

## Chapter 10: Silvicultural Influences on Wood Quality<sup>1</sup>

### Background

#### General Overview

For many years, old-growth timber of the Pacific Northwest had great marketing advantages relative to its competitors: large stems, narrow rings, a high proportion of clear wood and—in the case of Douglas-fir—superior strength properties. Some of the region's advantages in the timber trade have been reduced, however, as the major source of wood supply shifted from old-growth timber to young natural stands and plantations grown on relatively short rotations. In young-growth stands, stems (and thus logs) are smaller in diameter, growth rings are generally wider, knots are more abundant, and strength properties are reduced. A larger proportion of the stem is composed of juvenile wood; this wood occupies the core of a tree (from the pith outward for various numbers of rings) and differs from mature wood in several basic traits—wood density (lower or higher, depending on the species), shorter fiber length, and greater microfibril angle. Juvenile wood generally has lower mechanical strength, greater tendency to shrink and warp, and lower pulp yield. Although manufacturing changes allow utilization of smaller, younger trees for many products, the traits previously associated with old-growth trees are still very important for other products and may command premium prices so long as mills capable of handling logs more than 30 inches (75 centimeters) in diameter continue operation. The number of such large-log mills has been declining rapidly.

#### Brief History of Wood Quality Research

Differences in wood properties (hence, quality) of Douglas-fir were noted in an early unpublished monograph (see footnote 3 in chapter 4) on the species by Allen in 1899. Allen commented that lumbermen recognized two varieties of Douglas-fir based on color of heartwood: yellow fir was somewhat lighter, softer and easier to work than red fir.

Yellow fir trees were older (>75 years) than red fir trees (<70 years) and generally were growing on poorer sites and drier soils; at the time, some people believed the differences were caused primarily by age, but Allen considered the theory inconclusive because the oldest trees tended to occur on poorer sites.

One of the first activities after transfer of the Bureau of Forestry from the U.S. Department of the Interior to the U.S. Department of Agriculture involved the establishment of timber-testing laboratories in the Pacific Northwest at the University of Oregon (Eugene) and at the University of Washington (Seattle) about 1905–06 (Munger 1955; see also footnote 4 in chapter 4). Studies at the University of Oregon ended in 1907 (see footnote 4 in chapter 4), but work was continued for some time and eventually expanded at the University of Washington (Munger 1955). When the U.S. Forest Service established its Regional (then called District Forester's) Office in 1908 in Portland, Oregon, it included two small sections devoted to research—Forest Products and Silvics (Munger 1955). Wood properties of native species, including Douglas-fir, western hemlock, Sitka spruce, and western redcedar, were evaluated for structural and other purposes (for example, Cline and Knapp 1911). The Forest Products Laboratory at Madison, Wisconsin, was founded in 1910. Despite early recognition of the importance of both fields of scientific inquiry, it appears that little or no overlap or collaboration occurred between silviculture and forest products research; at the time, forest products and wood research was concerned primarily with the properties and use of the older, naturally-grown timber then being harvested. And during the first quarter of the 20<sup>th</sup> century, forest owners and managers were concerned primarily with reestablishment or regeneration of stands after harvest, and protection from fire. Munger's (1911) monograph on growth and management of Douglas-fir, however, did point out the significance of markets for small material (such as mining props and

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railroad ties) to yield and value obtainable from young stands, 30 to 70 years old. Management of young stands was limited and generally focused on high volume (quantity) production.

Although high volume production remained the primary management consideration for many years, quality as well as quantity of production gradually began to receive some attention. Paul (1932), a silviculturist at the Forest Products Laboratory in Madison, Wisconsin, published a thoughtful article in the *Journal of Forestry* titled “Improving the Quality of Second-Growth Douglas-Fir.” He suggested that management of second-growth stands be focused on three objectives: freedom from large and loose knots, uniformity of growth rate, and production of both dense wood for special uses and nondense wood for other uses. To achieve these goals, Paul proposed silvicultural practices to influence stand stocking—interplanting in poorly stocked stands to reduce knot size and enhance natural pruning, thinnings in well-stocked stands to maintain uniformity of growth rate, and dense stocking plus longer rotations to produce dense wood. It is surprising that Paul did not mention pruning. Pruning studies established in 1930 in British Columbia (Schenstrom 1931) and in the mid to late 1930s in the United States (Stein 1955a, Meyer<sup>2</sup>) appear to be the first attempts to study the effect of silvicultural manipulations on wood quality. It was another 20 years before research foresters attempted to quantify relationships between branch or knot size and spacing or stand density in plantations (Eversole 1955) and natural stands (Grah 1961).

