenerate the stand, and 2) the age structure of the regenerated stand. Reproduction methods vary in the treatments used to achieve regeneration. These treatments, like natural disturbances, can vary widely in severity. The most severe treatments, such as clearcutting, favor shade- intolerant species, also known as early-successional species. These species include some of the most commercially valuable conifers, such as western larch, ponderosa pine, Douglas-fir, and red alder. Less severe treatments remove only a portion of the original stand and tend to favor more shade-tolerant or late-successional species.

Harvest-regeneration systems traditionally focus on wood production, although each method may be applied for other purposes. Tables 1 and 2 summarize the application of the most common methods as applied to small-scale family forest lands in the Pacific Northwest.

## Even-aged Harvest Regeneration Methods

The most frequently used natural reproduction methods that result in even-aged stands are clearcutting, seed tree, and shelterwood harvests (Figure 5).[30]

### *Clearcutting Method*

Clearcutting is a valid and important regeneration treatment. When properly applied, the silvicultural practice is one of the most effective methods to regenerate shade-intolerant species. Because clearcutting may be the most efficient and least costly method of removing wood from forests, there are instances where economic efficiency is confused with good silvicultural practice. Impacts on aesthetics, water quality, wildlife habitat, and recreation are often cited as negative attributes of clearcutting. However, visual impacts can often be minimized and openings in the forest benefit many species of wildlife. Water quality should not suffer unless harvest roads are inappropriately laid out, constructed, or maintained. Commonly, a single-entry clearcut may have a lot less impact on soil and water quality than the multiple entries needed to implement other harvest regeneration systems.

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[7] See Selected Readings Section for complete reference.

[30] In all of these methods, under-planting with nursery or greenhouse grown seedlings is possible and commonly accomplished. See later section on planting for additional information.

**Table 1.** Harvest Regeneration System Alternatives for Interior and Dry Forests of Eastern Washington

| Forest Descriptions | Regeneration Systems | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Patch Clearcut | Seed-Tree[8] | Group Seed Tree | Shelterwood | Group Shelterwood | Single-tree Selection | Group Selection | Variable Retention | Two-tiered stands[9] |
| **Northeast Mixed Conifer** | Yes | Yes[10] | Yes | Yes | Yes | Maybe | Maybe | Yes | Yes |
| **Northeast Ponderosa Pine** | No[11] | Yes | Maybe | Yes | Yes | Maybe | Yes | Yes | Yes |
| **East slope Douglas-fir/ Ponderosa Pine** | Yes[12] | Yes[13] | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Grand fir** | Yes | No | No | Yes | Yes | Maybe[14] | Maybe | Maybe | Yes |
| **East side Lodgepole Pine** | Yes | No | No | No | Maybe | No | No | No | No |
| **South Central Mixed Conifer** | Yes | Yes[15] | Yes | Yes | Yes | Maybe | Yes | Yes | Yes |
| **Oak Woodlands** | No | No | No | Yes | No | Yes | Yes | No | Yes |

8 Brush control is almost always required when using this system.
9 In two-tiered stand harvests, root rot, stem rots, and dwarf mistletoe may result and become major problems.
10 Avoid ridges and other windy spots. Western larch is a preferred seed tree species.
11 Regeneration is difficult in this hot-dry forest condition.
12 Small acreage harvests only.
13 Use in sheltered areas only.
14 Area must be free of stem rots and dwarf mistletoe.
15 Limit seed trees to western larch or ponderosa pine only.

Clearcutting is used to regenerate species like west side Douglas-fir, red alder, lodgepole pine, and east side western larch that are adapted to stand-replacing disturbances. To be most effective, the clearcut should mimic the light and temperature of open fields—the conditions under which shade-intolerant species grow best. Depending on site, slope, and aspect, effective clearcuts can range in size from a few acres to 80 acres or more.[31] Clearcutting should be applied cautiously east of the Cascades on harsh, south or west facing slopes. If these sites are clearcut, seedlings will be exposed to soil surface temperatures that may be high enough to kill them, making regeneration difficult, if not impossible.

Patch cutting (small clearcuts within the confines of a single stand) is a valid clearcut application that can arrest the spread of laminated root rot in west side and coastal Douglas-fir forests. Patch cuts are also used to control the spread of dwarf mistletoes in east side forests. Some landowners utilize patch cuts to improve vistas, improve browse and grazing opportunities and to create firebreaks. Traditionally, patch clearcuts have been an ideal system used to manage for intolerant species, as well as to create age diversity across the landscape (Figure 5).

### *Seed Tree Method*

A modification of clearcutting that is used infrequently in northwest forests is the seed tree method (Figure 5). Eight to ten trees per acre are left widely scattered on the site following harvest to provide seeds for natural regeneration. Seed tree cuts are usually done in two phases. The first phase is called a "seed cutting," when most

31 Forest practices rules and regulations limit clearcut sizes to 40 acres on islands in salt water.

**Table 2.** Harvest Regeneration System Alternatives for West Side Forests

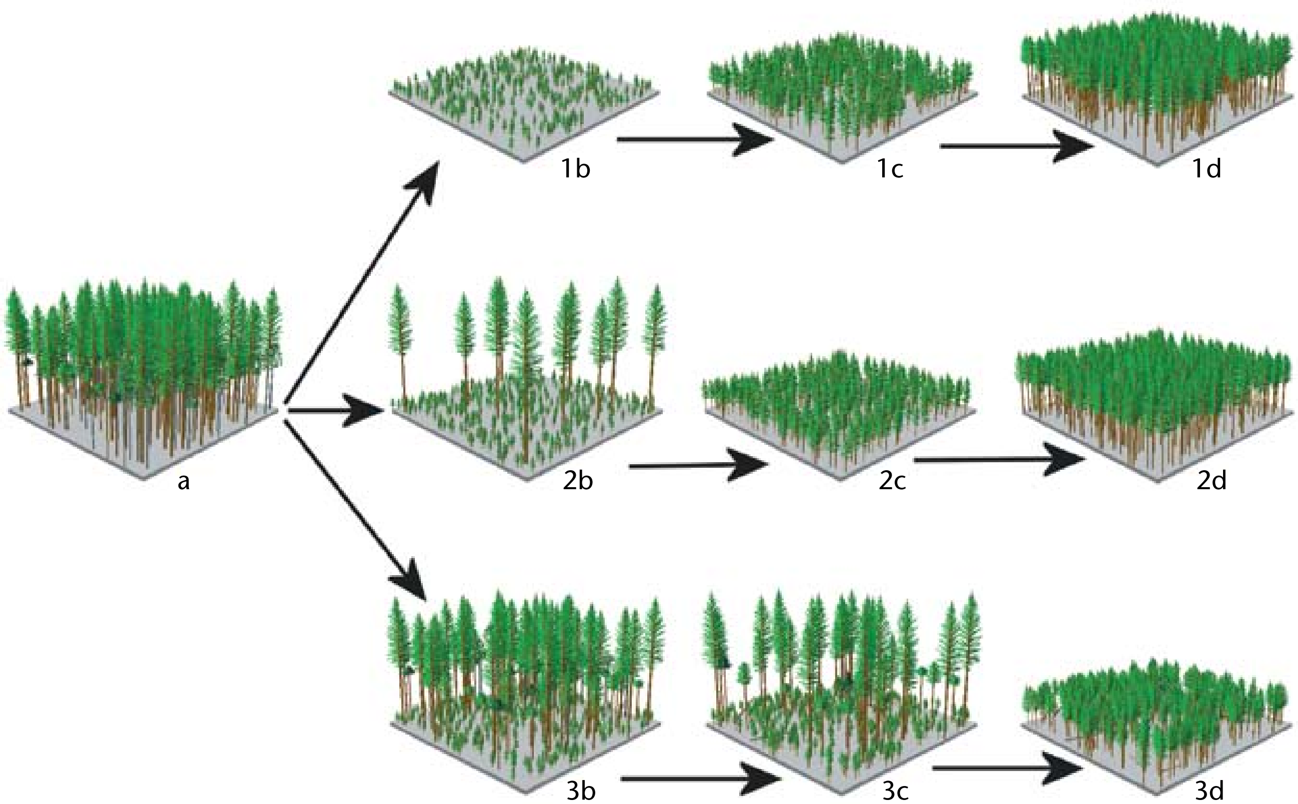
| Forest Descriptions | Regeneration Systems | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Patch Clearcut | Seed-Tree | Group Seed Tree | Shelterwood | Group Shelterwood | Single-tree Selection | Group Selection | Variable Retention | Two-tiered stands |
| **Cascades Douglas-fir/Hemlock** | Yes | No | No | No | Yes[16] | No | No | Yes | No |
| **Coastal Hemlock** | Yes | No | No | No | Maybe | No | No | Yes | No |
| **Sitka Spruce** | Yes | No | No | No | Maybe | No | No | Maybe | No |
| **True fir** | Yes | No | No | Yes[17] | Yes | Unknown | Unknown | Unknown | Yes[18] |
| **Red Alder–uplands** | Yes | No | No | No | Possible[19] | No | No | No | No |
| **Red Alder–riparian areas** | No[20] | No | No | No | Possible[21] | No | No | No | No |
| **Olympic Rain Shadow Mixed Conifer** | Yes[22] | No | No | Yes[23] | Yes[24] | Possible[25] | Possible[26] | Yes | Yes |
| **Cottonwood–riparian areas[27]** | Maybe[28] | No | No | Unknown | Possible[29], Unknown | No | Unknown | Unknown | No |

[16] Limit to dry sites only.
[17] Limit to sheltered areas only.
[18] Limit to sheltered areas only.
[19] Apply to sheltered areas only.
[20] May be appropriate under an alternative plan to re-establish conifer in a riparian management zone (RMZ).
[21] Brush control is almost always required when using this system.
[22] Avoid large clearcuts on south or west aspects.
[23] Brush control is almost always required in this forest type.
[24] Usually applied to help arrest the spread of root-rot fungi in the soil.
[25] Seek professional forestry advice.
[26] Seek professional forestry advice.
[27] Weed control may be required to control exotic weeds, such as Reed canary grass.
[28] May be appropriate under an alternative plan to re-establish conifer in a riparian management zone (RMZ).
[29] If replacing cottonwood with conifer species as a salmon habitat restoration measure.

of the trees on the site are harvested. Generally, fewer than 10 trees per acre are left on the site. The second phase, called a "removal cutting," occurs when the remaining seed trees are harvested after the regeneration is established. It is important that the removal cut take place before the new stand is more than about 10 years old, or the falling trees and other activities will severely damage the young saplings. Site preparation to induce regeneration is generally done before the final harvest, not afterward, as with clearcutting methods. Occasionally, seed trees are retained as part of the next stand and a two-aged stand results. The primary difference between the seed tree method and the clearcutting method is that with the former, seed sources are retained within the harvested area. The primary difference between the seed tree system and the various shelterwood systems discussed below is that the seed tree method has little effect on the microclimate (light and temperature) within the harvested area, while shelterwood systems do effect microclimate.

The primary considerations in deciding which trees should be retained are desired species, wind firmness, and seed-producing capacity. The best trees to retain will be in the dominant

**Figure 5.** Even-aged harvest-regeneration systems commonly used in Washington include clearcutting (row 1), seed tree (row 2), and shelterwood harvests (row 3). The figure illustrates a growth time sequence with original stand at the year 2000; then at 2005; 2015; and 2030, respectively.




crown class and have wide, deep crowns, relatively large live crown ratios, and thick, tapering boles.[32] If trees of poor quality are left as seed trees, the genetic quality of these trees will likely be poor, also. Problems encountered with the seed tree method include blow down of the retained trees, inadequate seed production to provide natural regeneration of preferred species, and the economic feasibility of returning to harvest the small number of trees retained in the stand. In east side forests, the seed tree method is often used to regenerate western larch. The seed tree method is not appropriate for most of the Olympic Peninsula and sites on the western slopes of the Cascades where periodic high winds would blow down retained trees.

Grouping seed trees to protect sensitive areas, such as bogs and fens, or along other watercourses, and for shelter in high wind areas, results in a harvest-regeneration system called a group seed tree.

### *Shelterwood Method*

In the shelterwood method, a partial overstory of 15–40 trees/acre is left to provide protection for seedling establishment (Figure 5). This method is used where seedling establishment might be difficult due to either excessively high or low temperatures (for example, steep, south-facing slopes or within frost pockets).[33] Depending on the number of trees left per acre and the spacing of these trees, shade-tolerant

[32] If a seed tree method is desired and trees with these characteristics are not present in sufficient numbers, they can be cultured if the harvest can be delayed 5–10 years. Potential seed trees are selected and competing trees are removed in a thinning to improve seed tree crown ratios and wind resistance.

[33] Care must be taken when implementing any harvest regeneration system on south-facing slopes. While the remaining overstory does provide shade for seedlings—thus reducing evapotranspiration for those small trees—there may be less available moisture overall, because of the demands of the overstory. Expect to get poor regeneration immediately near the overstory trees and improved regeneration at those locations where the overstory trees cast a shadow in afternoon.

or somewhat intolerant species can be regenerated by the shelterwood method. Stands created by shelterwood cutting are usually single-aged, but sometimes the goal of this method is to produce a stand with two or three age classes. Shelterwood methods are also used where landowners desire to retain high forest cover for aesthetic reasons or to spread timber harvest income over a decade or more.

There are three steps to the shelterwood method of regenerating a stand: 1) preparatory cuttings which remove unwanted species and stimulate seed production in desired species; 2) seed cuttings which induce natural regeneration; and 3) removal cuttings in which retained overstory trees are harvested. Frequently, preparatory cutting is not required, especially if some regeneration already exists or if desired stand composition and trees ready for potential seed production are already present. In some cases, especially in western Washington (where shrub growth is very rapid), artificial regeneration (planting seedlings) maybe required.[34] Seed cuttings open up the stand and allow natural regeneration to establish. Harvest of retained overstory trees can be done in one cutting, but sometimes several removal cuttings are used in order to optimize site growing space by selecting leave tree locations. Care must be taken with the timing of the removal cuttings. If regeneration is not firmly established, much of it can be lost to exposure if the overstory is removed prematurely. Removal cuttings generally cause some injury to the new stand, but this can be reduced (though not eliminated) by using sophisticated logging techniques, such as directional felling and skidding on designated trails or by skidding on snow. Less injury occurs when seedlings are still flexible. The greatest amount of damage occurs when large trees with broad crowns are felled into stands of saplings.

Shelterwood cuts can be uniform, with the remaining trees evenly distributed across the site, or retained trees can be clumped or left in strips. The shelterwood method is usually more aesthetically acceptable to the owner than clearcutting because the overstory is removed gradually. By the time the overstory has been completely removed, a young stand is already growing. Removal cuts can be scheduled to coincide with work being done in nearby stands or can be timed to take advantage of favorable markets and tax strategies.

The shelterwood method can also take the form of a series of thinnings late in the rotation. This can result in a higher proportion of shade-tolerant species established over a longer period. Under this system, the stand becomes more uneven-aged, with three or more age classes represented. Care must be taken during removal cuttings so that the regenerating stand is not damaged. This is especially true when regenerating trees include species that are very susceptible to stem-rotting organisms, which can invade through wounds caused by logging injury.[35] The shelterwood system is generally not an appropriate harvest method in red alder stands because alder is extremely susceptible to stem damage, very intolerant of shade, and often found on wet soils that cannot withstand repeated harvest entries. Many east side tree species can be regenerated under some type of shelterwood system. The shelterwood system is uncommon in west side forests, because it usually fails on sites with higher productivity, where regeneration is stunted and more vulnerable to browse damage.[36] However, we feel that it has a place on drier sites on the west side, and on those sites prone to late spring frosts. Additionally, it may be useful on prairie soils in Pierce and Lewis Counties. In these instances planting under the shelterwood may still be warranted. The shelterwood system may be a good choice for sheltered sites on salt-water islands, as an alternative to clearcuts and inappropriate "selection harvests." On drier sites, such as in San Juan County, salal and ocean-spray may overtake the site and inhibit natural regeneration.

As with the seed tree method described above, when the sheltered trees are grouped for site or tree protection, the harvest regeneration method is called a group shelterwood.

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[34] If seedlings are planted under a shelterwood, then it is technically that is an artificial reforestation procedure.

[35] Grand fir and western hemlock are particularly susceptible to bole injuries during logging. Root damage is also a concern, especially when using heavy footprint skidders, such as those with rubber tires or tracks. Additionally, soil compaction under these conditions is a concern, especially if the soil is wet.

[36] We strongly suggest that you seek advice from a professional forester if using the shelterwood system in western Washington. Site-specific variables will influence the success or failure of this harvest regeneration method.

## Uneven-aged Harvest Regeneration Methods

*Possibly the most common mistake made by people who are new to forestry and logging is thinking that the bigger trees are older and more mature than smaller trees*. In even-aged stands, large and small trees are all about the same age. In such stands, the bigger trees are more vigorous and should be left to grow while nearby smaller trees should either be: 1) removed from the stand if they are shade-intolerant species that have been suppressed; or 2) retained only if they are shade-tolerant species with excellent form and there is a good chance that they will reach the overstory before the end of the rotation, or be carried to maturity if the stand is converted to an uneven-aged structure.

When trees in a stand have a range of ages from young to old, the stand is called "uneven-aged." An uneven-aged stand contains at least three age classes. Most uneven-aged stands contain even more age classes, each of which established after a minor disturbance killed part, but not all, of the existing stand. In old, unmanaged stands, gaps in the overstory occur as individual trees die. Seedlings of shade-tolerant species, which have been slowly growing beneath the overstory canopy, fill in the gaps. This results in small pockets of roughly same-aged trees, but the stand as a whole is uneven-aged. Uneven-aged silvicultural systems were developed to try to duplicate this type of natural replacement of trees. In the absence of large-scale disturbances, old, even-aged Douglas-fir forests will convert to uneven-aged forests composed of western hemlock, western redcedar, and Douglas-fir. In the past, many ponderosa pine forests in eastern Washington were uneven-aged because western pine beetles and low-intensity fires periodically killed individual trees or small groups of trees, allowing seedlings to establish and grow in patches into the existing stand (Figure 6).

Uneven-aged harvest regeneration methods are commonly referred to as selection harvesting. Selection harvesting, or the removal of the *oldest trees*, can be organized by single trees or small groups of trees. *Selection harvesting should not be confused with "high-grading" (often called selective logging), which is the practice of removing the biggest and best trees from an even-aged stand, making little or no provision for regeneration, tree vigor, or spacing.*[37] Selection harvesting is applicable only in stands having multiple age classes. The oldest trees are periodically removed, providing more growing space for younger trees. When selection harvesting is applied to even-aged stands, it is generally—and wrongly—assumed that the largest trees are also the oldest. In an even-aged stand, the biggest trees are the best competitors for resources such as light, moisture, and nutrients. Removal of these big trees amounts to high-grading and usually results in a stand of trees having poor form and low competitive ability. The residual trees tend to be weak and prone to wind throw and breakage.