Except for a few reports from Canada (for example, Warrack 1948), research interest in the influence of silviculture on wood quality of Douglas-fir and other Northwestern species seems to have waned from the mid 1960s until the early 1980s. Several factors contributed to such decline in interest—a large portion of the wood supply continued to come from older forests, most economic analyses done between 1950 and 1980 indicated that there was little to be

gained by pruning most species (Fahey and Willits 1995), and a general belief that in the future most wood-based products would be made from reconstituted fiber (for example, Zivnuska 1972).

The situation began to change rapidly in the last quarter of the 20<sup>th</sup> century. Forest area in young managed stands and the proportion of timber harvest from such stands increased, and it became apparent that very wide early spacing and very short rotations have undesirable effects on stem characteristics and wood properties, and therefore on timber or log values. Consumers encountered poorer quality lumber in lumberyards and home improvement stores, and experienced the negative performance of such wood in service. As a result, research concerning the effects of stand management on the quality and value of wood produced has greatly increased during the past 20 years. Considerable effort has gone into quantifying the basic relationships (Briggs 1989, Maguire and others 1991), estimating log and lumber values from tree characteristics (Briggs and Fight 1992; Fight and others 1987a, 1987b, 1988), and using recently developed stand models coupled with assumptions regarding stem and wood traits to estimate timber values produced under a variety of management regimes (Barbour and others 2003).

### General Influences of Silvicultural Practices

Today it is well-accepted that the application and timing of several silvicultural practices can exert strong influence (of considerable economic importance) on stem characteristics and properties of wood produced in young managed forests:

**Stand density management** through initial spacing (plantations) and thinning (natural stands and plantations) can influence growth rates (ring widths), branch size and persistence (hence, number, size, and quality of knots), and the amounts and proportions of juvenile wood. Thus, wide spacings can produce large green branches and knots,

<sup>2</sup> Meyer, W.H. 1935. First report on Columbia thinning plots 4, 5, 6, 7, 8. Office report. On file with: Silviculture and Forest Models Team, Forestry Sciences Laboratory, Olympia, WA.

whereas breakage of dead branches during thinning can reduce the number of knots.

**Pruning** (sometimes called “artificial pruning” to contrast it with “natural pruning” or “self-pruning”) can increase the production of clear wood, reduce the number and size of knots, possibly improve the form factor of the lower log(s), and accelerate the transition from juvenile to mature wood.

**Fertilization or nutrient applications** can influence growth rate (ring width) and basic wood properties, including density of and the transition between earlywood and latewood, and probably the size and persistence of branches (knots).

**Genetic improvement (tree breeding)** can affect many stem characteristics and growth traits such as early growth rate, stem form, branching patterns, and basic wood properties such as density.

**Rotation length** will strongly influence stem size (log diameters), amount of clear wood, heartwood/sapwood ratios, and the proportion of juvenile wood.

Essentially all of these practices or decisions can influence the uniformity of wood properties in logs harvested. Uniformity in raw material supply is extremely valuable in all manufacturing processes (Haygreen and Bowyer 1996); this is fortunate because this opportunity to affect wood uniformity is the major wood quality advantage that managed young-growth timber has over the old-growth resource that fueled the timber industry and economy of the Pacific Northwest for many years. Wood properties of the latter were already in place and, although the outer rings had excellent properties, substantial and abrupt changes in growth patterns from the pith to the outer rings were common.

The history of research on each of these practices as related to wood quality is summarized in the sections that follow.