### *Single-tree Selection Method*

The method of regenerating forest stands that causes the least visual impact in a signal stand entry is single-tree selection. Often landowners choose this system for its visual rewards. However, the single-tree selection method may cause the *most* damage to residual trees and to soil resources through compaction, if applied inappropriately. Advice from a professional forester is advised. With this method, only fully mature trees are harvested. The intent is to create conditions favorable for regeneration. Some trees are removed from all age or size classes to maintain vigor and create an even succession of mature trees. High-risk, poorly formed, and culled trees should be removed in initial cutting cycles. Harvest entries are usually designed so that there is at least 10 years between age classes. This prevents confusion with categorizing trees by age class. Single-tree selection generally favors the establishment and regeneration of shade-tolerant species. However, this system can be used east of the Cascades to regenerate open stands of ponderosa pine, especially when prescribed fire is used periodically to destroy seedlings of Douglas-fir, grand fir, and excess ponderosa pine that might otherwise take over the site (Figure 6).

### *Group Selection Method*

As its name implies, this method involves removing small groups of trees. Group selections may target removal of two or three adjacent trees or create an opening up to 1–2 acres in size. When

[37] Selection harvesting is commonly confused with thinning. In thinning, the objective is to improve existing stand conditions, not to regenerate the stand.

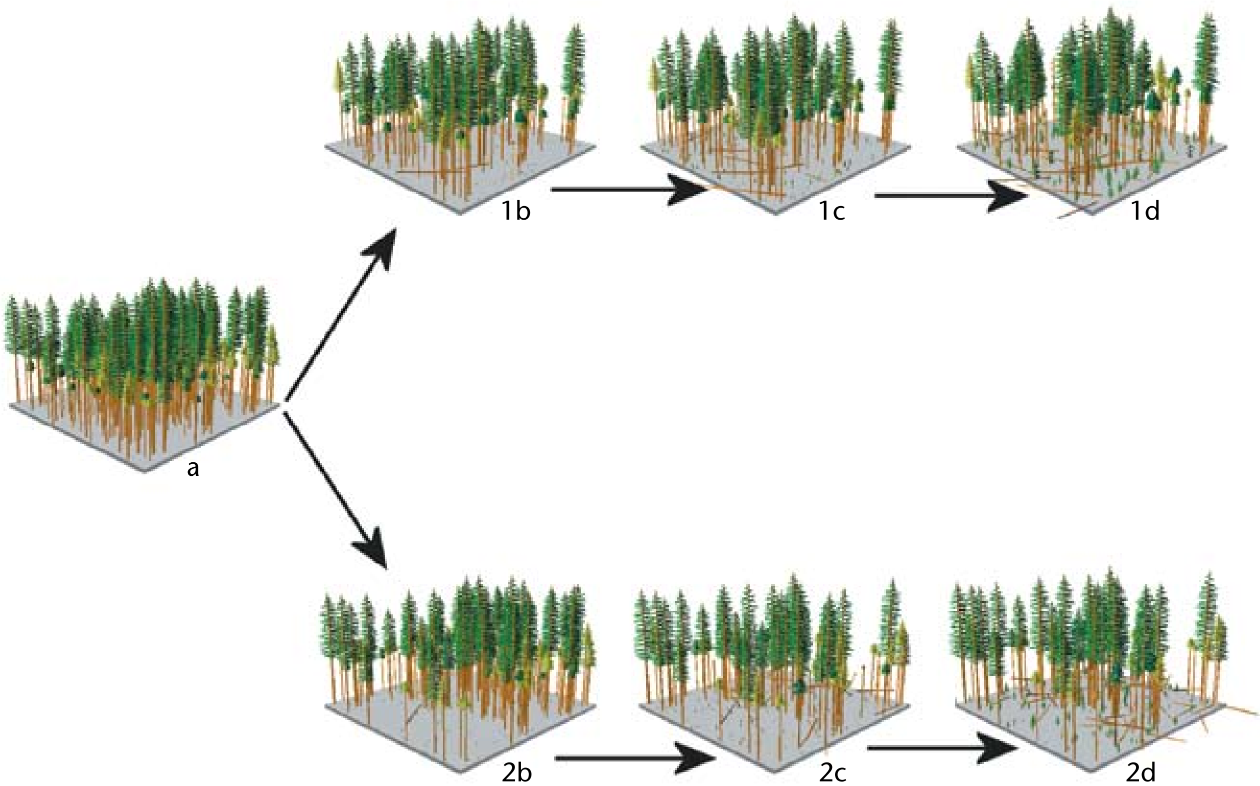



**Figure 6.** Uneven-aged harvest-regeneration systems sometimes used in Washington include single-tree selection (row 1) and group selection (row 2). This figure illustrates a growth time sequence with original stand at the year 2000; then at 2005; 2015; and 2030, respectively.

the opening is small, the gap is shaded for much of the day and shade-tolerant species will eventually fill it in. More shade-intolerant species might establish and grow in western Washington and on better sites in eastern Washington if the canopy opening is larger, but choosing the correct group size is difficult and site specific.[38] Therefore, group selection methods are generally not recommended for west side forests and are only recommended for east side forests where prior disturbances have resulted in multi-aged stand conditions.

With both single-tree and group selection, the establishment and growth of young trees will be strongly influenced by older trees in the stand. These influences will vary with site, climate, and gap size. Shade from the overstory can protect seedlings from the effects of too much sun. On the other hand, competition from older trees for limited soil moisture can adversely affect the establishment and growth of younger trees.

### Drawbacks to Using Uneven-aged Harvest Regeneration Systems

While uneven-aged methods tend to leave most of the forest intact, there are drawbacks. Uneven-aged methods can deteriorate into high-grading, the practice of taking only the largest trees on the site. The largest trees in a stand are not necessarily the oldest. For uneven-aged methods to work, the oldest—not the largest—trees must be harvested. Soil compaction is another problem that can be encountered with uneven-aged methods. Stands managed under uneven-aged silvicultural systems are entered every decade or two. Repeated entries may severely degrade some types of soils, especially if the entries occur when soils are wet. Logging operations performed for selection methods may be difficult, if not impossible, on very steep slopes.

[38] Recent partial harvest experiments and demonstrations at C.L. Pack Forest, near Eatonville, Washington, resulted in substantial red alder regeneration, which is inconsistent with group selection sustainability.

The forester who chooses to use uneven-aged methods must maintain a wide variety of tree diameters in the stand. For the first few cutting cycles, emphasis is placed on achieving a favorable distribution of tree diameters and ages, and not on economic returns. In west side forests, it will take many years to convert an even-aged stand to an uneven-aged stand using small patch clearcuts. On many sites, uneven-aged structure may not be achieved. In some cases, uneven-aged silviculture may run counter to natural disturbances. For instance, even-aged stands of lodgepole pine were created and maintained naturally by bark beetle epidemics and stand-replacing fires that occurred at periodic intervals. Maintaining lodgepole pine stands in uneven-aged conditions requires more intensive management, but such stands may not be sustainable, given inherent regional disturbance regimes (for example, mistletoe, bark beetles, or fires).

### "Selective Logging"

The term "selective harvest" or "selective logging" has become common in Washington. Used to describe a partial harvest (something less than a clearcut), it implies that someone has selected the trees for a harvest. It is often confused with terms used to describe uneven-aged methods, but "selective harvest" has no silvicultural meaning and should ***NOT*** be confused with group and single-tree selection methods, or with the selection of cut and leave trees in an appropriately designed thinning. Too often in application, selective harvesting is nothing more than diameter-limit cutting, the practice of removing the biggest and best trees from an even-aged stand. This is also referred to as "high grading" the stand, as it decreases the genetic quality of trees left on the site.

## Variable-Retention Silviculture

*Two variable-retention silvicultural methods are green-tree retention and two-tiered stands. These approaches favor the retention of biological legacies, and are based on scientific estimates and experience. Demonstrations and research have started to measure biological impacts and sustainability of these methods.*

### *Green Tree Retention Method*

One of the practices advocated by variable-retention silviculture (VRS) is the retention of numerous live trees on site following harvest. These leave trees are not be harvested at a later time, such as with the shelterwood harvest regeneration system. VRS objectives include providing habitat for wildlife and retaining some of the original forest floor, including shrubs, plants, and populations of beneficial mycorrhizal fungi. It is believed that retention of these "biological legacies" will enhance the diversity of plant and animal life in the regenerating forest stand over a long time. Operationally, VRS must plan for future access to avoid injuring trees that are left on the site forever. Because the economic value of retained trees will not be realized, there is a tendency for poor quality (from a market perspective) trees to be chosen for retention. This is not a problem, unless the trees chosen for retention are likely to blow over, or if the stand will be regenerated from seed. If planting will be used to regenerate the stand, retaining large, limby trees with thick, tapered boles reduces the likelihood of blow down. Trees with forked or dead tops are also good candidates for retention. These "defective" trees provide perching or nesting habitat for a variety of birds and small mammals.[39]

Retained trees may be uniformly scattered over the site or clumped. Retaining trees in groups might be operationally more efficient and may reduce the tendency of individual trees to be blown over. Besides retaining living trees on the site, it is important from the standpoint of wildlife to retain some snags. Snags can be retained individually for certain bird and mammal species requirements or within clumps of live trees, to reduce the possibility of injury to loggers during the harvest operation (Figure 7).[40]

### *Two-tiered Stands*

With another VRS method, a portion of the stand is removed, allowing trees to regenerate

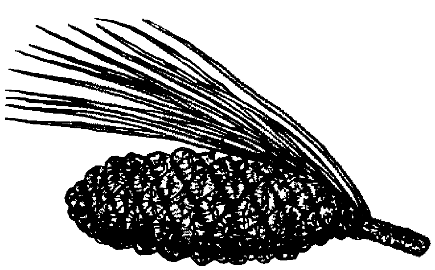
[39] However, these defective trees will likely reproduce, and the silvicultural prescription should plan for their removal or suppression if the poor trait is genetically reproduced and not desirable in the future stand.

[40] In some instances, birds prefer individual snags for nesting if they tend to be territorial. Secondary cavity nesters, such as owls, bats, and squirrels, prefer individual snags along green tree edges. Conversely, clumped snags will benefit primary cavity nesters if the snags are among green trees. If the snag is used primarily for foraging, its arrangement amongst other snags is less important.

**Figure 7.** Variable-retention harvest regeneration system example. Configuration and species retained mimic natural conditions after a non-stand replacement disturbance.

and grow beneath an existing overstory. Two-tiered stands retain even greater amounts of the biological legacies discussed above. Essentially, the two-tiered system is a shelterwood method with the removal cutting postponed indefinitely. As with all methods where only a portion of the original stand is removed, care must be taken not to damage the trees that remain.[41] The two-tiered stand method can work well if enough of the overstory is removed so that the younger age class is not competing with the overstory. West of the Cascades, two-tiered stands of Douglas-fir will be difficult to establish on wet sites where western hemlock, which is more shade tolerant, may overtop the younger age class of Douglas-fir. East of the Cascades, two-tiered stands of Douglas-fir may be more easily established, but may be at high risk to defoliating insects and mistletoe infestations.

Understanding of the two-tiered VRS system is complex, both ecologically and silviculturally, and must be guided in site-specific applications by thorough knowledge and experience.



# Regeneration Principles

## Artificial Regeneration—Planting Seedlings

Planting seedlings is clearly the favorite regeneration method in western Washington, regardless of the harvest system utilized. Planting seedlings in eastern Washington is not quite as common, but nevertheless is a major regeneration practice. A successful plantation requires: 1) seedlings that are healthy and adapted to the climate and site, 2) seedlings that have been handled, stored, and planted correctly, 3) a favorable planting micro site or *spot*, and 4) minimal or no competition from other vegetation during the early stages of development. If any one of these four conditions is not met, the plantation will likely fail.

It is very important to plan your regeneration activities well in advance of timber harvesting. This is especially true when seedlings will be ordered from commercial nurseries.

### *Seed Sources*

Seedlings must have parent trees from a geographic region that is reasonably close to where they will be planted. This geographic region is called a seed zone. Washington has many recognized seed zones and nursery personnel keep track of them during the nursery operations. If you order

[41] Root damage from soil compaction is not easy to detect until symptoms appear in the affected trees.

seedlings from a commercial nursery you will be asked for the seed zone.

Why are these seed zones so important? Seedlings grown from seeds that were collected in local seed zones usually will out-perform those that come from long distances or different elevations. It only makes sense that Douglas-fir from east side forests will not do as well if planted on the west side, or west side Douglas-fir goes to east side forests for planting. Additionally, it does not make sense to plant low-elevation grand fir at high elevations and expect them to survive and grow well. While these examples are extreme, close adherence to seed zones and elevations are your best bet. Given the time, labor, and expense needed to establish a plantation, it is foolish to ignore basic seed provenance principles. Early growth and high tree vigor are your best predictors for a successful plantation.

### *Stock and Stock Types*

Planting stock comes in two basic types; bare-root seedlings grown in an outdoor seedling nursery, and seedlings grown under more controlled environment in a greenhouse. Greenhouse-grown seedlings are grown at close spacing, usually in Styrofoam containers, and are called *container* or *plug* seedlings.

Outdoor nursery seedlings generally take one to two years to grow, depending on species. Greenhouse-grown seedlings generally take one year or less to grow, depending on species. Stock types are identified by years in a nursery bed and transplant bed, or in a greenhouse (see Table 3).

### *Site Preparation*

Site preparation is the activity associated with making the site ready for seed dispersal or

**Table 3.** Stock Types

| Stock Type Name | Root Medium | Description |
|---|---|---|
| **1+1 Stock Type** | Bare Root | This term designates a seedling grown for one year in a seedbed, harvested, root pruned to 5 inches and transplanted back into a nursery bed at approximately 6 seedlings per square foot. The transplanting process results in a larger caliper and a more fibrous root system. The root system on a 1+1 plus the extra storage of food in the stem and root system will allow the seedling to survive on an infertile site, compete with other vegetation, and give it a better chance of surviving browse damage. |
| **2+0 Stock Type** | Bare Root | This term designates a seedling that was grown at approximately 25 seedlings per square foot in the seedling bed and grown in the field for two years (never transplanted). After two years, the seedling is ready for out-planting. The production costs are low because the seedling has not been lifted, packed, and transplanted, as with all of the transplant stock types. The root systems on such stock type are pruned horizontally in the ground at a six-inch depth and vertically between each row at the end of the first growing season. This stock type will survive on a site that has low competing vegetation and minimal levels of animal browsing. |
| **2+1 Stock Type** | Bare Root | This stock type is grown in the initial seedbed at 25 seedlings per square foot. At the end of the second year, the seedling is harvested, sorted, root pruned and transplanted back into the nursery bed at a density of six seedlings per square foot. The result is a seedling with a large caliper and root mass. This large stock type is useful for areas requiring quick green-up or areas of extreme animal browse. In most situations in Washington, a 1+1 or Plug+1 are very suitable and less expensive than 2+1 stock type. |
| **Plug (P)** | Container | This is a seedling grown in a greenhouse in narrow, deep containers. For some species, growing plug stock type is necessary because of germination and early growth. Various sizes of containers are available but the target is a styro-2A (2 cubic inch container), if the seedling will be used for a Plug+1 stock type. |
| **Plug+1 (P+1)** | Container | After growing in the greenhouse for a year, this type of seedling is extracted from the container, root pruned at five inches and transplanted in a nursery bed at approximately 6 seedlings per square foot. As with the 1+1 stock type, root pruning and transplanting generates a larger caliper stem and more mass in the root system. Cedar, hemlock, larch, and some species of pine and true firs are propagated as Plug+1. |

*Not all species and stock types are grown for all seed zones each year, so it is very important that you communicate your seedling needs to a commercial or state forest nursery with enough time to insure availability.*

Table adapted from Washington DNR, Webster State Nursery web site (http://www3.wadnr.gov/dnrapp3/webster/).

planting. It usually includes slash disposal, weed control, and sometimes soil scarification. Most harvest units should be planted as soon as practical after harvesting in order to give the seedlings a competitive advantage before other vegetation becomes established that will compete with the newly planted seedlings. Slash disposal must be accomplished to allow tree planters access to the ground where they must scrape duff away from the *immediate* planting spot. Most of our conifer species require planting micro-sites that are free of duff and competing vegetation.

Natural regeneration is commonly used in eastern Washington, and site scarification, or the removal of the soil duff layer, is generally required to expose *small-sized microsites (6–10 feet in diameter)* suitable for conifer seed germination. Scarified spots that are too large invite the germination of invading weeds and can lead to erosion. Timing is important here, as seed is not produced every year by each species. If grasses or competing shrubs capture a site first, conifers will be at a competitive disadvantage. Commonly, natural regeneration and plantation failures are often the result of poor site preparation.

### *Planting Techniques*

Most landowners plant trees themselves and use a standard shovel to do the work (Figure 8). Commercial reforestation contractors often use specialized shovels, dibble bars, hoedads, power augers, or planting bars. Regardless of the planting implement, the work is hard and time-consuming requiring a dedication to the appropriate technique. The ultimate goal is to have thrifty, high vigor, rapidly growing seedlings on the site within three years of planting. Generally, after three years, a young tree can compete with adjacent grasses and shrubs for available light and moisture. Correct site preparation and weed control measures are critical for success.

Proper seedling handling procedures prior to planting are also important. The nursery where you purchase seedlings can supply information. *Plant Your Trees Right*, an Extension publication available from Washington State University provides helpful information.[42]

### *Plantation Timing*

Successful plantation establishment requires hard work, planning, and a good sense of timing. Since seedlings are the best alternative for

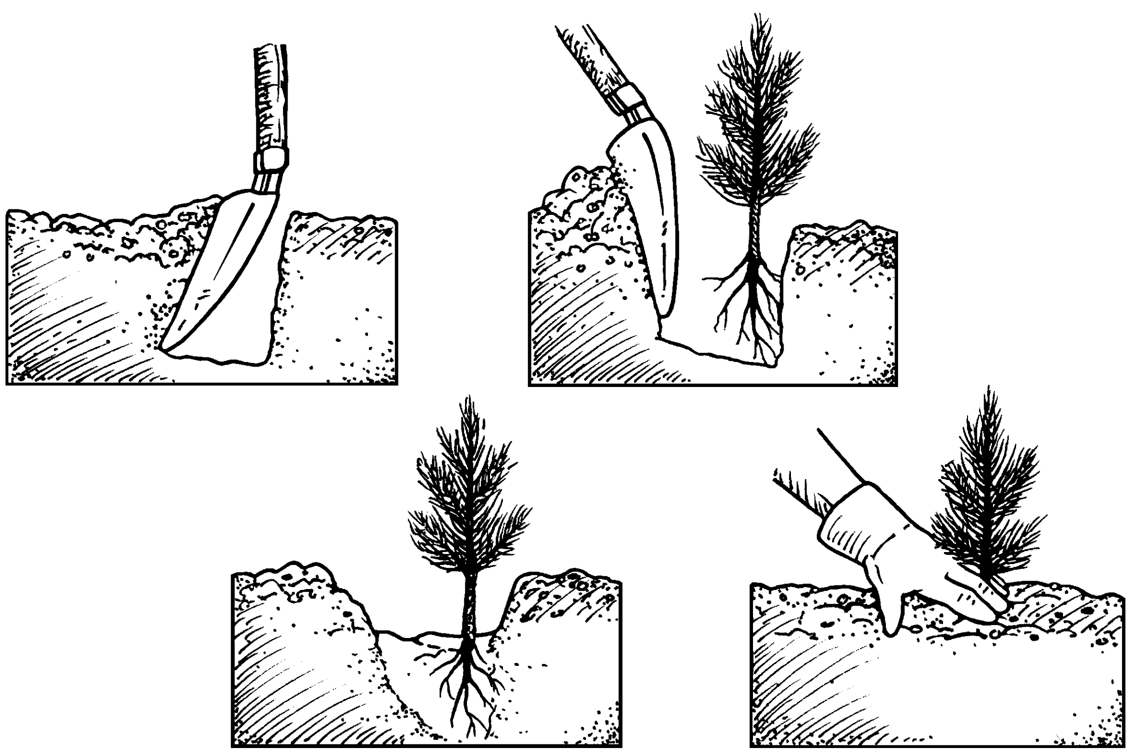


**Figure 8.** Tree planting steps using a common shovel.

[42] Publication PNW033 is available from WSU Extension publications.