## **Pruning**

Old-growth Douglas-fir was highly valued for its large proportion of fine-grained clear wood, much in demand for the

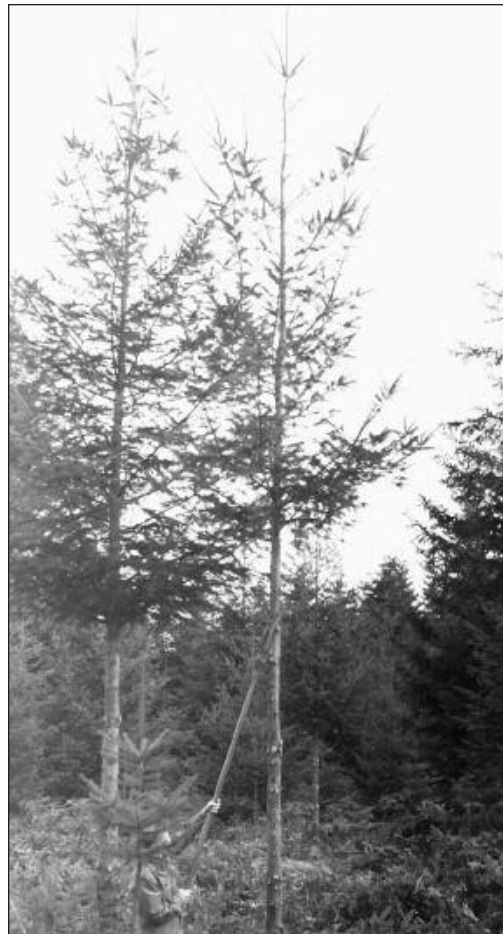


Figure 32—Early experimental pruning at Wind River.

plywood industry as well as for a variety of other specialized uses. Paul (1932) pointed out the influence of stocking and stand density on size and looseness of knots in young-growth trees. It was early recognized that, even in well-stocked stands, natural pruning in unmanaged young-growth stands was a very slow process. Bransford and Munger (1939), Kachin (1940), and Paul (1947) conducted independent assessments on formation of knots, limb death, and production of clear wood; their reports estimated that production of substantial amounts of clear wood would require 100 to 150 years. It was therefore natural to consider pruning as one component of future management of young stands (fig. 32).

Some small-scale trials date from the early 1930s (for example, Schenstrom 1931). A small amount of operational pruning was done by Civilian Conservation Corps crews on national forest land during the 1930s, although records are largely lacking. Pruning was one of the treatments in the Kugel Creek thinning study (established 1937, destroyed by fire in 1951). There was also some small-scale pruning done about 1940 on the Pack Experimental Forest of the University of Washington. A pruning study was established in 1937 (Stein 1955a) in a 28-year-old site IV stand on the Wind River Experimental Forest, comparing growth effects of different degrees of crown removal. The British Columbia Forest Service installed a combined thinning and pruning study in stands aged 14 to 20 years (Warrack 1948), and a pruning treatment was also superimposed on the Pacific Northwest Station's Voight Creek thinning study established in 1949.<sup>3</sup>

Early reports provided time and cost data (Welch 1939), healing times, and effects on stem growth. Anderson (1951) used material from the Kugel Creek and Wind River studies to show that healing time for pruned Douglas-fir was strongly influenced by diameter growth rate, bark thickness, and pruning technique as it related to stub length. Stein (1955a) evaluated stem growth in the Wind River study. He found that in this previously unmanaged naturally seeded 28-year-old stand, removal of 25 percent of live crown (length basis) produced a small increase in diameter and height growth, but that removal of 50 percent and 75 percent of live crown substantially reduced growth. Stein concluded that one could remove the lower third of live crown in previously unpruned stands without reducing growth. Staebler (1963) showed that early pruning removing one-third or more of the live crown altered bole form, producing more nearly cylindrical stems and reduced ring width in the lower bole.

Shaw and Staebler (1950, 1952) analyzed the effects of different factors on profitability of pruning, and concluded

that diameter growth rate of pruned trees is crucial. Other important factors are price premium for clear wood, cost of pruning, and interest rate.

A general shortcoming of most early pruning research, aside from matters of experimental design and documentation, was that most trials were established beyond the optimal age and without the stocking control needed to ensure rapid diameter growth after pruning. Hence the potential gains in clear wood were generally underestimated.

Research and operational interest in pruning revived in the 1980s based largely on product recovery evaluations using Douglas-fir trees from a thinning/pruning study established in the early years (Cahill and others 1988) and development of simulation programs that allowed estimation of expected clear material and economic returns (Fight and others 1987a, 1987b; Mitchell 1995). The Stand Management Cooperative has installed an extensive series of new pruning studies in the last decade. The Mount Hood National Forest established an elaborate replicated trial in the early 1990s, and several other trials have been established by private owners.

The current state of knowledge about pruning Douglas-fir has been summarized by Oliver and others (1986), by O'Hara (1991), and in a later comprehensive symposium on pruning and wood quality in northwestern conifers (Hanley and others 1995). In sum:

- There is a large amount of published research on pruning Douglas-fir (and other species worldwide). The available information is adequate as a basis for operational applications.
- Simulations indicate pruning should be profitable on good sites under reasonable projections of current costs and price differentials.
- Pruning should be done at an early age and in conjunction with stand density control (or density control plus fertilization) to maintain rapid diameter growth, provided that the species is not susceptible to epicormic branching as a result of the combined

<sup>3</sup> Shaw, E.W. 1949. Pruning at the Voight Creek Experimental Forest. 6 p. Office report. On file with: Silviculture and Forest Models Team, Forestry Sciences Laboratory, Olympia, WA.

treatments (Berntsen 1961b, DeBell and others 2006.)

- Pruning is best done on a limited number of trees that are expected to reach rotation age. Greatest benefits will be obtained on moderately long rotations.
- Some information is available on results of pruning Sitka spruce, western white pine, and red alder, but there is virtually no information available on results of pruning other major Northwestern coastal conifer species such as western hemlock and redcedar.

Operational application of this knowledge has so far been relatively minor, limited mainly to integrated companies in which owners and managers of the forest also control their own mills. A major obstacle to widespread application appears to be uncertainty as to whether a seller of pruned logs or stumpage will be able to command a premium commensurate with the increased value of the manufactured products, in the absence of any mechanism by which a buyer can be sure of pruning history and standards.

### **Initial Spacing and Thinning**

Although Paul (1932) had identified opportunities to influence three aspects of wood quality (knots, growth rate, and wood density) by regulating stocking or stand density throughout the rotation, for the next two decades, research on relations between wood quality and stand management was limited primarily to the studies of branch mortality, natural pruning, and artificial pruning as discussed in the previous section. No one seems to have measured and reported the effects of stocking on branch (or knot) size or branch mortality in Douglas-fir until Eversole (1955) reported results from 27-year-old trees in a research plantation of various spacings. He showed that mean size of the largest limbs in whorls below breast height increased from 0.36 to 0.73 inches (0.91 to 1.85 centimeters) and height to live crown decreased from 19.5 to 6.7 feet (5.9 to 2.0 meters) as square spacing increased from 4 to 12 feet (1.2 to 3.7 meters). A few years later, Grah (1961) conducted work in natural, 20- to 40-year-old Douglas-fir stands on

the relation of average spacing to knot diameter. Grah's linear regression may represent the first attempt to quantify and develop a predictive relationship between a silvicultural attribute (stand density) and a wood quality trait in Douglas-fir.

During the past two decades, effects of spacing on stem form, branch persistence and height to live crown as well as knot size have been investigated for Douglas-fir (Robbins 2000, Smith and Reukema 1986) and other species such as western hemlock and redcedar (DeBell and Gartner 1997, DeBell and others 1994a). Wider spacings increased stem taper, branch persistence, and knot size, but height to live crown was reduced. Studies in intermediate-aged stands specific to effects of thinning on wood quality are limited. Given that thinning generally tends to maintain or increase radial growth rate in the remaining trees, it appears to have little or mixed effects on average wood density of some species (for example, Douglas-fir, Briggs and Smith 1986) and reduce it somewhat in others (for example, western hemlock, DeBell and others 1994b, 2004). Regardless of the specific effects of maintained radial growth rate on density of subsequent wood, the more uniform growth rate and wood density from pith to bark is probably beneficial for most applications.

### **Fertilizer Application**

The primary objective in fertilizing Douglas-fir stands is to enhance tree and stand volume growth. Soon after research trials demonstrated good growth response of Douglas-fir stands to added nitrogen, researchers at University of Washington (Erickson and Lambert 1958) began to assess effects of fertilizer on some wood properties.