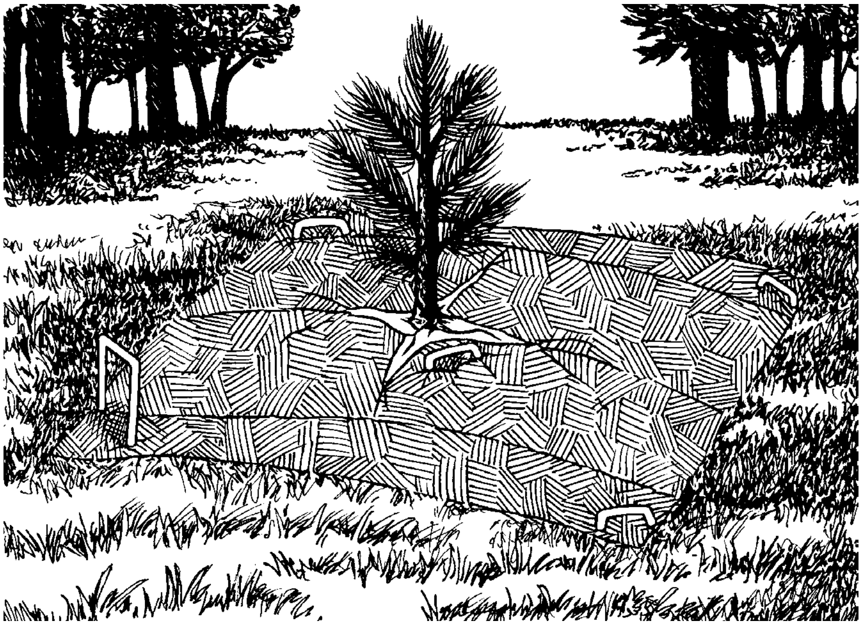


**Figure 9.** A geo-textile cloth, "Fabric Mulch," is used on harsh sites to improve seedling survival and growth by retarding weed completion and improving soil moisture retention.

plantations, you must find a vendor and order your seedlings up to three years in advance of planting date. This timing requirement is critical for less commonly planted species found in small or little-used geographic seed zones. In extreme cases, you may have to provide seed to the nursery from your local seed zone and have the seedlings custom grown. In western Washington, seedlings are commonly planted from January through March. In eastern Washington, seedlings are usually planted in late fall, early winter, and most commonly after snowmelt in the spring. Planting into frozen soil will decrease survival significantly.

### *Plantation Maintenance*

Periodic plantation maintenance is *required*, especially during the first three to five years. The biggest threat to newly planted trees is the competition from adjacent vegetation, as this vegetation may rob the young trees of light, water, and nutrients. Grasses and shrubs are usually the first plants that rob seedlings of vigor and stunt their initial height growth. Grass competition is usually eliminated by use of directed spray herbicides or by geo-textile ground-cloth barriers called "fabric mulch" (Figure 9). Without this release from competition, plantations often die or at least do not perform up to expectations.

Animal damage is the next important factor that must be addressed. In young plantations, damage from mountain beaver (*Aplodontia rufa*) and deer are common in west side forests.[43] In east side forests, pocket gophers, deer, and elk may do significant damage. As the plantation gets older, damage from black bear, elk, porcupine, and cougar should be monitored and mitigated as appropriate.

Root and stem diseases are major factors leading to poor plantation and natural stand performance. Ideally, the fungi in the soil that initiates these diseases will be identified prior to planting. If so, tree species can be selected for planting to contain or mitigate most of these diseases.

Bark beetles can devastate a plantation if the trees are allowed to lose vigor. The best protection against these stand-threatening insects is to maintain high tree vigor by reducing competition. In pine stands, the *Ips* beetle can be a critical pest. It breeds in slash and can attack standing green adjacent trees.

Wildfire is the universal threat to plantations. Correct slash disposal prior to planting is very important to minimize fire hazard. Also, thinning (or initial wide spacing) and pruning may help reduce the "crowning" of a wildfire.

[43] A nocturnal rodent, mountain beaver are strict herbivores and eat just about any type of succulent vegetation available, including plants that are often inedible to other wildlife species, such as nettle, bracken fern, and salal. Plants are also gathered and dried ("haystacking") near the mountain beaver's burrow system, probably for food storage and nesting material. This rodent enjoys Douglas-fir seedlings.

## Natural Regeneration

Natural regeneration is the establishment of seedlings on a site, germinated from seeds from adjacent parent trees. Too many landowners think of natural regeneration as easy to do and free of cost, but neither is true. Natural regeneration requires site preparation, knowledge of the silvical characteristics of the adjacent tree species, and correct timing for an adequate seed supply. Too often, this last factor is overlooked and the site is lost (meaning that soil conditions are no longer favorable for conifer seed germination) before adequate adjacent parent trees produce seed.

### *Factors Affecting Natural Regeneration*

Often landowners feel that natural regeneration is the best method to use to reforest a harvested area because it is "free"—simply sit back and let nature do the work of establishing new trees in your forest. Unfortunately, in most west side forests and the more productive areas on the east side, this belief may be erroneous. In terms of "cost," there is little or no financial outlay up front for natural regeneration, except for site preparation (and this can be very expensive). However, the real cost may come in production losses associated with waiting for a seed crop. Most of our conifer species only produce good seed crops in three to five year intervals. You may also need to do a second site preparation if the seeds are not quickly produced in adequate numbers. Of course, you also need favorable weather for the seed to germinate.

Natural regeneration is alo a bit of a gamble from a genetic perspective. While we strive for excellent genetic diversity in a species, with natural regeneration, we can only assume that the subsequent generation of trees will be from genetically superior parent seed. There is no way to assure this condition in nature. Nursery-grown seedlings are more likely to come from seed developed under controlled conditions, called forest tree improvement. Forest tree improvement has focused on commercially important species such as Douglas-fir. The objective of forest tree improvement is to emphasize advantageous traits in the selection process; it can also be used to isolate genes that give seedlings disease and insect resistance.[44] Western white pine is a species that has been improved for disease resistance. Western white pine is susceptible to white pine blister rust, an exotic fungus. As such, if natural white pine regenerates on a site, they will undoubtedly be vulnerable to repeated losses from this disease. In this case, planting disease-resistant stock is best, and it is now available from many nurseries.

Silviculturists are always trying to speed up nature to improve tree vigor, to grow trees faster, straighter, and better. In addition, the Washington Forest Practices Act requires prompt regeneration. Moreover, if we do not adequately stock our harvested lands quickly, they may be lost for many decades, as shrubs and other generally undesirable species will invade. Once undesirable species are established, it may take many attempts to eradicate them. A good example is the invasion of many wetter sites on the west side by reed canary grass, an exotic grass, which is very difficult to eradicate. On the east side, many forested sites may be captured by knapweeds and other exotics that are usually not desired. Other important factors for natural regeneration are species composition and stocking levels. Under artificial regeneration, you can control what combination of species will be found on the site and how they are distributed. Natural regeneration is much more variable and difficult to control.

In east side forests, natural regeneration is the preferred alternative for many extensively managed sites, if timber management is a secondary objective of the landowners. However, a common problem is either too much, or too little, regeneration under this scenario. If timber management is a primary goal, prioritize your most productive sites and invest time and energy on those sites to achieve successful regeneration the shortest possible time.

[44] Genetic selection for disease resistance is operationally well established. Insect resistance is currently under study.

# Intermediate Cultural Practices

Intermediate cultural practices is a collective term, and is defined as all of the activities done to a stand after tree establishment and before harvest regeneration activities start anew. An older term that describes intermediate cultural practices to improve an existing stand without yielding products is Timber Stand Improvement or TSI (for example, precommercial thinning).

If producing quality sawlogs is a forest management objective, intermediate cultural practices are very important. In this scenario, intermediate cultural practices may include weeding, thinning, pruning, and fertilizing. Under more extensive management, weeding and thinning may be all that is needed.

## Weeding

Weeding is simply the removal of unwanted trees, shrubs, and grasses from a stand to improve growing conditions for the favored tree species. It is best to implement a weeding early in the rotation to assure early "free to grow" conditions for the remaining trees. If competing vegetation is significant, it can result in a decrease in tree vigor and health, or even death. Unwanted vegetation is usually controlled by herbicide applications or by using hand or power brush cutters. Common brush species controlled in Washington using weeding techniques, include blackberries, knapweeds, and scotch broom.

## Thinning

Thinning reduces competition for light, water, and nutrients by removing some of the trees in a stand. The main reasons for thinning are to increase the vigor and diameter growth of the remaining trees. Without thinning, a stand will produce many small-diameter trees, which may not be particularly valuable. With thinning, fewer trees remain to be harvested, but they will have larger diameters and generally greater value.[45] On many sites, especially in eastern Washington and on saltwater island sites, thinning is critical for maintaining forest health and stand vigor. When too many trees compete for resources, many will become weak and unable to resist attacks from insects and pathogens. Thinning stands in the correct manner as described below will make them more resistant to insects and disease.

### *Precommercial Thinning*

Precommercial thinning (PCT) is the application of thinning principles to a young, submerchantable stand. In other words, the trees that are thinned out have no commercial value, so are simply lopped and scattered on the forest floor to decompose.[46] Initial PCT is done when the trees just begin to compete with each other for essential resources. Each acre in a stand has fixed amounts of growing space, light (for photosynthesis), nutrients, and available water for tree (and all other plant) growth. The combination of these resources allows trees (and everything else in the ecosystem) to utilize the site. The growth potential of a site is simply an expression of these factors. The goal of thinning is to redistribute this *growth potential* to fewer stems, thus allowing each remaining stem to acquire additional resources from the fixed ecosystem pool. Why is this important? Generally, stands are overstocked and carry too many stems per acre. This overstocked condition results in lower tree vigor and reduced growth rates.

Overly dense stands are a problem across Washington. West of the Cascades, trees in overstocked stands grow slowly in diameter and become susceptible to wind throw. In some of the worst cases, stands stagnate, and trees collapse under the weight of their crowns. In eastern Washington, unthinned stands lack the vigor to withstand insect and disease attacks. The removal of smaller trees can also help prevent fires from spreading into the crowns of trees. Some "apparently open stands" in east side forests are overstocked and require thinning, since trees in these stands compete more for moisture than they do for light.

The decision to forgo thinning usually results in unhealthy, overly-dense stands. Deciding how frequently to thin is difficult, and depends

[45] Currently, logs with diameters over 11 inches have higher values than smaller logs in eastern Washington. Additionally, in western Washington, big logs generally over 30 inches in diameter have lower values per board foot because of changes in mill standards.

[46] For many years, thinning slash from PCT operations was piled and burned to clear the site. Burning is now discouraged during thinning operations as it removes vital nutrients from the forest ecosystem and also degrades air quality.

a great deal on the objectives of the landowner. Frequent thinning can "capture volume that would be lost to mortality," that is, trees that are likely to die soon can be harvested while they still have monetary value by periodically removing the least competitive trees; the remaining trees are then allowed to continue growing at their maximum rate. Thinning too frequently can be detrimental in some instances, as repeated stand entries by logging equipment and workers may compact soils, and inappropriate felling and indiscriminant skidding can adversely impact or potentially damage the residual stand.

Common west side initial precommercial thinning practices remove excess trees by the time the crowns compete for light—generally at age 12–15 years. The "leave trees" are spaced, on average, from 12–18 feet, depending on the owner's objectives. Initial PCT in east side forests is more variable because site quality is much more variable. However, as a rule, initial PCT is conducted at an older age on the east side; generally 20–25 years of age for natural stands and 15–20 years in plantations.[47]

A major benefit of PCT is species selection and the removal of diseased, deformed, or broken trees. Based on landowner objectives, remove those trees that are generally undesirable by species and condition first, favoring the vigorous, healthiest trees in the stand. This is your opportunity to maintain, improve, or reduce tree species diversity and the resultant habitat diversity. PCT does not need to be applied in a uniform, row-by-row manner. Clumping to benefit wildlife is fine and encouraged on many sites. Because of potential stand health concerns, in east side forests true firs (*Abies* spp.) are discriminated against to favor species such as Douglas-fir, western larch, and ponderosa pine. In west side forests, western hemlock is discouraged in the Cascades, while on the coast it should be favored, along with Sitka spruce and lodgepole or shore pine. Western white pine is native to many conifer forests, but since it is affected by white pine blister rust (an introduced disease), it must be managed carefully, especially when young. If you have white pine or wish to plant white pine, consult with a professional forester before implementing your thinning.

Red alder PCT is not common historically. However, given new knowledge about this species and its increasing value, PCT has become an important cultural practice for this species. PCT in red alder stands can start very early in the rotation. Often landowners use loppers and thin out alder when the trees are less than an inch in diameter at the ground. This process may be repeated numerous times over the life of the stand.[48]

### *Commercial Thinning*[49]

In commercial thinning, when market value of the thinned-out trees is greater than logging costs, the landowner receives revenue. Commercial thinning costs (falling, bucking, skidding, loading, transporting, etc.) are typically greater per unit volume than for clearcutting. However, the long-term economic returns from thinned stands are almost always greater than from non-thinned stands.

Most thinning practices are intended to control tree density by managing the trade-off between increasing diameter growth on individual trees and increasing the per acre volume yield.[50] In a nutshell, each stand can grow a given amount of wood per acre per year, until the site capacity is reached. Basal area/acre[51] is one measure of site capacity; another measure is trees per acre. Basal area is expressed as square feet of wood per acre. The greater a stand's basal area, the greater the proportion of an acre that is occupied by tree stems. Basal area is one measure of density, but does not tell anything about the number of trees per acre, or their size. A basal area of 100 square feet per acre could be more than 500 6-inch trees or about 130 trees that are 12 inches in

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[47] Utilization standards are being reduced, and currently 3 1/2 inches on the small end of the log is common in many locations. These smaller standards reduce the need to conduct a thinning, or even eliminate the need. On some of the better sites in Washington, sawlogs will be produced in 20–25 years.

[48] See the section, "Thinning in Red Alder" for additional information.

[49] Adapted from: *Thinning Young Douglas-fir West of the Cascades for Timber and Wildlife*, O.T. Helgerson and J. Bottorff, WSU Extension Bulletin EB1927.

[50] Generally, tree height growth is independent of tree density.

[51] Cross-sectional area is measured at 4.5 ft. above the ground; this is the point at which diameter at breast height or DBH is measured.

diameter. Knowing both basal area and number of trees per acre is necessary to estimate appropriate tree distribution.

In unmanaged stands, basal area increases as trees grow in diameter. The density of trees in a stand controls the rate of diameter growth. As some trees die, those that survive grow larger to fill the available space. In older stands, basal area growth occurs on fewer and fewer trees. In very old stands, a few very large trees may account for most of the basal area.

The timing of thinning operations is related to stocking. For stands in which timber management is the primary objective, optimum stocking is the point where both volume growth per acre and volume growth per tree are maximized. Research foresters have identified optimum stocking levels for different forest types in which timber production is the primary objective. Different stocking levels may be required for stands managed primarily as wildlife habitat.

Most of the stand attributes that relate to stocking and thinning assume that stands are even-aged. In an intensively-managed stand, thinning may be prescribed two to five times, or even more, during a single rotation. As the stand matures, the temptation to harvest trees is difficult to resist. "Making space for smaller trees" is often used as the reason for removing the biggest trees from a stand. However, it is usually the smaller trees that should be removed and the big trees left to grow even larger, since the bigger trees have proven to be better competitors than smaller trees of the same age. Following harvest of large trees, the smaller ones that are retained do not always respond with increased vigor and growth. They may languish and even die.[52] Ultimately, the decision of when to harvest a particular tree is a question of health, condition, and maturity—and not always size.[53]

### *Crown or High Thinning*

Two general commercial thinning approaches exist. High thinning, or thinning from above, is the taking of primarily larger overstory trees from above. High thinning provides high immediate financial return, but can reduce future tree growth and financial returns even into negative numbers. The smaller and more slender understory trees left behind often have less leaf area to influence growth; take longer for their growth to respond to thinning; are prone to sunscald, logging damage, windthrow, and snow breakage; and may be genetically less fit. However, damaged trees, have value as wildlife habitat, especially trees greater than 20 inches in diameter.

### *Low Thinning*

Low thinning is a thinning method whereby the smaller, less vigorous trees are removed from the stand. In a low thinning, the objective is to remove these less vigorous trees, recovering their value before they die from being crowded. While immediate financial returns are less, future growth, stand health, and financial returns will be greater. Faster growth accumulates on higher-value larger trees that have fuller crowns and are better able to utilize the increased light, water, and nutrients provided by thinning. These larger trees are less prone to physical damage by logging or weather.

### *General Conifer Stocking Levels After Thinning*

While it is beyond the scope of this introductory bulletin to discuss all of the factors impacting determination of stocking levels over time across many sites, we find that a few "rules of thumb" are generally accurate. If timber management is a primary objective, the old saying "room to grow and none to waste" is appropriate. It simply means that as trees grow over time, they need enough space to fully develop and should be spaced uniformly throughout the stand, so as to not "waste" ground. Another timber management rule of thumb is the D+ rule. Thinning is initiated when the average spacing is D+4. After thinning, it should aver-age D+7. For example, if your trees average 10 inches in diameter, thinning should start when the spacing falls to 14 feet

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[52] This phenomenon is referred to as *thinning shock*. Thinning shock is not fully understood, but factors that induce it are crown ratio, initial stocking levels, and general site quality. Western redcedar is particularly vulnerable if the site is of low fertility and the initial stocking level is high.

[53] Many mills throughout the Pacific Northwest have reconfigured their equipment to be very efficient in the conversion of small logs to products. In this regard, smaller-diameter logs may currently be more valuable than larger ones, and this is likely to continue to be the case. Currently, conifer logs greater than 20–24 inches in diameter (large end), are less valuable than those that are smaller. Depending on location, this reduction in value can be as much as $100 per MBF. This trend will undoubtedly continue as engineered wood products become more common in the market place.

(10+4) and should be increased by removing trees so that the average is 17 feet (10+7).

***A word of caution:*** these guides are simple approximations and do not apply very well if managing for wildlife or other objectives requires less uniform stocking levels. The next section will address relative density and present an example of a more sophisticated guide. The Landscape Management System (LMS) is even more accurate LMS and "grows trees in the computer," based on management scenarios. It is discussed later in this bulletin.

### *Relative Density as a Measure of Full Stocking*

Various methods can be used to determine when to thin a stand, based on how close the stand is to full stocking.[54] Relative Density (RD) is an easily-calculated method based on numbers of trees per acre (TPA) and average DBH (See Table 4). For west side Douglas-fir, an RD70 indicates full stocking—the site is holding about all the trees it can for a particular average diameter (see side bar). Such a stand would contain dead and dying, suppressed trees. For wildlife management objectives, this would correspond to a "closed canopy" of between 70% and 100% canopy cover.

Measuring DBH on sample plots before thinning is relatively easy and will give you an estimate of the range of tree sizes. This can provide a good initial estimate of the trees to cut and those to leave, for a desired average DBH for leave trees and associated trees per acre. After thinning, use RD to estimate the future average size when a second thinning could occur. As with precommercial thinning, you can make the following commercial thinning choices when trees are large enough to sell: conduct no thinning, thin for timber, or thin for wildlife. Be aware that RD provides only a general guide and it may not always be feasible to thin at exact RD recommended sizes.

**Commercial Thinning for Timber— Western Washington Example**

For an intermediate financial return from thinning and to maintain full stocking for timber production, the RD thinning guidelines indicate landowners should grow Douglas-fir to about RD55 (the Timber Upper Limit) and then harvest enough trees to give about RD35 (the Timber Lower Limit, Figure 10). Thinning to this level helps ensure that increased light, water, and nutrients made available by thinning go into wood production on the leave trees, and do not greatly enhance understory plant development. In terms of canopy cover for wildlife habitat, thinning to this level corresponds to "moderate cover" (40% to 69% canopy cover).

Depending on log markets, it may be better to grow Douglas-fir trees to larger sizes and greater RD values before the first commercial thinning

**Relative Density (RD)**

Relative Density is a descriptive term that relates the density of a stand to a theoretical "full stocking" level.

Mathematically, RD = Stand Basal Area (BA) in square feet per acre divided by the square root of the quadratic average of DBH in inches.

The quadratic average is the square root of the average of squared diameters. For smaller areas, a simple average DBH can work about as well as the quadratic average in calculating RD.

Stand basal area (BA) is equal to the sum of the cross sectional area of trees at breast height on an acre of land. It is also equal to the BA of a tree of average diameter multiplied by trees per acre (TPA). To convert tree DBH to BA, square the DBH and multiply by 0.0054. Thus, a 10-inch DBH tree would have a basal area equal to (10 x 10 x 0.0054) or 0.54 square feet. If that tree represented average tree diameter in our example stand of 355 TPA, the stand BA would equal (355 x 0.54) or 194 square feet. The RD for this stand would be equal to ($194/\sqrt{10}$), or 61, thus RD=61, a stand approaching full stocking.

[54] Many stocking guidelines are *rules of thumb*, based on the experience of the forester. Others are based on physical properties.

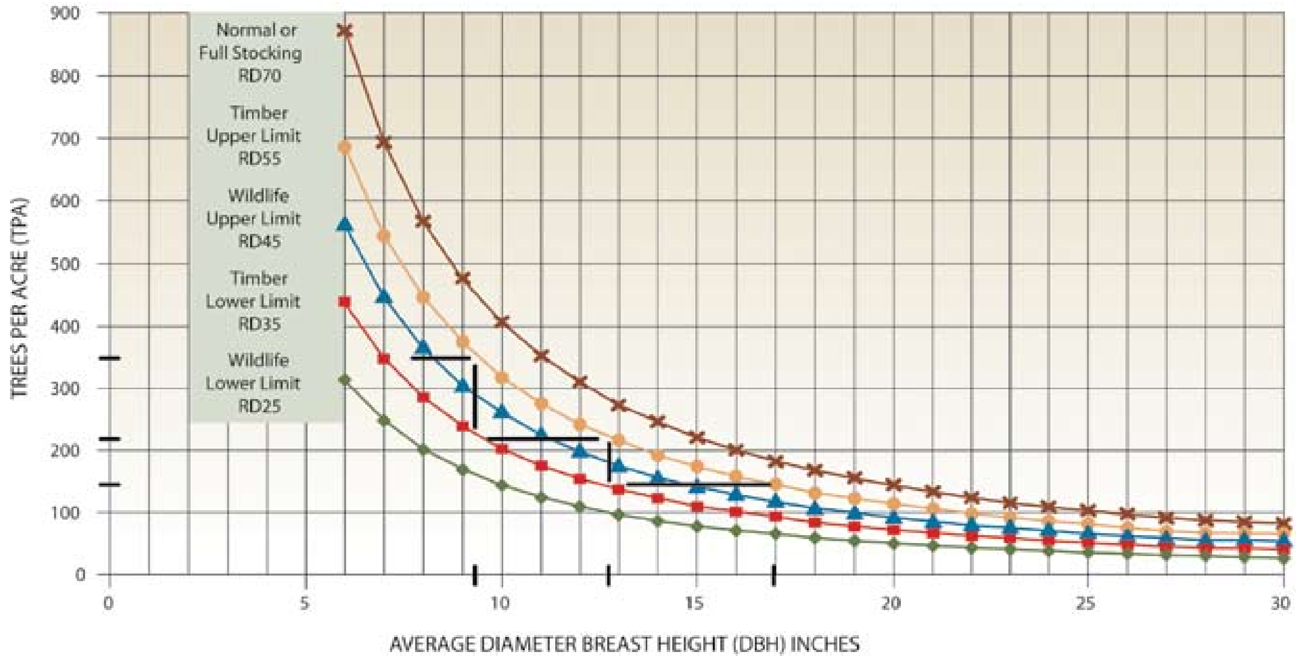


**Figure 10.** Stand density diagram for west side Douglas-fir, showing general guidelines for normal or full stocking, at a relative density of 70 (RD70); the upper timber limit, RD55; the upper wildlife limit, RD45; and the lower wildlife limit, RD25.

if the trees are too small to sell at about RD55. While this practice may result in some loss of growth, landowners may find the larger trees easier to sell. However, delaying thinning for too long, can create trees that will not respond as well in growth after thinning. For a "real world" check on using RD, also observe the live crown ratio of the overstory trees (the portion of total tree height mostly covered with green live branches or the living crown). Try to thin before average live crown ratio drops below about one third of total tree height.

As an exercise, apply the RD thinning guides in Figure 10 and Table 4 for west side Douglas-fir timber production for trees growing at about an 11-foot average spacing (355 TPA), a good spacing for early timber growth. Follow the dark line indicating about 355 TPA in Figure 10 right to the Timber Upper Limit and then down to the Timber Lower Limit. To maintain good growth, thinning should occur when average DBH is between 9 and 10 inches, with an average spacing of about 14 feet. From there following the dark line to the right indicates hypothetically that thinning could be repeated when trees average about 13 inches DBH and again at about 17 inches DBH.

In the real world, staying strictly within "timber" or "wildlife" guidelines or exactly following the dark line "stair step" can probably not be done, due to market needs, immediate shifts in average diameter caused by thinning from above or below, future tree death, or natural in-growth. In an actual forest stand, you can re-check your target leave tree TPA for a given RD using the estimated average size of the leave trees. Even if your primary goal is timber management, you will need to leave a requisite number of standing wildlife trees if clearcut.[55]

**Commercial Thinning for Wildlife**

Thinning to enhance understory shrub and herb growth for wildlife follows the same step-wise pattern as does thinning for timber. A landowner would consider thinning the example 355 TPA when they approached the Wildlife Upper Limit of RD45, or when they were 8 to 9 inches DBH. Potentially, the example 355 TPA would be thinned to the Wildlife Lower Limit of about RD25 (Figure 10), leaving about 200 TPA

[55] This is a requirement by Washington State Forest Practices Act. "Defective" trees retained for this purpose will have minimal monetary value, but can benefit wildlife if they are still alive at the time of clearcut.

**Table 4.** Thinning Guidelines for Wildlife and Timber Using the Concept of Relative Density

| | Wildlife Lower Limit RD25 | | Timber Lower Limit RD35 | | Wildlife Upper Limit RD45 | | Timber Upper Limit RD55 | |
|---|---|---|---|---|---|---|---|---|
| Avg. Leave Tree DBH (inches) | Trees/Acre (TPA) | Avg. Tree Spacing (feet) | TPA | Avg. Tree Spacing (feet) | TPA | Avg. Tree Spacing (feet) | TPA | Avg. Tree Spacing (feet) |
| 6 | 312 | 11 | 437 | 10 | 561 | 8 | 686 | 8 |
| 7 | 248 | 13 | 347 | 11 | 446 | 9 | 545 | 8 |
| 8 | 203 | 14 | 284 | 12 | 365 | 10 | 446 | 10 |
| 9 | 170 | 16 | 238 | 13 | 306 | 11 | 373 | 10 |
| 10 | 145 | 17 | 203 | 14 | 261 | 12 | 319 | 11 |
| 11 | 126 | 18 | 176 | 15 | 226 | 13 | 276 | 12 |
| 12 | 110 | 19 | 154 | 16 | 198 | 14 | 243 | 13 |
| 13 | 98 | 21 | 137 | 17 | 176 | 15 | 215 | 14 |
| 14 | 88 | 22 | 123 | 18 | 158 | 16 | 193 | 15 |
| 15 | 79 | 23 | 110 | 19 | 142 | 17 | 174 | 15 |
| 16 | 72 | 24 | 100 | 20 | 129 | 18 | 158 | 16 |
| 17 | 65 | 25 | 92 | 21 | 118 | 19 | 144 | 17 |
| 18 | 60 | 26 | 84 | 22 | 108 | 20 | 132 | 18 |
| 19 | 55 | 28 | 77 | 23 | 100 | 20 | 122 | 18 |
| 20 | 51 | 29 | 72 | 24 | 92 | 21 | 113 | 19 |
| 21 | 48 | 30 | 67 | 25 | 86 | 22 | 105 | 20 |
| 22 | 44 | 31 | 62 | 26 | 80 | 23 | 98 | 21 |
| 23 | 42 | 32 | 58 | 27 | 75 | 24 | 91 | 21 |

spaced on the average between 14 to 15 feet apart (Table 4). For wildlife habitat, this level of thinning corresponds to an "open canopy," ranging from about 10% to 39% cover. The leave trees could continue to grow to the Wildlife Upper Limit RD45, about a 12-inch diameter, before they would start crowding out understory plants.

To increase horizontal structural diversity, selectively apply commercial thinning as you would precommercial thinning, retaining wildlife trees as legacies, when possible. If your goal is to accelerate development of wildlife habitat found in late-successional forest structure, use repeated thinnings to create a mosaic of unthinned areas, timber- and wildlife-thinned areas, and small openings holding under-planted trees and shrubs. Retain wildlife trees and create snags and coarse woody debris during the thinning processes. A professional wildlife biologist can help determine a layout of snags, wildlife trees, and thinned, unthinned, and open areas benefiting wildlife. Work with your logger or consulting forester to ensure that this layout is compatible with the proposed logging system and is clearly identified for the logger. Crew safety around snags is important during commercial thinning. Leaving unthinned timber around snags is required in Washington and increases thinning crew safety.[56] Green tree windthrow is a concern, especially if your trees are tall and thin, with H/D ratios exceeding 80. Snags are generally more susceptible to breakage and windthrow than green trees (see sidebar).

[56] In some instances, birds prefer individual snags for nesting if they tend to be territorial. Secondary cavity nesters, such as owls, bats, and squirrels prefer individual snags along green tree edges. Conversely, clumped snags will benefit primary cavity nesters if the snags are among green trees. If the snag is used primarily for foraging, its arrangement among other snags is less important.

## Height-Diameter Ratios (H/D)

Windthrow and stem breakage may occur whether you are thinning for timber or wildlife. Trees at least risk for stem breakage have H/D ratios less than 60; trees at most risk for breakage or windthrow have H/D ratios greater than 80. The H/D ratio is total tree height divided by DBH (diameter at breast height is measured outside bark 4.5 feet above the ground on the uphill side of the tree). Thus, an 80-foot tall tree with a 12-inch DBH (one foot) has an H/D ratio of (80/1) or 80. High-risk locations are ridgelines, the upper third of leeward slopes, narrow valleys parallel to storm winds, or saddles or gaps in ridges perpendicular to winds. High-risk stand factors include exposeure of the sides of a stand to the southwest, excessively dense trees, root disease, shallow or poorly drained soils, or pit-and-mound micro-topography (indicating a history of windthrow). For high-risk trees and stands, consider avoiding commercial thinning; clear-cutting is likely the best option. For healthy stands with deeper soils on high-risk sites, you can reduce windthrow risk by leaving a stable windward edge 60 to 100 feet wide, and removing only 15% to 20% of the stems and leaving hardwoods. Inside the stand, create no openings larger than one-half dominant tree height, leave hardwoods, thin from below no more than 20% of the stand basal area, and remove all unstable trees or trees on unstable areas. Do not thin single-storied, high-density stands.

### *High Stumps or Short Snags?*

Create short snags by leaving stumps at least three feet tall on trees felled for timber.[57] This is an easy way to provide habitat for some snag-dependent cavity nesting birds, bats, and other mammals. Trees with excessive butt swell, sweep, rot, or other defects are excellent candidates. Locate high stumps where they will not interfere with logging operations or create logging safety hazards. Mechanical tree harvesters may be able to leave higher stumps more safely than hand felling; check with your logger.

### *Thinning in Red Alder*[58]

Thinning red alder is different than thinning conifers because the trees grow differently. Initial height growth of red alder is rapid,and usually more rapid than height growth of nearby conifers in the same time period. To make the most of alder's rapid juvenile growth, it is essential to avoid the early overcrowding that may occur.[59] On an average growing site, a 10-year-old tree may be 35 feet tall, and on the best sites, 50 feet tall. By age 25, the rate of height growth in red alder has slowed considerably to about half of what it was at age 10. Alder is short-lived; its growth pattern is initially very rapid but tapers off quickly, and alder reach about 80% of their lifetime height in the first 30 years. This initial height growth is what sets the length of the main stem (or log) in the tree (Figure 11). Thus, initial commercial thinning should be delayed until the bottom of the crown is at least 22 feet above the ground. Maintaining higher stand densities while the stand is young will reduce the amount of lower tree branches, resulting in clean, straight boles. Once thinning has started, it needs to be a repetitive process, implemented on a roughly a 10- to 15-year cycle, so that the crowns continue to expand and the trees continue to add inches to their stem diameters. When and how much to thin alder depends on factors such as current stand density, stand age, site quality, and competing vegetation. An appropriate spacing can be determined based on the average size of crop trees ("leave trees") in prospective thinning units (Table 5).

Lower densities (wider spacing) within the ranges in Table 5 may be appropriate on better quality sites. Higher densities may be more appropriate on lower quality sites, on sites with high levels of competing vegetation, or on sites with very crowded initial densities.

If you manage the forest floor vegetation for non-timber forest products, such as ferns or

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57 By common agreement, the general height of a usable snag is 10 feet. However, there is new evidence that cavity-seeking birds use very short snags (in the 3-foot range) when taller snags are not available.

58 From D.E. Hibbs, *Managing Red Alder*, Oregon State University EC1197, and Glenn R. Ahrens, *Improving Landowner Returns from Red Alder in the Pacific Northwest*, GBA Forestry, Inc. and the Western Hardwood Association.

59 Thus, adequate spacing at age 1 to 4 years is recommended in those natural stands that contain many hundreds or thousands of trees per acre. In this stage of development, thinning to uniform spacing to favor dominant trees is most important. This thinning can be avoided if you are managing a plantation with relatively uniform tree spacing and stocking, up to 540 trees per acre.

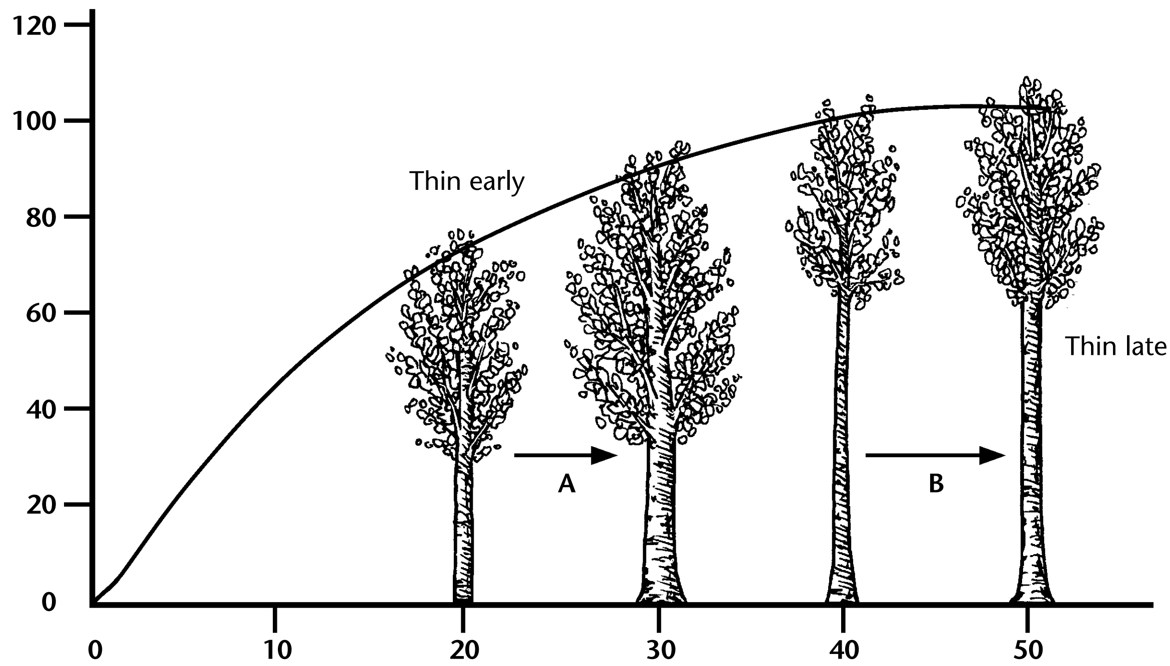



**Figure 11.** Red alder thinning response, showing that early thinnings (tree A) produce greater crown and diameter-growth effects tan later thinnings (tree B).

mushrooms, red alder stand density will need to be adjusted, and wood quality and growth potential will be impeded.