As fertilization became operational in the late 1960s and 1970s, basic wood properties were assessed in some fertilized young Douglas-fir trees (for example, Megraw and Nearn 1972, Siddiqui and others 1972). Results indicated that whole ring density was slightly reduced, more so in the latewood than earlywood component, thus increasing uniformity throughout the ring. Work on fertilizer-wood quality relationships has not been extensive, and most

hypotheses about the effects of fertilizer on other aspects of wood quality have been based on how increased growth rate, increased foliar retention, and longer branch persistence might increase size of the juvenile core and number and size of knots. Cahill and Briggs (1992) provided a comprehensive review of fertilization effects on wood properties and tree value, including an analysis of potential effects on specific wood and fiber products.

## Genetic Improvement

Perhaps the earliest work related to wood quality and forest genetics of Douglas-fir occurred when Munger and others collected seed from mother trees for the 1912 heritability study (chapter 7) and diagrammed the form of each tree stem (Munger and Morris 1936). Although the outplanting trial established from this collection represents one of the oldest forest genetic trials in the world, there was little followup on wood quality traits, probably because Douglas-fir inherently has superior stem and wood characteristics. But as tree improvement or tree breeding programs developed in other regions, particularly in areas where pulp and paper dominated the industry, wood quality became an important consideration (Zobel 1961a, 1961b). Soon thereafter McKimmy (1966) collected increment cores from trees in the above-mentioned 1912 Douglas-fir heritability study and evaluated their specific gravity, presumably the first attempt in the Pacific Northwest to examine the tie between genetics and a specific wood property. McKimmy found that trees from different sources differed significantly in specific gravity, but differences were even greater among the four outplanting locations.

During the 1960s, interest developed in abnormal stem forms (forking, sinuosity, and ramicorn branching) sometimes observed in rapidly growing Douglas-fir plantations (Campbell 1965), but it received little attention in genetics research until the 1980s (Adams and Howe 1985). Recent work demonstrated that forking, sinuosity, and ramicorn branching are subject to genetic improvement (Schermann and others 1997). Also in the 1980s and continuing to the present, research increased on the genetic influences on

wood density (specific gravity) and its components, including correlations of juvenile wood properties with those at later ages (McKimmy and Campbell 1982, Vargas-Hernandez and Adams 1992). Although the stem form traits and wood density are heritable, they are considered of secondary importance to volume and adaptability in current Douglas-fir breeding programs (Howe and others 2005).

## Rotation Age

Tree and stand age have direct and indirect influences on wood quality: stem size and the length of branch-free bole increase, whereas the proportion of juvenile core wood, sapwood/heartwood ratio, and ring width decrease as stands become older.

The first scientific report related to age effects on wood quality is probably Allen's report on yellow vs. red fir in 1899 (footnote 3 in chapter 4). The amount of heartwood was recognized as important in western redcedar, where its resistance to decay was highly valued for outdoor applications. Various notes on self-pruning followed Paul's (1932) paper, which revealed that little clear wood is formed during the first 100 years of tree life. As the concept and properties of juvenile (or core) wood became more widely recognized (Wellwood and Smith 1962, Zobel 1961b), the negative properties associated with young rapidly-grown trees became apparent (Jozsa and others 1989). Juvenile wood usually comprises the first 10 to 20 rings outward from the pith (Di Lucca 1989). Compared to later "mature" wood, juvenile wood tends to have lower specific gravity, greater tendency to shrink and warp, lower mechanical strength, and lower pulp yield (Senft and others 1985). It is therefore less desirable for many uses. The amount of heartwood is important in some species, such as western redcedar where its resistance to decay is highly valued for outdoor applications.

Until recently, large trees were desirable for reasons beyond specific wood characteristics; harvest and hauling costs were lower for large trees than for small ones and manufacturing costs were reduced for many wood products, in part because recovery was higher. Recent changes in mill

technology to handle small logs more efficiently and trends toward use of engineered wood products, however, have reduced or eliminated such advantages. At present, large trees may be difficult to market (Barbour and others 2002) and may actually incur a penalty of 25 percent or more (Mason 2002).