On those sites where unwanted exotic vegetation, such as reed canary grass (*Phalaris arundinacea*) is common, it is advisable to keep overstory alder densities at the high end of the range to help shade out the invading species. Additionally, very dense alder patches must be thinned down gradually due to the risk of sunscald, wind, and ice/snow breakage.

## Pruning

Pruning is the removal of a tree's lower branches. Pruning is commonly used to improve wood quality but may be applied to forest trees for a variety of additional reasons including: to increase financial returns from clear or select wood; to increase understory vegetation for wildlife habitat; to reduce fuel ladders[60]; to improve visual aesthetics; to reduce the incidence of blister rust in white pine; and to improve access within stands. When coupled with thinning, pruning reduces stand stagnation and improves structural diversity in the stand, resulting in improved access and wildlife forage.

Although pruning can be costly to implement, removing branches can convert what would be loose-knotted lumber having minimal stumpage value to clear material with very high value.[61] Pruning is usually implemented after a thinning, since thinning can stimulate the development of large branches and increase the number of knots in the wood. Pruning is applied to species that have rot-resistant branches, as wounds created during pruning can serve as infection courts for diseases. Common species pruned in Washington include Douglas-fir (for wood quality), western white pine (for disease control), western redcedar (for stand access and aesthetics), ponderosa pine (for fuel ladder reductions), and noble and grand fir (for bough materials).

[60] Fuel ladders are those branches near the ground that allow a low-intensity ground fire to jump to the tree crown, with dire consequences.

[61] There is currently no system in place to certify at the time of harvest that a stand was pruned years before. It is important for landowners to keep accurate notes (inventory data, dated photos, etc). as to when the pruning was accomplished, and thus be able to prove that the pruning was done. These notes will allow the landowner to capture the added value at harvest.

**Table 5.** Desired Red Alder Stand Density After Thinning, Based on Average Tree Diameter

| Average Diameter (inches) | Maximum Trees/Acre | Maximum Spacing (feet) | Minimum Trees/Acre | Minimum Spacing (feet) |
|---|---|---|---|---|
| 3 | 1300 | 5 | 760 | 7 |
| 4 | 850 | 7 | 470 | 9 |
| 5 | 570 | 8 | 310 | 11 |
| 6 | 450 | 9 | 250 | 13 |
| 7 | 330 | 11 | 190 | 15 |
| 8 | 280 | 12 | 160 | 16 |
| 9 | 230 | 13 | 130 | 18 |
| 10 | 200 | 14 | 110 | 19 |
| 12 | 150 | 15 | — | — |
| 15 | 110 | 17 | — | — |

For wood quality improvement, prune in "lifts," each about 8 feet high. In the first lift, remove lower branches up to 8 feet on a 20- to 24-foot tree. Prune about 130–150 trees per acre. In the second lift, remove lower branches up to 14–15 feet on a 26- to 32-foot tree. Prune about 115–130 trees per acre. In addition, on the third lift, remove lower branches up to 20 feet on a 36- to 40-foot tree. Prune about 105–120 trees per acre. Lifts are generally spaced in time every 5 years. Generally, *never* remove more than one third of the crown at any one time. For best wood-quality results, prune crop trees when they are small—about 4 inches DBH or the size of a tuna fish can (Figure 12). Conifer pruning is a simple technique. Be sure to cut off the branch just outside the branch collar adjacent to the main stem. Do not leave a stub! Avoid tearing the bark on the main stem as the branch falls. Bark tearing is minimized if you avoid pruning during the spring when the tree is actively growing (Figure 13). Coupled with thinning programs that promote and maintain rapid diameter growth, pruning can provide some of the greatest returns available in timber-production silviculture.

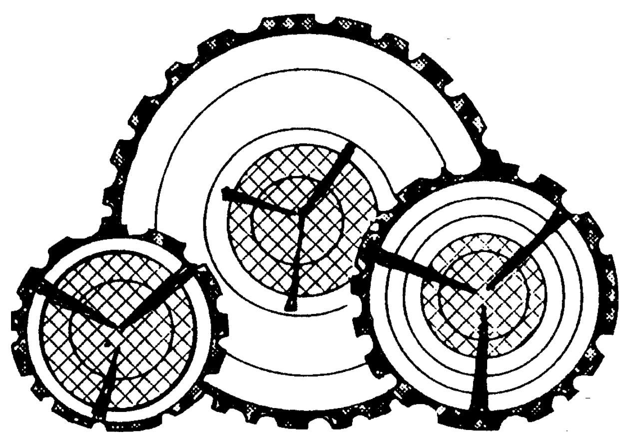


**Figure 12.** Proportion of 4-inch woody core for small- to larger-diameter trees. Early pruning, implemented when the tree is the size of a "tuna fish can," is a good plan if your objective is wood quality improvement.

From *Forest Pruning and Wood Quality of Western North American Conifers*, Hanley et al., 1995. Univ. of Washington, Seattle, WA.

### *Pruning White Pine for Disease Prevention*

Pruning the lower branches of western white pine, coupled with low thinning, is one of the best approaches to prevent the infection of the

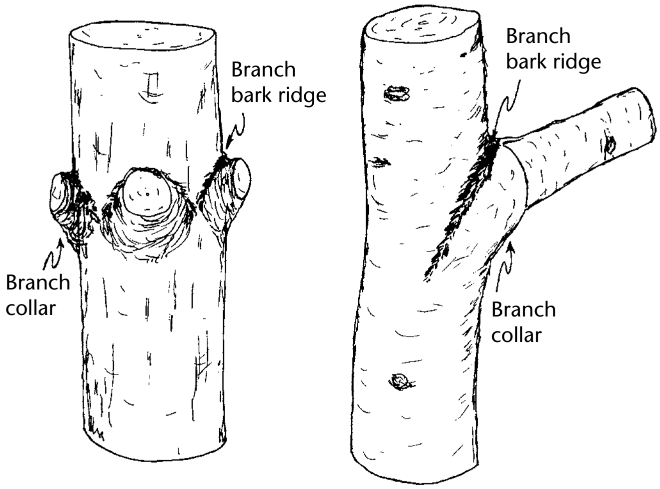



**Figure 13.** Conifer branches are pruned outside the branch collar. Cut from A to B. Do not leave a stub, as this will result in poor wood quality and an entry point for wood rotting fungi.

From *Forest Pruning and Wood Quality of Western North American Conifers*, Hanley et al., 1995. Univ. of Washington, Seattle, WA.

tree from white pine blister rust. This exotic fungus enters the needles on branches near the ground, travels down the branch (killing it as it goes), and can enter the main stem, killing the tree above that point. If the branch foliage has turned red, a condition called "flagged," prune it off between the branch canker and the main stem. We recommend that the pruning saw or clippers be sanitized between cuts with common household bleach. This prevention practice needs to be done prudently and periodically to be effective.

Pruning is a common practice used to gather holiday boughs and other greens. When pruning trees for this purpose, cut off branches at a larger branch or main stem. Avoid leaving a stub on the branch because this can serve as pathogen corridor. Avoid taking more than one third of the foliage off at any one time, to minimize the impact on tree vigor.

## Fertilizing

Owners of second-growth conifer forests might find forest fertilization an excellent way to increase timber production, provide improved wildlife habitat, improve general forest health, and increase financial return. Proper use of fertilization, along with other cultural techniques, such as thinning and pruning, can increase both the quality and quantity of wood grown during a normal rotation.

Forest fertilization is more than just a *growth enhancing* technique. Well-nourished trees are crucial to the health of forest ecosystems. Forest fertilization can improve wildlife habitat and aid in conservation goals.

Forest fertilization is a way of maintaining or enhancing nutrients normally available to healthy stands of trees. It is not a remedy for critical nutrient deficiencies caused by poor management practices. Rather, forest fertilization is a way of supplementing a normal forest's diet with nutrients to enhance growth. West side conifer stands are usually excellent candidates for fertilization. In fact, Pacific Northwest forest industries and agencies have long used forest fertilization to enhance the yield of both east side and west side second-growth Douglas-fir. Forest fertilization is an integral part of the management regime planned for many conifer plantations established today. However, fertilization remains a largely underutilized practice among family forest landowners.

Nitrogen is the element most commonly deficient in most forest soils, yet considerable nitrogen usually is present in the soil organic matter at these same sites. Nitrogen only becomes available to plants through the process of decomposition and mineralization. Mineralization is a natural process that converts organic forms of elements to inorganic forms that trees can absorb through their roots.

During growth periods, trees often require more nitrogen than is available in the soil. When this occurs, trees develop a deficient condition. Nitrogen deficiencies appear as a general "yellowing" of the needles, with reduced growth. Applying fertilizer gives trees a "shot" of readily available nutrients. Potassium deficiencies render trees more susceptible to disease and insect attack or death. The most culpable organisms for this mortality are root rots and bark beetles. Usually, these are Armillaria and Phellinus root rots (*Armillaria ostoyae* and *Phellinus weirii*) and western and mountain pine beetles (*Dendroctonus brevicomis* and *Dendroctonus ponderosae*).

Before you fertilize, evaluate your forest in the following five categories: species, stocking, overall forest health, stand age, and nutrient availability. On the west side, Douglas-fir stands are the most commonly fertilized and are also the stands that show the best responses to this practice. Generally, on poorer west side sites, responses will be greater than on high-quality sites. Expect the highest responses in healthy, young stands. Western hemlock stand responses have been inconclusive and inconsistent. In east side forests, ponderosa pine, Douglas-fir, grand fir, lodgepole pine, and western larch have all demonstrated nitrogen growth responses.

Foliage and soil analyses are useful tools in west side forests to help you determine which stands may be limited in either macro- (nitrogen, phosphorus, or potassium) or micronutrients (commonly sulfur or boron). These analytical techniques have not proven practical to assist with stand selection in east side forests. Foliar analysis serves as a site-specific tool for small acreages (usually less than an acre), unless the samples are systematically collected from your acreage. Microsite variability makes this analytical tool impractical for diverse, smaller ownerships. Site variability is influenced by slope and aspect. *We recommend using the Habitat Type series to identify stands for nitrogen fertilization in east side forests* (Figure 14).[62]

Nitrogen is the most common growth-limiting nutrient in even-aged stands. Response to nitrogen fertilization has been demonstrated in an extensive set of field trials on the east side. Geographic Subregions are used in conjunction with Habitat Types to determine high-priority stands to fertilize in east side forests (Figure 15).

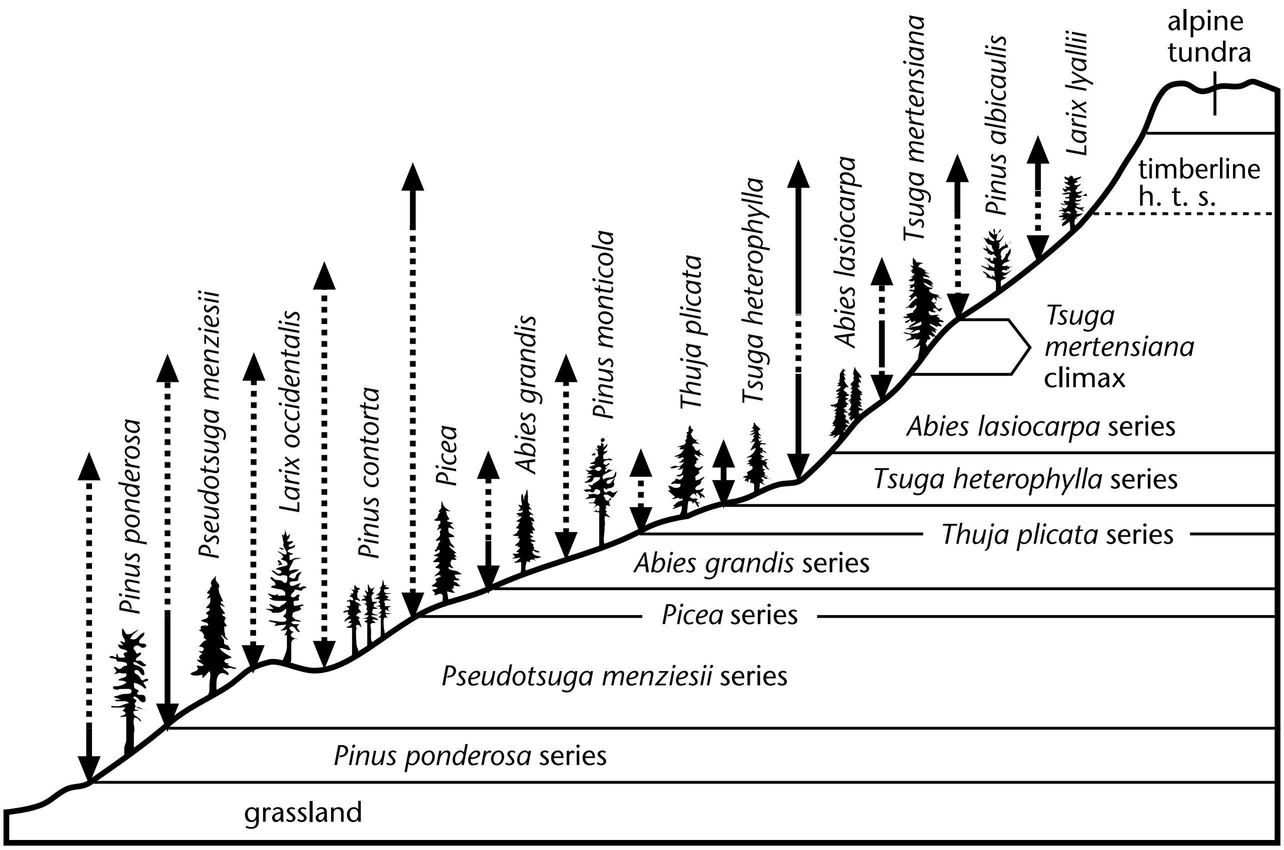



**Figure 14.** Habitat Type Series illustrating the relationship between potential vegetation and general elevation. Habitat Type Series is an important consideration when fertilizing stands in Eastern Washington.

[62] In some east side forests where potassium is deficient, the addition of only nitrogen has been shown to be detrimental. See *Fertilizing Eastern Washington Coniferous Forests* (WSU Extension bulletin EB1874) for additional information.

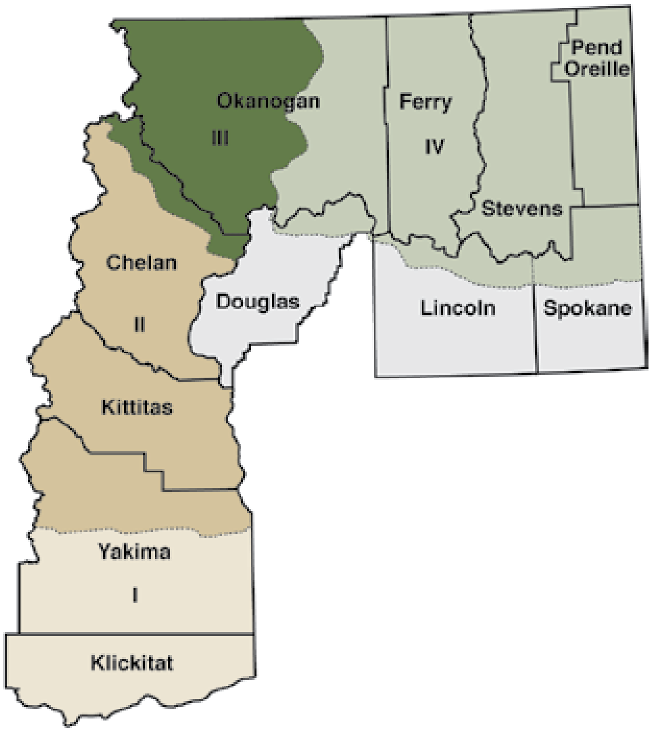



**Figure 15.** Geographic sub-regions are used in conjunction with Habitat Type Series to determine high priority stands to fertilize in eastern Washington.

After considering Geographic Subregion and Habitat Type series in deciding whether to apply nitrogen fertilizer, growers should also evaluate soil parent material.[63]

In general, expect maximum growth response in young thinned stands, since nutrient demand is highest at about the time of tree canopy closure. Fertilization at this stage of development can help achieve significant increases in growth rates and allows harvesting of a large number of stems of merchantable size in subsequent commercial thinnings. If you do not remove increased stand growth by subsequent thinning, tree mortality will reduce the growth gains considerably over time. Commercial thinning allows harvesting of merchantable volumes as well as encouraging larger, healthier residual trees. It also recovers the investment in fertilization in a shorter time, effectively increasing the financial return.

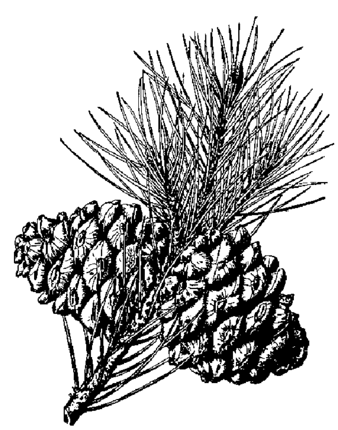
Fertilize within 10–15 years of the final harvest for two important reasons: first, money invested in fertilization is held for the shortest period before financial returns are realized; and second, the volume gain will occur on larger, higher value trees and can be captured in the final harvest.

Nitrogen is the element most commonly used as a fertilizer for second-growth coniferous forests. *In all forest fertilizer applications, on both east and west sides, nitrogen should be applied*. Nitrogen usually is applied as urea [$CO(NH_2)_2$]. Urea has 46% N content, higher than other nitrogen fertilizer formulations, which makes it more economical to apply.[64] When potassium (potash) is needed, it is often is applied as KCl (potassium chloride) in a mixture with urea. Potassium in the form of KCl has 52% K content.

Apply the fertilizer mixture in the rainy season—during late fall, winter, or early spring. Optimal conditions for application are cool, wet, windless weather with temperatures of 55°F or lower. Never apply nitrogen fertilizer in hot, dry, windy weather as volatilization can occur. In volatilization, fertilizer N is transformed into ammonia gas that dissipates into the atmosphere!

Fertilizer can be applied by hand over snow without problems. It melts through the snow cover (up to 18 inches) rapidly and dissolves into the soil. Do not apply fertilizer on bare frozen ground. These conditions inhibit movement of the chemicals into the soil profile and increase the likelihood that the fertilizer will migrate to streams and lakes.

The frequency of fertilizer application largely depends on the age of your stand and the length of the potential investment period. Response to a single nitrogen application can last up to eight years on the west side and up to five years on the better east side sites.



[63] See *Fertilizing Eastern Washington Coniferous Forests* (EB1874) for additional information.

[64] If 200 lbs of nitrogen are to be applied, it would take approximately 400 lbs of urea to supply this since urea is approximately half nitrogen. Applying 400 lbs of a granular substance over an acre is expensive, difficult, and time consuming. If possible, tying into an industrial project that is using helicopters as a subcontracter will save you time and money.

# Desired Future Conditions—How to Forecast the Future

What are your wishes regarding your forest in the future? What do you want it to look like in 10, 25, or even 50 years from now? Determining desired future condition is one of the hardest tasks in silviculture, *and one of the most important*. Simply stated, the manipulations you apply to your stands today may very well set the course of development into the future. Should you thin now, wait ten years, or not thin at all? Should you harvest now or in ten years? Do insects or disease influence your stands, and how do these factors influence your future management strategies? These are all commonly asked questions. In the past, guesses about future stand conditions were achieved by trial and error, and just plain, old-fashioned experience and ecosystem knowledge. Now we use computers to "grow" stands into the future, based on any number of silvicultural alternatives. Growth and yield models have fundamentally changed the way silvicultural decisions are made because we can generate stand statistics and stand visualizations well into the future. These computer tools allow us to play "what if?" games, before we decide on a silvicultural pathway. Two prominent public models are used in this region, ORGANON and the Forest Vegetation Simulator (FVS).[65] ORGANON is an individual tree growth model developed for southwest Oregon, northwest Oregon and the lands of the Stand Management Cooperative (including western Washington). It will project stand development for several species mixes, stand structures, and management activities. The Forest Vegetation Simulator (FVS) is the USDA Forest Service's nationally-supported framework for forest growth and yield modeling.

With many models already available, and because it is sometimes difficult to use the correct model, forest scientist technologists at the College of Forest Resources at the University of Washington, have developed an interface that makes using most of these computer models more user-friendly. This interface is called the *Landscape Management System*.

## Landscape Management System

The Landscape Management System (LMS) is an evolving set of software tools *designed to aid in forest management planning and education at the stand and landscape level. It is not a substitute for ecosystem knowledge and experience, but works with these to help you make decisions*. LMS is not a decision-making software package. LMS is a computerized system that integrates landscape-level spatial information, stand-level inventory information, and individual tree growth models to project changes through time across forested landscapes. LMS coordinates the execution and information flow between many different computer programs (more than 50). These programs: format, classify, summarize, and export information; project tree growth and snag decay; manipulate stand inventories; and present stand and landscape level visualization and graphics (Figure 16). Stand projection in LMS is accomplished by the use of external growth models, such as ORGANON and FVS.

LMS uses the Stand Visualization System, developed by the USDA Forest Service, to produce graphic visualization of forest stands. For example, stand visualization can be used to display silvicultural alternatives over time. Many figures presented in this bulletin were generated using this stand visualization system. Stand treatments may include: thinning to target basal areas, stand density index, and trees per acre; treatment from above, below, or proportionally; with species selection (include or exclude), diameter limits, and new tree growth from planting or natural regeneration. Projected inventory information can be presented to the user via various tables linked to Microsoft Excel. Tables can be viewed in a text editor, spreadsheet, or saved to a file for subsequent analysis.

Landscape visualization on larger land parcels comprised of many stands is accomplished through links to EnVision, a program developed by the USDA Forest Service that drapes forest inventory information across a three-dimensional digital elevation model. Landscape visualization has been used to develop visual backdrop alternatives and green up sequences (Figure 17).

[65] Other models are also available: 1) FPS (Forest Projection System) from Forest Biometrics (www.forestbiometrics.com)—software for forest inventory, growth projection, silvicultural planning, and long-term harvest scheduling; 2) SPS (Stand Projection System) from Mason, Bruce & Girard (www.masonbruce.com), applied to over 20 species in six western states and three Canadian provinces; and 3) TASS (Tree and Stand Simulator) from British Columbia Ministry of Forests is a growth simulator that generates growth and yield information for even-aged stands of pure coniferous species in coastal and interior forests of British Columbia.

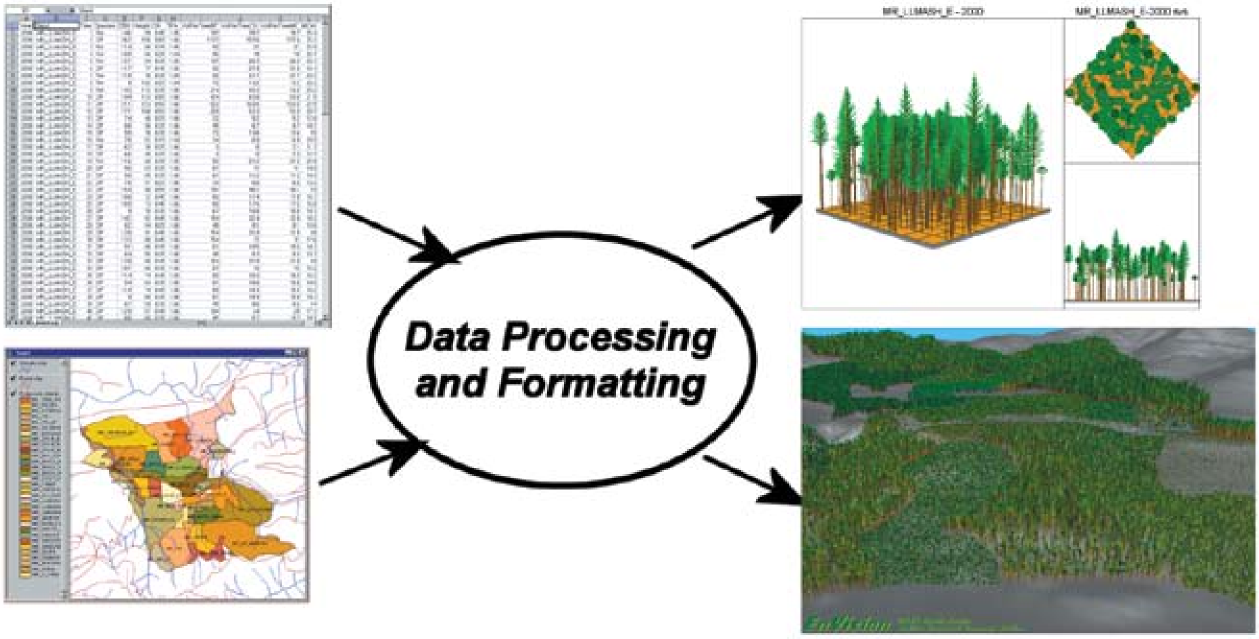



**Figure 16.** Schematic diagraph of the inputs and outputs from the Landscape Management System (LMS). Examples of stand and landscape visualization using tree inventory information. Stand visualization is created using the Stand Visualization System (WinSVS) developed by the USDA Forest Service. Landscape visualization is created using EnVision, Environmental Visualization Software also developed by the USDA Forest Service.

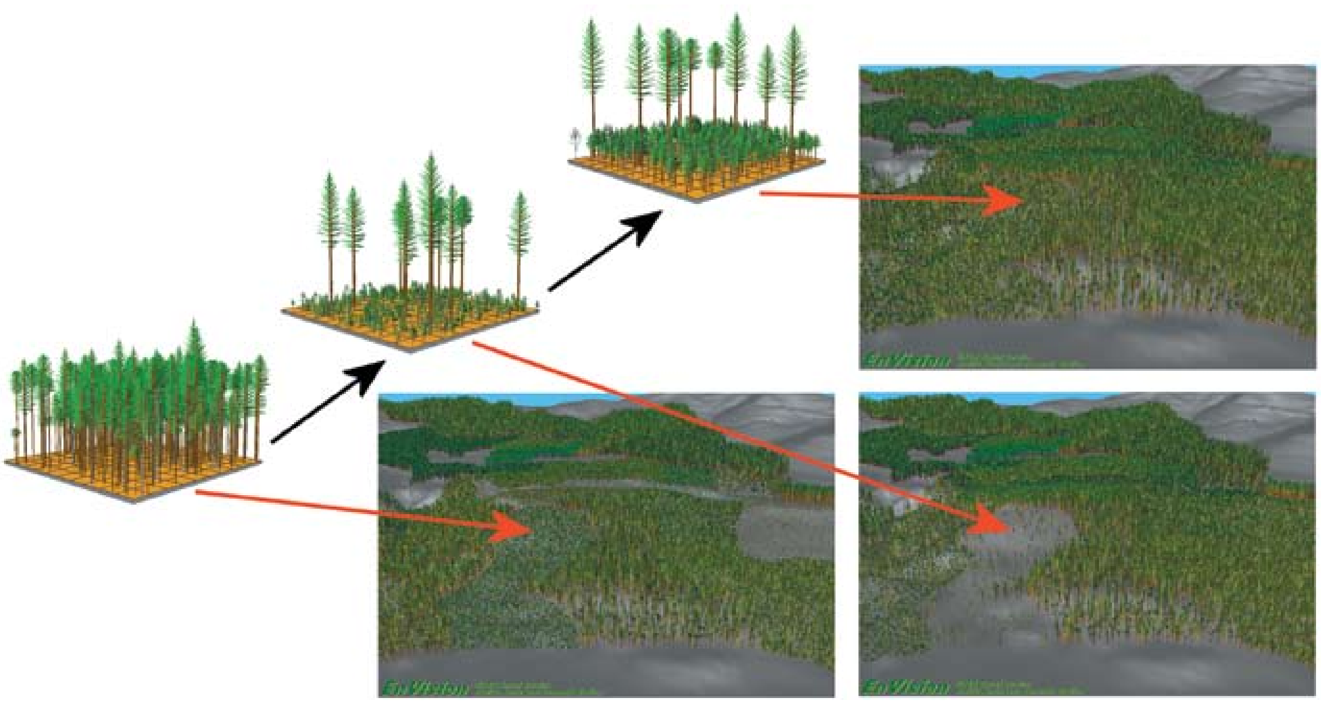


**Figure 17.** Example of landscape visualization showing the development of one stand after implementation of a lightly cut shelterwood, through time. Visualizations like this may help you plan harvests in sensitive viewing areas.

To explore Landscape Management System, set your web browser to: http://lms.cfr.washington.edu/. This website includes tutorials, downloadable software, examples, training updates, and contact information for the scientists who developed the program.

LMS may be difficult for novice computer users. Further refinement has brought about Inventory Wizard, a software program that greatly simplifies the tree and stand input processes in LMS. It is available at the same website listed above. Many private consulting foresters as well as Washington DNR Stewardship Foresters have been trained in the LMS system. They will be able to help you with this sophisticated and very accurate software. Once you master it, you will find it an indispensable aid in your quest to achieve silvicultural objectives.

## Silvicultural Application Examples

Among its many applications, silviculture can be used to protect forests against damage or destruction from insects, diseases, and fires. Prescriptions to maintain healthy forests might include thinning to reduce stocking levels, or to remove unhealthy individuals or susceptible species from a stand. The species composition of a stand and its structure can also be adjusted to minimize damage from wildfires.

### Protecting Lodgepole and Ponderosa Pines from the Mountain Pine Beetle

The mountain pine beetle (MPB) is the most destructive bark beetle in the west. Dense stands of mature lodgepole and ponderosa pine are especially susceptible. Mountain pine beetles are a natural part of western ecosystems, and for this reason will never be eradicated (nor should they be, as they serve to create small stand openings that support biodiversity of both flora and fauna). The death of a few trees on your property doesn't necessarily mean an epidemic is getting started. However, a high-risk lodgepole pine stand is one with an average age of more than 80 years and an average tree DBH of more than 8 inches. A high-risk ponderosa pine stand has a high stand basal area (over 100 sq. ft.), and an average tree DBH of 10 inches. In July and August (when trees are most likely to be under stress from water deficiency), adult beetles emerge. Females find a new host tree and bore through the bark to the phloem (just under the bark). There, they emit pheromones that attract males and other females. The other females that are attracted will also colonize the tree; this "mass attack" strategy overcomes the tree's defenses. Essentially, the success or failure of bark beetle attack is primarily influenced by the physiological condition of the tree. Healthy, vigorous trees are able to overwhelm attacking beetles with pitch, while trees that have been stressed may not have the available resources for massive pitch production. During outbreak conditions, however, sheer numbers may simply overwhelm an otherwise healthy tree.

To sanitize a stand, it is best to keep the stocking level low, so that the trees do not compete for light, nutrients, or soil water. Tree vigor will decline and beetle susceptibility will increase if any of these resources becomes limited. More importantly, thinning stands before crown closure—an operation that not only increases the vigor of the residual stand, but also slows the spread of an outbreak if individual trees have been attacked—can help prevent infestations. This healthier condition is more productive for traditional silvicultural goals, as well.

*Once a mountain pine beetle outbreak begins to spread in lodgepole pine*, thinning the stand ahead of the edge of the outbreak can minimize it. This stoppage is possible because outbreaks expand on a tree-to-tree basis; the incoming beetles switch their attacks from a recently attacked-stem to the *next largest tree*. The distance that beetles will travel from an attack or *focus tree* is directly proportional to the DBH of the nearby trees. If the distance to the next larger tree is too great, the mass attacks or spread of the infestation dies out. This relationship is expressed in Table 6. For example, if the average tree diameter (DBH) is 11 inches, then thinning trees to a minimum spacing of 18 feet will stop the outbreak from expanding.[66]

In ponderosa pine stands, a traditional low thinning (the smaller least-vigorous trees of the stand are removed) will result in overall

[66] From R. L. Edmonds, et. al. 2000. Forest Health and Protection. McGraw-Hill Higher Education. 630 p.

**Table 6.** **Minimum Spacing After Thinning to Stop an Expanding Outbreak of Mountain Pine Beetle in Lodgepole Pine**

| Average DBH (inches) | Minimum Spacing After Thinning (feet) |
|---|---|
| 8 | 7 |
| 9 | 9 |
| 10 | 14 |
| 11 | 18 |
| 12 | 21 |
| 13 | 27 |
| 14 | 32 |

increases in vigor for the remaining trees, and thus reduce successful attacks by the beetle. Spacing of leave trees should be at least 13 feet. All competing Douglas-fir and grand fir should be removed in the thinning.

In general, silvicultural prescriptions can be used to both sanitize before a MPB attack and to mitigate the impact after an attack starts. These approaches differ by stand species; see Table 7 for silvicultural guidelines. The *Ips* bark beetle, which builds up in slash and then moves into green trees, may exacerbate the MPB problem. Treatment of the thinning slash is mandatory. Generally, slash is piled and burned or lopped and scattered.

### *Reducing the Spread of Laminated Root Rot in West Side Douglas-fir*

Laminated root rot (*Phellinus weirii*), is the most serious forest disease in western North America. It affects almost all commercially-important conifer species in Washington. A fungus that can persist in the soil for 50 years or more causes laminated root rot. Douglas-fir, Pacific silver fir, and grand fir are most susceptible to infection. Lodgepole pine, western white pine, ponderosa pine, and western redcedar are tolerant or resistant to the disease. Hardwoods, such as red alder, big leaf maple, and black cottonwood are immune. A silvicultural prescription for treating a west side Douglas-fir stand in which laminated root disease exists could include removing susceptible species within 50 feet of all disease pockets and replanting with western redcedar or red alder. In extreme cases, stump removal may be used to disrupt root-to-root contact.

### *Reducing the Spread of Root Diseases East of the Cascades*

A lot of wood is lost to root diseases in the interior Douglas-fir and grand fir forest types each year. Annual loss is increasing because fire suppression has allowed the establishment and growth of Douglas-fir and grand fir in areas that previously supported stands of ponderosa pine and western larch.

Silvicultural prescriptions to reduce the incidence and spread of annosus root disease (*Heterobasidion annosum*), laminated root rot, and armillaria root disease (*Armillaria ostoyae*), could include the following: 1) patch clearcut the stand and replant with resistant species such as ponderosa pine, rust-resistant white pine, or western larch; 2) harvest with the group selection method within root disease pockets, and leave all resistant species within pockets, cutting all susceptible trees (true firs and Douglas-fir) within 50 feet of any infected tree; 3) thin the stand, removing all infected trees and the most susceptible trees, and leave resistant species.

### *Reducing the Threat of Catastrophic Fires in the Inland West*

Fire suppression and high-grading have changed the structure and composition of many forests in the Inland West. Ponderosa pine and larch, species with thick bark that insulates from effects of low- and moderate-severity fires, were preferentially harvested. Suppressing fires allowed more shade-tolerant seedlings of Douglas-fir and grand fir to establish and grow.[67] Even low-severity ground fires usually kill seedlings of these species. Some silvicultural prescriptions to reduce the threat of catastrophic fires in a multi-storied, mixed species stand on a dry site might include: 1) removing grand fir and all but a few dominant Douglas-firs; 2) planting ponderosa

[67] Douglas-fir is considered an intermediate shade-tolerant species in east side forests and a shade-intolerant species in west side forests.

**Table 7.** **Generalized Mountain Pine Beetle (MPB) Sanitation and Salvage Treatments using Silvicultural Approaches for Lodgepole and Ponderosa Pine Stands**

*Robert Gara, Ph.D. (personal communication) provided information presented in this table.*

| Objective | Lodgepole Pine Stands | Ponderosa Pine Stands |
|---|---|---|
| **Sanitation**<br><br>***(before MPB attacks)*** | Use small patch cuts and thinning from below to increase beetle dispersal (the distance that a beetle must fly to move from one tree to the next). Reduce rotation ages to less than 80 years. Harvest all "focus-attack trees" and thin adjacent trees from below to a spacing of at least 15 feet. Mountain pine beetle outbreaks are mitigated if the distance between suitable host trees is in the range of 12–20 feet.<br><br>Remove diseased and unhealthy trees while thinning from below. Minimize damage to remaining trees.<br><br>Pile and burn slash or lop and scatter in the sun to reduce the possibility that Ips beetles will attack and augment tree vigor reductions. | Thin from below to remove low-vigor trees from the stand, which will result in increased tree vigor for the remaining trees. Stocking levels should be less than 200 trees per acre, with average spacing of at least 15 feet. High-vigor ponderosa pine will be able to resist mountain pine beetle attack. Remove diseased and unhealthy trees and logging debris, and minimize damage to standing trees.<br><br>Pile and burn slash or lop and scatter in the sun to reduce the possibility that Ips beetles will attack and augment tree vigor reductions.<br><br>Reduce Douglas-fir and grand fir competition by thinning them out. |
| **Salvage/ mitigation**<br><br>***(during an MPB outbreak)*** | Harvest trees in a way that mimics natural processes, such as cutting small patches to mimic a low-intensity fire. In addition, thin the adjacent stands *from above* to remove the *largest trees* in the stand, *which are within the spacing criteria as illustrated in Table 6*. This approach will reduce the number of "attack-candidate" trees within the stand that possess suitable phloem thickness, and that are close to the initial-attack or focus tree. In a few years, if the stand continues to loose vigor after this treatment, you may wish to consider stand replacement.<br><br>Pile and burn slash or lop and scatter in the sun to reduce the possibility that Ips beetles will attack and augment tree vigor reductions. | Harvest trees in a way that mimics natural processes, such as cutting small patches to mimic a low-intensity fire. Thin stand from below to a spacing of at least 15 feet between trees. Increase overall stand vigor by removing competing Douglas-fir and grand fir, if they are found in the lower crown-classes.<br><br>Pile and burn slash or lop and scatter in the sun to reduce the possibility that *Ips* beetles will attack and augment tree vigor reductions. |

pine seedlings; and 3) initiating periodic underburning to reduce fuel buildup and eliminate regeneration of grand fir and Douglas-fir. The overall goal should be to achieve a single-canopy stand dominated by ponderosa pine.