### **Simulation Estimates of the Effects of Silviculture on Wood Quality**

In recent years, simulation techniques have been used to estimate the effects of management on the various factors of wood quality and value. In general, these techniques “grow” trees with individual tree simulation programs such

as ORGANON and TASS that can predict quality-related values such as taper, crown dimensions, branch size, and juvenile wood core. These predictions can be combined with bucking and sawing simulators to generate estimates of product out-turn and value. Examples are TREEVAL (Briggs 1989, Briggs and Fight 1992), SYLVER (Mitchell and others 1989), and ORGANON + TREEVAL (Maguire and others 1991). Simulations have shown that regimes that produce the largest trees or the highest volumes are not necessarily those that produce highest value. Value criteria can lead to management decisions considerably different (higher planting density, longer rotation) from those made with volume as the primary criterion.

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## Chapter 11: Silviculture of Associated Species<sup>1</sup>

The preceding discussions have been concerned primarily with Douglas-fir research. In this section we summarize the considerably shorter history of silvicultural research on the principal associated species.

### **Western Hemlock**

After Douglas-fir, western hemlock is the most important species in terms of volume and area occupied. It occurs throughout most of the Douglas-fir region and is the climax species in most of the region—hence the designation of much of the region as the western hemlock zone. The species is most abundant and reaches its best development in the high rainfall areas along the Pacific coast (where it is associated with Sitka spruce) and at mid elevations in the western Cascades.

In the early years, hemlock was regarded as a low-value species with limited markets, influenced in part by the poor reputation of eastern hemlock and by the high defect common in old-growth western hemlock. Attitudes changed rapidly after World War II (WWII) as the combined result of depletion of timber supplies, expansion of the pulp and paper industry, increased use of hemlock in construction, and an expanding Asian market. However, prices for hemlock have historically been substantially lower than for Douglas-fir.

Prior to WWII, relatively little research was devoted to hemlock. Allen (1902) published a monograph on the species, summarizing available knowledge on the silvical characteristics of the species, its wood properties, and its potential for management. Watson and Billingslea (1914) published observational data on hemlock seed production, seed dispersal by wind, and the relationships between seedbed conditions, shading, and early growth of seedlings. It was early realized that hemlock can become established and can survive for long periods in dense shade, but good growth requires at least partial overhead light. Isaac (1930) measured wind dispersal of hemlock seed, along with that

of Douglas-fir. Meyer (1937) prepared normal yield tables for mixed spruce-hemlock stands in Washington, Oregon, and Alaska. These were later reworked by Barnes (1962).

In 1935, twelve 0.4-hectare (1.0-acre) permanent plots were established in 83-year-old even-aged spruce-hemlock at the Cascade Head Experimental Forest. Briegleb (1940) reported results of the first six growing seasons. Fujimori (1971) examined biomass production on these plots and concluded that the values obtained were among the highest in the world. Smith and others (1984) gave a much more complete summary of 33 years of development. Results showed extremely high volumes and growth rates, with average net mean annual increment (MAI) of 17.6 cubic meters per hectare per year (252 cubic feet per acre per year) at age 83 and 16.5 cubic meters per hectare per year (236 cubic feet per acre per year) at age 116.

After WWII, there was a marked expansion of research on hemlock, both in the United States and in British Columbia. A commercial thinning trial established in 1952 in a 50-year-old stand at the Hemlock Experimental Forest showed a slight gain in volume production (mostly because of salvage of mortality) and increased diameter growth (Hilt and others 1977). Variation in initial stand conditions, departures from the original design, and 1962 storm damage precluded sensitive comparisons, and the experiment was abandoned. Graham and others (1985) reported results of light thinning in a 100-year-old stand at Cascade Head, and a number of other more-or-less similar hemlock thinning trials were established by other organizations in the 1950s and 1960s (for example, Omule 1988b). Results were generally similar, with some reduction in windfall and other mortality but little gain in overall production.

Several studies of plantation spacing or precommercial thinning were established in the same period. Thus, the University of British Columbia spacing trials established in the 1950s at Haney, British Columbia (Reukema and Smith 1987), included hemlock. Precommercial thinning trials established at Cascade Head in 1963 and at Clallam Bay in

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1971 showed striking response and very high growth rates (Hoyer and Swanzy 1986).

Shelterwood cuts have resulted in good natural regeneration (Williamson and Ruth 1976) and are a viable alternative to the prevailing practice of clearcutting, although growth of regeneration in the trials cited was inversely related to amount of overstory retained (Jaeck and others 1984).