### *Silvopasture Management (Forest/Livestock Grazing)*

Silvopasture management is an agroforestry practice that integrates the management of forest stands, forage, and livestock. Silvopasture results when forage is deliberately introduced or enhanced in a timber production system, and the timber and pasture are managed as a single integrated system. Quite often, forestland grazing is thought of as a silvopastural enterprise. However, since the timber, forage, and livestock may not be managed as an integral unit, it is technically not silvopasture. Comprehensive land utilization in silvopastural systems provides a relatively constant income from livestock sales and selective sales of trees and timber products. Well-managed forage production provides improved nutrition for livestock growth and production. Potential products of the tree component include: sawtimber, veneer logs, pulpwood, firewood, posts and poles, organic mulches, and other secondary products.

Silvopastural systems are designed to produce a high-value timber component, while providing short-term cash flow from the livestock component. Overall, silvopasture stands can provide economic returns while creating a sustainable system with many environmental benefits. Well-managed silvopasture stands offer a diversified marketing opportunity (Figure 18).

In theory, integrating trees, forage, and livestock creates a land management system that produces marketable products while maintaining long-term productivity, as mentioned above.

**Figure 18.** Silvopastural system utilizes concurrent management opportunities from forestry and grazing simultaneously.

Economic risk is reduced because the system produces multiple products, most of which have an established market. Production costs are reduced, and distributing management costs between timber and livestock components enhances marketing flexibility. Theory is fine, but it is not so easy to apply this theory to the land. Silvopasture is intensive management and requires almost daily diligence. Too commonly, an extensive management scenario involving livestock and trees often results in the death of the trees in short order.

Actually, where trees and forage are both planted and managed from bare ground, silvopasture is very rare. Grazing by livestock in a forested setting is more common, especially east of the Cascades. On drier sites, ponderosa pine stands are well suited for silvopastures because they can adapt to diverse growing conditions, respond rapidly to intensive management, such as fertilization and thinning, and permit light to reach the forest floor. Remember to select and use tree and grass or forbs species and planting/harvesting patterns that are suitable for the site.

The forage component should be a perennial crop that is: 1) suitable for livestock grazing; 2) compatible with the site; 3) productive under partial shade and moisture stress; and 4) responsive to intensive management and heavy utilization.

Livestock grazing must be intensively managed. Potential livestock choices may include cattle, sheep, llamas, mules, and horses. A successful silvopasture requires understanding forage growth characteristics and managing the timing and duration of grazing to avoid browsing of young tree seedlings or elongating shoots. Livestock should be excluded from tree plantations during the spring when tree bark and buds are vulnerable to browsing or trampling injury. Improper management of silvopasture can reduce desirable woody and herbaceous plants through over-grazing and soil compaction. Large, established trees can suffer root damage and reduced vigor from over-grazing. Thus, proper animal and tree management is the key to success. Under an ideal system, tree growth can be enhanced by harvesting the grasses and forbs that otherwise would compete with the trees for moisture and nutrients. In these situations, the livestock can increase both short-term and long-term profitability by allowing both agricultural and forestry practices to be implemented at the same time.

The selected livestock system must be compatible with tree, forage, environment, and land use regulations. In general, browsing animals such as sheep and goats are more likely to eat trees. Large grazing animals such as cattle are more likely to step on young trees. Younger livestock are more prone to damage trees than

## Creating a Silvopasture

### *Existing Forest Stands*

Potential practices needed to implement silvopasture on existing forest stands include but are not limited to:

- **Forest Stand Improvement—**The goal should be to reduce stand density and allow about half the light to reach the ground.
- **Forage Planting—**The goal should be to establish the desired grasses and forbs for livestock and wildlife.
- **Fencing—**Install interior power fencing for management of a rotational grazing system.
- **Livestock Watering Facilities—**Proper placement will help distribute grazing activity.
- **Prescribed Grazing—**The goal should be to maintain or improve the plant community, as well as the quantity and quality of the forage, to maintain soil condition, and protect the trees.

From USDA National Agroforestry Center Note 18: From Pine Forest to A Silvopasture System. April 2000.

### *Existing Open Pasture*

Potential practices needed to implement silvopasture on existing open pasture include but are not limited to:

- **Site Preparation—**The goal should be to reduce competition between the existing grass and the newly planted trees.
- **Tree Establishment—**Plant the desired trees in the appropriate configuration and control competition.
- **Use Exclusion—**Defer grazing to allow trees to grow above heights where their terminal growth is not susceptible to livestock damage.
- **Forage Planting—**Establish desired grasses and forbs for livestock and wildlife.
- **Fencing—**Install interior power fencing for management of a rotational grazing system.
- **Livestock Watering Facilities—**Proper placement will help to distribute grazing activity.
- **Prescribed Grazing—**The goal should be to maintain or improve the plant community, as well as the quantity and quality of the forage, to maintain soil condition, and protect the trees.

From USDA National Agroforestry Center Note 22: From A Pasture to A Silvopasture System. December 2000.

are older, more experienced animals. When grazing tree seedlings by livestock does occur, it can be a learned response, passed on to the offspring by the mother. In this situation, the parent and offspring offenders need to be removed from areas with silvopasture applications.

Due to the extreme variability of potential silvopastural applications and responses, we recommend that you contact the USDA Natural Resources Conservation Service for information about specific sites. This agency is an excellent source of local technical assistance.

# The Value of Good Silviculture to Special Forest Products (SFP)

A dynamic and ever changing forest provides a multitude of opportunities for a wide variety of plants to establish and multiply. When there is plant diversity within the forest there is a great opportunity of obtaining periodic or annual financial value from special forest products, for personal use or commercial gain. Is there any greater satisfaction from land ownership than picking *and eating* huckleberries during a family visit to the forest? Since it's hard to find information about sustaining *specific* SFP species in *specific* stands, it's best to aim for obtaining the greatest plant diversity within the forest by thinning and pruning to allow sunlight onto the forest floor. Thinning should be irregular here; that is, both low and high techniques may need to be used. We just do not know enough about the ecosystem conditions favorable for the reproduction of many SFP, such as mushrooms, ferns, and lichens, to be more specific in our recommendations.

As a forest goes through its life cycle, the plant community that supports special forest products changes. Sun-loving plants (shade-intolerant) thrive in the conditions that occur after a timber harvest or other disturbance, as more light reaches the forest floor. These plants can thrive until the canopy starts to close with new trees. Many forest floor plant communities can be maintained as long as they receive at least eight hours of filtered sunlight each day. As the sunlight becomes more defused, these plants will loose vigor and be replaced by more shade-tolerant species. Many ferns will be common in closed-canopy conditions.

Maintaining an open stand structure (savanna-like) environment dominated by deciduous trees, such as Oregon white oak and bigleaf maple, will favor shade-intolerant plants. By periodically thinning and pruning the overstory, the landowner will create the growing conditions necessary to maintain wild grasses, blackberries, beargrass, fireweed, clovers, roses, salmonberry, red-osier dogwood, scotch broom, oceanspray, thimbleberry, and Saskatoon and black raspberries. As the growing conditions change to more consistency of soil and air temperatures, moisture, and light levels, a change in the plant community also occurs. More mesic conditions such as these favor salal, evergreen huckleberry, sword fern, red huckleberry, Indian plum, rhododendron, tree moss, and lichens. Even with a closed canopy, the landowner must insure that enough diffuse light is getting to the forest floor to enable these plants to grow, flower, and fruit. If the overstory is stocked to a point where the shrub community occupies less than 40% of the forest floor area, it is time to initiate thinning and pruning to maintain a healthy sustainable understory community.

The proper use of thinning, pruning, and harvesting techniques will enable a forest landowner to manage their forest for special forest products throughout the life of the forest. All thinning scenarios that have been designed to optimize tree growth also result in increased understory shrub growth.[68]

Achieving sustained yields of special forest products takes planning and silvicultural skill. The landowners that have plans to incorporate special forest products into all their forest and not just one stand will find that harvest of these products is more sustainable as one site becomes too shaded or too sunny, and other sites take their place in production.

## Forest Rehabilitation

Rehabiliation is relative in regard to silvicultural practices. Rehabilitation depend on your objectives and the condition of the exiting forest. A perceptive landowner once told a group of inexperienced colleagues that he started implementing forestry practices on his land when he realized that his "brush patch" would remain a brush patch until he did something about it. In this instance, he initiated a weeding to eliminate unwanted vegetation, which allowed his planted conifers to reach their full growth potential. In a different scenario, if his primary objective for land ownership was to observe migratory songbirds, he might leave some of the shrubbery to provide hiding cover and food mast. Rehabilitation questions arise and new scenario pathways are commonly initiated when land ownership changes.

Rehabilitation is general applied in stands that are overgrown with shrubbery, as in the example above; that are over-stocked and in need of thinning; or that have been previously harvested with little regard to tree spacing, quality, species, or health. Therefore, the first step with any rehabilitation strategy is to inventory your stand conditions and determine what actions are necessary to speed up or slow down forest succession, allowing you to achieve your goals. Often, initial rehabilitation activities address dangerous situation, such as leaning and other hazard trees, those that are infected with disease (especially root rot), and other health issues often associated with late-successional species, such as grand fir and western hemlock.

## Restoration in Ponderosa Pine Forest Types[69]

In their book, *Mimicking Nature's Fire, Restoring Fire-Prone Forests in the West* (Stephen Arno and Carl Fiedler, 2005, Island Press, Washington, D.C.), the authors present an emerging strategy that recognizes the essential role of fire and make recommendations by individual forest types. Arno and Fiedler define *restoration forestry* as the application of treatments to approximate historical [stand] structure and ecological

[68] Care must be taken to insure that the tree canopy is not opened up too much. As a general rule, if the forest floor receives over four hours of direct sunlight (especially during the early afternoon), the shade tolerant plants will lose leaves, turn brown, and become susceptible to disease, rendering them useless for commercial or ornamental purposes.

[69] The advice given here is relatively new and generally untried in Washington state; however, it has been used in similar forest types throughout the west with good results.

process in tree communities that for centuries were shaped by distinctive patterns of fire. The intent is not to re-create a single, distinct *historical condition*, but rather a range of conditions approximating historical forests.

We feel that their approach is justified and may be worth trying in Washington, primarily for the mixed conifer and ponderosa pine forests. In the latter, for example, Arno and Fiedler advocate improvement or selection cuttings that remove larger shade-tolerant grand firs, reducing tree density to approximately 50 square-feet basal area to induce regeneration of shade-tolerant pine and larch. The key to these treatments is that the selection harvesting prescription is concentrated on the larger grand fir and Douglas-fir *as well as removal of these species from throughout the diameter distribution range on the site*. This initial cutting treatment will make progress toward a sustainable multi-aged structure featuring large pines and probably larch. This cutting treatment will remove excessive fuels or augment existing fuels *to facilitate controlled under burning*. Controlled under burning kills small firs and stimulates forage plants, to improve wildlife habitat and reduce fuel loadings caused by years of fire exclusion. While many family forest landowners are not interested in introducing fire back into their ecosystems, under controlled and periodic applications, low ground firers can help protect the forest from uncontrolled stand-replacement fires. *We strongly recommend that you seek the advice of a forester or wildlife biologist before starting any rehabilitation program, especially those using fire as a silvicultural tool since rehabilitation efforts are general site specific.*

## Intensive Culture of Hybrid Poplar Clones

Hybrid poplar culture continues to be of interest to agricultural and forestland owners. In western Washington, it has been found that poplar culture for intensive fiber production is commonly not suitable for most upland forest sites unless the site has been severely disturbed. Wet sites, and those adjacent to or previously used in agricultural enterprises, are common candidates. Also, poplar clones are used for *phytoremediation* purposes—the trees chemically mitigate polluted sites. Poplar also has the ability to mitigate waste-water from industrial and agricultural sites when planted in a buffer (Figure 19).

Poplar is a general term for trees in the genus *Populus*, including cottonwoods and aspen.

**Figure 19.** Short rotation silviculture using hybrid poplars is more similar to some agricultural systems than to most traditional forestry methods.

Hybrids are produced when different species, usually within the same genus, are cross-fertilized. This can occur naturally or through purposeful plant breeding. Hybrids often grow more rapidly than either parent and are more tolerant of environmental extremes, making them good candidates for short-rotation silviculture. Once these hybrids are produced, cuttings are taken for out planting. These cuttings are called clones, as they have the identical genetic makeup of the parent tree. The three most important rules for successful short-rotation silviculture using hybrid poplars are: 1) plant hardy, disease-resistant clones; 2) plant clones in good, valley bottom soil—most nonalluvial (hill) soils will not give satisfactory yields; and 3) control competing vegetation. Planting hybrid poplars involves obtaining cuttings from a desired clone. These cuttings are generally one-year-old shoots from plants grown specifically for planting stock. Cuttings are planted vertically in well-prepared soil, and roots generally form rapidly. Mechanical cultivation and herbicides are used to control weeds that compete with the trees.

Short rotation silviculture using hybrid poplars is more similar to some agricultural systems than to most traditional forestry methods. If you are interested in establishing poplar culture, read the reference materials suggested in the Further Reading Section.

## Working with Foresters and Loggers

Loggers can influence the outcome of silvicultural treatments in many ways. Good communication is essential between landowners, the forester who develops the prescription, and the logger who implements those prescriptions. Communication failures can lead to silvicultural failures. Loggers should ask foresters and landowners questions so that they have a clear understanding of the objectives behind treatments they are asked to implement. Loggers also possess basic knowledge of ecology and silviculture. The success or failure of a prescription is the combined responsibility of the forester, the landowner, and the logger.

Throughout the Pacific Northwest, logger education is common. In Washington, over 1,000 loggers have attended basic ecological and silvicultural educational programs to increase their knowledge about ecosystems.[70]

Since landowners will "live with the results" of any harvest operation, they must express their expectations to a logger clearly and in understandable terms. Consultant foresters may be of immense help in this regard.

## Rules and Regulations

Lawmakers in Washington have passed numerous rules and regulations over the years with the intent of improving or protecting habitats for natural resources, mainly wildlife, fish, water, and air. These regulations are significant and complex as they relate to silvicultural operations, especially in riparian areas. Prior to implementing any significant silvicultural activity, such as harvesting or thinning, it is strongly suggested that you contact the Washington Department of Natural Resources (DNR) regarding the latest rules and regulations. In most cases, a regulatory forester from DNR will meet with you on site to help you (and your logger) harvest timber in a legal and environmentally friendly manner.

## Proper Communications

Proper communications using terminology understood by consulting foresters, loggers, and you, the landowner, *is essential*. Silvicultural failures are often the result of not conveying your exact objectives to your advisors. You are responsible for the results of management activities on your land, even if they are inappropriate or not aesthetically attractive. You cannot afford to gamble with these outcomes, as they will outlive your single generation, and several more to come.

*Learn as much as you can about your forest ecosystem and get the help you need—**before** applying treatments to the forest.*

[70] The Washington Contract Loggers Association administers this program, with assistance from WSU Extension and Washington Department of Natural Resources. Similar programs exist in Idaho and Oregon.

## Acknowledgements

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## Selected Readings

This publication is designed for readers in Washington State, however much of it is applicable for throughout the Pacific Northwest. Listed below are selected publications from Washington, Idaho, and Oregon that you may find useful. All the publications listed can be ordered from the following publishers or can be downloaded from the Internet.

### Washington

Washington State University Extension
http://pubs.wsu.edu

- A Guide to Floral Greens: Special Forest Products, EB1659
- Managing Your Timber Sale, EB1818
- Fertilizing Eastern Washington Coniferous Forests: A Guide for Non-industrial Private Forest Landowners, EB1874
- Roads on Small Acreage Forests, EB1910
- Forest Ecology in Washington, EB1943
- Silvicultural Management Strategies for Pests of the Interior Douglas-Fir, MISC0237
- Measuring Trees, PNW0031
- Plant Your Trees Right, PNW0033
- Thinning: An Important Timber Management Tool, PNW0184
- Forest Stewardship Planning Workbook, PNW0490
- Logging Selectively: A Practical Field Guide to Partial Timber Harvesting in Forests of the Inland Northwest and the Northern Rockies, PNW0534
- Rotten Truth: Control of Common Forest Root Rots of the Pacific Northwest, VT0094 (video tape)
- Edible Wild Mushrooms, MNEB357
- Inventory Wizard: A New Tool That makes it Easy to get Started with the Landscape Management System, EB1983
- Thinning Young Douglas-fir West of the Cascades for Timber and Wildlife, EB1927

### Idaho

Idaho Cooperative Extension
http://www.cnr.uidaho.edu/extforest/Publications.htm

- Control Deer and Elk Browse Damage, UI Extension Forestry Information Series CNR-CD No. 1
- Pocket Gophers and Tree Seedlings, UI Extension Forestry Information Series CNR-CD No. 1
- After the Burn: Assessing and Managing Your Forestland After a Wildfire, UI Extension Forestry Information Series CNR-CD No. 1
- Basics of Thinning for the Woodland Owner, UI Extension Forestry Information Series CIS 654
- Diameter Limit Cutting, UI Extension Forestry Information Series CNR-CD No. 1
- Diameter Limit Cutting: A Questionable Practice, CIS 630
- Does it Pay to Thin? UI Extension Forestry Information Series CNR-CD No. 1
- Evaluating Forest Ecosystems for Silvicultural Prescriptions and Ecosystem Management Planning, 1996 BULL 59
- Improving Forest Productivity for Timber: A Key to Sustainability, UI Extension Forestry Information Series CNR-CD No. 1
- Silvicultural Decisions I: Planting vs. Natural Seeding, UI Extension Forestry Information Series CNR-CD No. 1
- Silvicultural Decisions II: Mechanized vs. Conventional Logging, UI Extension Forestry Information Series CNR-CD No. 1
- Silvicultural Decisions III: Thinning, UI Extension Forestry Information Series CNR-CD No. 1
- Silvicultural Decisions IV: Trees on the Edges of Clearcuts and Other Openings, UI Extension Forestry Information Series CNR-CD No. 1
- Silvicultural Decisions V: Why and How to Thin, UI Extension Forestry Information Series CNR-CD No. 1
- Silvicultural Decisions VI: Site Preparation for Natural or Planted Regeneration, UI Extension Forestry Information Series CNR-CD No. 1

- Silvicultural Decisions VII: Thinning vs Selection Harvest/Regeneration, UI Extension Forestry Information Series CNR-CD No. 1
- Snag Management, Forest Management No. 10, Idaho Department of Lands
- Species Diversity: A Management Tool for Woodland Owners, UI Extension Forestry Information Series CNR-CD No. 1
- Stress Kills Trees Too!, UI Extension Forestry Information Series
- Thinning: An Important Timber Management Tool, UI PNW 184
- Thinning Increases Growth in Young Ponderosa Pine Plantations in the Palouse Range, UI SN 26
- Weekend Warrior Logging: Are You Being Safe?, UI Extension Forestry Information Series CNR-CD No. 1
- Measuring Trees, UI PNW031
- Income Opportunities in Special Forest Products: Self-Help Suggestions for Rural Entrepreneurs, Agriculture Information Bulletin AIB – 666, US Department of Agriculture, Washington D.C.
- Logging Selectively, UI PNW 534
- I Want to Log “Selectively”: A Practical Guide to Partial Timber Harvesting, UI VIDEO (40 minutes)

## Oregon

Oregon State University Extension
http://eesc.orst.edu/agcomwebfile/EdMat/edmatindexfor.html

- Managing Woodlands in the Coastal Fog Belt, EC 1131
- Thinning Systems for Western Oregon Douglas-fir Stands, EC 1132
- Managing Hardwood Stands for Timber Production, EC 1183
- Converting Western Oregon Red Alder Stands to Productive Conifer Forests, EC 1186
- Using Precommercial Thinning to Enhance Woodland Productivity, EC 1189
- Managing Red Alder, EC 1197
- Pruning to Enhance Tree and Stand Value, EC 1457
- Ecology, Identification, and Management of Forest Root Diseases in Oregon, EC 1512
- Needle Diseases in Oregon Coast Range Conifers, EC 1515
- Seedling Care and Handling, EC 1095
- Understanding and Controlling Deer Damage in Young Plantations, EC 1201
- Successful Reforestation: An Overview, EC 1498
- Plant Your Trees Right, PNW 033
- Enhancing Reforestation Success in the Inland Northwest, PNW 520
- Measuring Timber Products Harvested from Your Woodland, EC 1127
- Estimating Site Productivity on Your Woodland, EC 1128
- Tools for Measuring Your Forest, EC 1129

## Woodland Fish and Wildlife Group

http://www.woodlandfishandwildlife.org/

- Coastal Douglas Fir Forests and Wildlife
- Managing Ponderosa Pine Woodlands for Fish and Wildlife
- Managing Small Woodlands for Cavity Nesting Birds
- Riparian Areas: Fish and Wildlife Havens

# Glossary[71]

**Advanced reproduction**
Young trees established before a regeneration cutting.

**Age class**
All trees in a stand within a given age interval, usually 10 or 20 years.

**Artificial regeneration**
Regenerating an area by broadcast seeding or by planting seedlings or sprouts.

**Broadcast burn**
*See* Burning methods.

**Buffer**
A protective strip of land or timber adjacent to an area requiring attention or protection. For example, a protective strip of unharvested timber along a stream.

**Canopy**
The uppermost layer in a forest, formed collectively by tree crowns.

**Canopy layers**
Forests with varying age classes may have several height classes.

**Cleaning or Weeding**
A precommercial practice of freeing seedlings or saplings from competition with shrubs, vines, or other ground vegetation.

**Clearcut Harvest Regeneration System**
A harvest and regeneration technique removing all the trees (regardless of size) on an area in one operation. Clearcutting is commonly used with shade-intolerant species such as Douglas-fir or lodgepole pine, which require full sunlight to reproduce and grow well. Clearcutting produces an even-aged stand.

**Co-dominant trees**
Trees whose crowns form the general level of the stand, receiving full light from above but comparatively little from the sides. *See also* Crown class.

**Competition**
In a forest, the struggle for water and light among neighboring trees having similar requirements.

**Crop tree**
A tree identified to be grown to maturity for the final harvest cut. Usually selected on the basis of its species, its location relative to other trees, and its quality.

**Crown**
The branches and foliage of a tree.

**Crown class**
A relative designation of tree crowns. *Dominant trees* are those with crowns above the general level of the canopy. *Co-dominant* trees are those with crowns forming the general level of the canopy. *Intermediate trees* are those with crowns below the general level of the canopy. *Suppressed trees* are those much shorter than the general level of the canopy.

**Crown closure**
The point when, in a young stand, the crowns of the trees begin to touch each other.

**Crown ratio**
A measure of the length of a tree's crown relative to total tree height.

**Cull**
A tree or log of merchantable size, which, because of a defect, is useless for its intended purpose.

**Cutting cycle**
The planned time interval between harvesting operations in the same uneven-aged stand. For example, a cutting cycle of 10 years in an uneven-aged stand means that a harvest cutting of trees is made every 10 years.

**Density**
The quantity of trees per unit of area. Usually expressed as trees/acre.

**Diameter limit**
The smallest (occasionally the largest) size to which trees or logs are to be measured, cut, or used. The points to which the limit usually refers are stump, breast height, or top.

**Diameter-limit cutting**
A harvest based on cutting all trees in the stand over a specified diameter, regardless of tree vigor, species, or spatial distribution. Usually results in the long-term degradation of the stand.

**Dibble bar**
A flat or round metal tool used to make a hole for planting containerized seedlings.

**Direct seeding**
Sowing tree seed to regenerate a forest.

**Disturbance**
A natural or human-caused event, such as a forest fire, disruptive wind storm, or insect infestation that alters the structure and composition of an ecosystem.

**Dominant trees**
*See also* Crown class.

[71] For a more complete glossary, including many illustrations, see *Terminology for Forest Landowners*, EB1353, available from WSU Extension publications or as a PDF file at http://cru.cahe.wsu.edu/CEPublications/eb1353/eb1353.pdf.

**Even-aged management**
Stand management designed to remove (harvest) all trees at one time, or over a short period, to produce even-aged stands.

**Forest management**
The application of scientific, economic, and social principles to managing a forest property for specific objectives.

**Forest Plan**
A document that guides all natural resource management activity and establishes management standards and guidelines for a National Forest, embodying the provisions of the National Forest Management Act (1976).

**Forest Practices Act**
Washington State legislation designed to protect public resources, such as water and wildlife, from effects of indiscriminate management practices. All forest operations on private lands must comply with regulations administered by state forestry personnel.

**Growing stock**
All the trees growing in a stand, generally expressed in terms of number, basal area, or volume.

**Habitat**
The local environment in which a plant or animal naturally lives and develops.

**Hardwood**
A term describing broadleaf trees, usually deciduous, such as oaks, maples, cottonwood, ashes, and elms.

**Harvest**
Removing trees in an area to obtain an income or usable product.

**Harvesting methods,** *also*
**Harvest Regeneration Methods**
*See* Clearcut harvest; Seed-tree harvest; Selection harvest; Shelterwood harvest.

**Hazard reduction or Slash reduction**
The burning, crushing, or scattering of slash to reduce the risk of forest fires or forest fire damage to an area.

**Heel-in**
To store young trees before planting by placing them in a trench and covering the roots with soil.

**Height** *or* **Merchantable height**
Tree height (or length of the tree trunk) up to which a particular product may be obtained. For example, if 6-inch minimum diameter sawlogs were being cut from the tree, its merchantable height would be its height up to a diameter of 6 inches. The products being cut determine merchantable height.

**Total height**
Tree height from ground level to top.

**High-grading**
A harvesting technique that removes only the best trees to obtain high, short-term financial returns at the long-term expense of remaining stand growth potential. *See also* Diameter-limit cutting.

**Intermediate cut**
Removal of immature trees, between the time that the stand is established and the time the stand is harvested, to improve the quality or reduce competition among remaining trees. In contrast to a harvest cut, an intermediate cut may or may not generate income.

**Intermediate trees**
*See also* Crown class.

**Intolerant species**
Tree species that is incapable of establishing or growing in the shade of other trees.

**Leave trees**
Trees left standing by design after a harvest or thinning.

**Liberation cutting**
An operation to release young trees from overtopping older trees.

**Logging cost**
The total cost of felling, bucking, skidding, loading, and hauling associated with forest harvesting.

**Logging residue**
*See also* Slash.

**Management plan**
A written plan for the organized handling and operation of a forest property. It usually includes data and practices designed to provide optimum use of forest resources according to the landowner's objectives.

**Mortality**
Death of forest trees because of competition, disease, insect damage, drought, wind, fire, and other factors.

**Multi-storied**
Forest stands containing trees of different heights.

**Natural Regeneration**
Trees established because of natural seeding.

**Noncommercial cutting**
Cutting trees to improve growth conditions of the stand. Trees cut in this operation do not yield a net income, usually because the trees cut are too small to be marketable.

**Overmature**
A stand of trees that is older than normal rotation age for the type.

**Overstocked**
A stand or forest condition, indicating more trees than desired.

**Overstory**
That portion of the trees in a stand forming the upper crown cover.

**Partial cut**
Any cutting scheme that removes less than the total tree stand at any one time.

**Pile and burn**
A controlled burn where slash is concentrated, usually by machinery, before burning.

**Plantation**
A reforested area established by planting trees.

**Planting bar**
A hand tool used to plant seedlings. *See also* Dibble bar.

**Planting stock**
Seedling trees ready for planting.

**Plug seedling**
A seedling tree grown in a small container, under carefully controlled environmental conditions. Seedlings are removed from containers for planting. Also called containerized seedling.

**Pole stand**
A stand of trees whose diameters range from approximately 5 to 9 inches.

**Prescription**
A management action to cause orderly change in a forest.

**Pruning**
Removing live or dead branches from standing trees to improve wood quality.

**Reforestation**
Reestablishing a forest on an area where forest vegetation has been removed.

**Regeneration cutting**
A harvesting technique that provides for stand regeneration, such as clearcutting, seed-tree, selection, and shelterwood cutting methods.

**Relative stand density**
The ratio, portion, or percent of absolute stand density to a reference level defined by a standard level of competition.

**Relative stand density index**
A widely used measure that expresses relative stand density in terms of the relationship of a number of trees to stand quadratic mean diameter.

**Release cutting**
Improving the species composition in young stands by cutting inferior species. This operation releases the better trees from competition.

**Reproduction**
Young trees. Also the process of forest replacement or renewal, which may be introduced artificially by planting, or naturally by sprouting or self-seeding.

**Residual**
Trees left in a stand, after cutting, to grow until the next harvest.

**Rotation**
The number of years required to establish and grow trees to a specified size, product, or condition of maturity.

**Salvage cut**
Harvesting damaged or defective trees for their economic value.

**Sanitation cut**
Harvesting trees that are infected by, or highly susceptible to, insects or diseases, to protect the rest of the forest.

**Scarify**
To disturb the forest floor and topsoil in preparation for natural regeneration, direct seeding, or planting.

**Second growth**
Young forests that originated naturally or were planted on the site of a previous stand, which was removed by cutting, fire, or other means.

**Seedling**
A tree, usually less than an inch in diameter, and no more than 3 feet in height, which has grown from a seed (in contrast to a sprout). Also refers to nursery-grown trees that have not been moved in the nursery to obtain more growing space. *See* Transplant.

**Seed-tree Harvest Regeneration System**
Removing nearly all trees from the harvest area at one time, but leaving a few scattered trees to provide seed for a new forest stand. Usually 5 to 10 trees per acre are retained. These are removed later, after sufficient regeneration is established.

**Seed year**
A year in which a given species produces a large seed crop. Used in reference to trees that produce seed irregularly or infrequently.

**Seed zone**
Areas which have similar climate and elevation conditions. Used to specify where tree seed was collected and where trees from such seed will probably grow successfully.

**Selection harvest**
Harvesting individual trees or small groups (group selection) of trees at periodic intervals (usually 8 to 15 years) based primarily on their vigor and age. Selection harvesting perpetuates an uneven-aged stand.

**Selective logging**
Removing only desirable species or trees over a certain diameter, also known as diameter limit cutting.

**Shade-intolerant**
A term applied to tree species that grow better in direct sunlight than in the shade of other trees. The opposite of shade-tolerant. Examples include coastal Douglas-fir, western larch, lodgepole pine, and red alder.

**Shade tolerance**
A tree's capacity to develop and grow in the shade of, and in competition with, other trees. Examples of highly shade-tolerant species are western hemlock, western redcedar, and Pacific yew.

**Shelterwood Harvest Regeneration System**
Harvesting trees in a series of two or more operations. New seedlings grow and become established in the partial shade protection of older trees. Harvests are usually 5 to 10 years apart, yielding an even-aged stand.

**Silviculture**
The art, science, and practice of establishing, tending, and reproducing forest stands with desired characteristics, based on knowledge of species characteristics and environmental requirements.

**Site**
An area evaluated for its capacity to produce forest products. Evaluation is based on combined biological, climatic, and soil factors.

**Site preparation**
Preparing an area of land for forest establishment. Methods used may include clearing, chemical vegetation control, or burning.

**Slash**
Non-merchantable residue left on the ground after logging, thinning, or other forest operations. Includes tree tops, broken branches, uprooted stumps, defective logs, and bark. Slash can have certain ecologicalbenefits, such as adding nutrients to the soil or providing wildlife habitat.

**Species**
A group of organisms (plants or animals) that are very similar in appearance and can interbreed freely with each other but not with other groups.

**Species composition**
In a forest, the mixture of tree species in a stand.

**Stand**
A recognizable area of the forest that is relatively homogeneous and can be managed as a single unit. Stands are the basic management units of the forest. Stand types include:

*All-aged*
A stand that supports trees of all ages and usually all sizes. This stand type is rare. Contrast it with an even-aged stand.

*Even-aged*
A stand in which trees are essentially the same age (within 10 to 20 years).

*Fully stocked*
A stand where trees effectively occupy all growing space, yet ample room exists for developing crop trees.

*Mixed*
A stand that has more than one species in the main tree canopy.

*Overstocked*
A stand that is overcrowded, thus reducing tree vigor.

*Pole*
A stand in which most trees are 5 to 9 inches in diameter.

*Pure*
A stand in which at least 80% of the trees belong to a single species.

*Residual*
The stand, which remains after cutting.

*Sawtimber*
Most trees in the stand are large enough in diameter (usually 10 to 12 inches DBH or larger) to be sawn into lumber.

*Understocked*
A stand in which crop trees do not effectively occupy the growing space.

*Uneven-aged*
A stand that supports trees of several age classes (technically, more than two age classes).

**Stand density**
A quantitative measure of stand stocking, or the number of trees for a given area.

**Stand structure**
Stages in the natural development of a forest stand, which often include distinct phases such as stand initiation, stem exclusion, understory reinitiation, and old growth.

**Stewardship**
The responsibility to manage forest land with practical wisdom.

**Stocking**
A description of the number of trees, basal area, or volume per acre in a stand compared with a desirable level for best growth and management. Often stocking is used as a relative term, such as partially stocked, normally stocked, or overstocked.

**Suppressed trees**
Trees much shorter than the general level of the canopy.

**Sustainability**
Forest development that incorporates the means to maintain biological diversity, resilience to stress, and ecosystem health and integrity, in the context of the ability to meet future as well as present human needs.

**Thinning**
Tree removal in a forest stand that reduces tree density and tree-to-tree competition. Thinning encourages increased growth of fewer, higher quality trees. Thinning types include:

*Commercial thinning*
Any thinning of merchantable trees.

*Crown thinning*
A thinning that removes the dominant and codominant trees.

*Low thinning*
A thinning that removes the smallest, suppressed trees.

*Natural thinning*
A natural process where trees die because of root or crown competition.

*Precommercial thinning*
Any thinning of non-merchantable trees, often called PCT.

*Row thinning*
A plantation thinning that removes specific tree rows.

*Selection thinning*
A thinning that selects and removes individual large trees.

**Thinning shock**
A condition where trees sometimes show signs of ill health or stress after a thinning operation that opens up the stand.

**Timber stand improvement (TSI)**
Applying cultural practices to a young forest stand to improve the growth and form of trees and achieve the desired stocking and species composition.

**Transplant**
A very young tree or seedling lifted from a nursery seedbed and replanted at the nursery.

**Tree farm**
Privately owned woodland in which producing timber is a major management goal. It may be recognized as a "certified tree farm" by the American Tree Farm System.

**Understory**
That portion of the trees or other vegetation below the canopy in a forest stand.

**Uneven-aged management**
Managing a forest by periodically harvesting trees of all ages to maintain a broad age (or size) class distribution. The forester maintains a greater number of trees in each smaller age-class than in the next older or larger class, up to some maximum age. This type of management is not common in the West. *See* Selection harvest.

**Weed tree**
A tree of a species with relatively little or no economic value.

**Wildling**
A seedling naturally reproduced outside of a nursery, used in forest planting.

## Publication Evaluation

*Dear Reader:*

*Please take a moment and answer the following questions. Your response will allow WSU Extension Foresters, to evaluate this publication and make improvements in the future. Simply cut this page out of the publication and return to the address below. Thank you!*

### SILVICULTURE FOR WASHINGTON FAMILY FORESTS EVALUATION FORM

**Please indicate your rating of the following:**

On a scale of 1, 2, or 3, with 1 being poor and 3 being excellent. *Please circle your response.*

1 2 3 Was the publication informative?

1 2 3 Did the publication provide you with answers?

1 2 3 Does the title provide an accurate description of the contents?

1 2 3 Would you recommend this publication to others?

1 2 3 How do you rate the overall content of the publication?

1 2 3 Were the illustrations useful?

1 2 3 Was the publication easy to understand?

Have you implemented any of the recommendations?

_____ Yes _____ No

If "yes", which ones? And on how many acres? (# Acres ______ )

If "no", why not?

Please let us know if any sections are difficult to comprehend or that need improvement.

Cut out form

Please let us know if any illustrations are difficult to comprehend or need improvement.

______________________________________________________________________________

______________________________________________________________________________

What needs to be added to the publication?

______________________________________________________________________________

______________________________________________________________________________

**Please tell us a little about your family forestland:**
Does your family have a Forest Stewardship Plan? Or a Forest Management Plan?

______________________________________________________________________________

If you have a Forest Stewardship Plan, did you development via the coached planning workshop, approach? Or did a consulting forester develop it?

______________________________________________________________________________

______________________________________________________________________________

How did you find out about this publication?

- ❏ Direct mail
- ❏ Forest Stewardship Notes Newsletter
- ❏ Journal/Newsletter announcement (name):______________________________
- ❏ Colleague
- ❏ Other—explain:______________________________________________

Acres owned ____________________ County where forestland is located ________________________

Do you live on the property? ______ Yes ______ No

What future educational topics do you feel should be addressed in our publication series?

______________________________________________________________________________

We encourage you to comment below on any aspect of the publication that you feel should be addressed. Please include your name if you wish.

______________________________________________________________________________

______________________________________________________________________________

***Thank you for your responses!***

Please mail form to: Donald Hanley
Extension Forester
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