Recent problems with Swiss needle cast on Douglas-fir in the Oregon coastal zone have reduced the formerly common practice of planting pure Douglas-fir after clearcutting, in favor of hemlock or mixed-species plantings.

Comprehensive summaries of past research and the state of knowledge as of the date of publication include Ruth and Harris (1979), Atkinson and Zasoski (1976), and Burns and Honkala (1990). We will not attempt to list here the many contributors, but only the major points that have been established by research as discussed in the above references.

- On suitable sites, hemlock volume production can exceed that of Douglas-fir.
- Hemlock is often abundant in the understory of older stands and advance regeneration frequently provides a hemlock component in areas planted to Douglas-fir.
- Artificial regeneration techniques are available.
- Hemlock often reproduces abundantly from natural seeding, but reproduction is often patchy and sometimes excessively dense, so precommercial thinning is often needed.
- Shelterwood regeneration has been successful but has not been widely used. The most common regeneration method in the past has been clearcutting, with or without slash burning, and either natural or artificial regeneration.
- As in other species, commercial thinning increases diameter growth but has no great effect on total volume production.
- A number of health problems affect management of hemlock: (1) hemlock is very susceptible to butt rots that enter through logging injuries; (2) it is

susceptible to root rots, particularly laminated root rot (*Phellinus* root disease), similarly to Douglas-fir; (3) cut surfaces of stumps are often infected by spores of annosus root disease, and treatment of stumps has been recommended although not widely practiced; (4) dwarf mistletoe is common in older hemlock stands; (5) and hemlock is less windfirm than Douglas-fir.

- Dwarf mistletoe and susceptibility to butt rots and to windfall make selection systems—which would otherwise be well suited to this shade-tolerant species—questionable. The butt rot threat has caused some to question the merits of commercial thinning in hemlock stands.
- Hemlock has not shown consistent response to nitrogen fertilization.

## Western Redcedar

Western redcedar is a high-value species with unique wood properties. Although it occurs throughout most of the Douglas-fir region, it is most abundant and reaches its best development in the high-rainfall areas along the northern Pacific coast and on the lower slopes of the western Cascades. Its abundance has decreased considerably since initial Euro-American settlement, primarily because of wildfire and the management regime of clearcut, burn, and plant Douglas-fir that prevailed until recently.

Despite its high value, there has been relatively little silvicultural experimentation with redcedar. This lack of interest probably arose from the common perception that redcedar is a relatively slow-growing species, compared to Douglas-fir and hemlock. This perception may stem from the fact that redcedar, as a shade-tolerant species and one that often has slower height growth in early life than its associates, commonly develops in a subordinate position. Most available information has been derived from observation of existing trees and stands (beginning with Jackson and Knapp 1914), plus empirical trials of seeding and planting techniques analogous to those used with other species. Manipulative experiments are few. The

species has received less attention in the United States than in Canada, where it makes up a considerably larger proportion of the resource.

Pure redcedar stands of natural origin are rare. Nystrom and others (1984) located four fully stocked stands that had originated by natural seeding on areas cut about 1920. They examined patterns of height, diameter, and volume growth among crown classes and found stand volume production comparable to that of Douglas-fir on similar sites. Trees in these uniform well-stocked stands had excellent form, small limbs, and were free of the basal fluting common in redcedar grown in the open or in sparsely stocked stands.

Oliver and others (1994) reviewed the available information and suggested that redcedar grown in fairly dense pure stands (or possibly mixed redcedar-hemlock stands) could be expected to have good stem form, high yields, and reduced incidence of the large lower branches and basal fluting common in trees developing in an understory position. Kurucz (1978) developed site index curves from stem analyses of selected trees growing in mixed-species stands. There are no North American yield tables for the species.

Several plantation spacing trials have been established in recent years:

- The University of British Columbia spacing trials previously referred to (Reukema and Smith 1987) included fixed-area plots of redcedar and one Nelder plot with redcedar in addition to hemlock and Douglas-fir. At age 25 on this very good site, average trees of Douglas-fir were larger than the hemlock, which in turn were larger than the redcedar. Comparisons were somewhat obscured by damage, particularly browsing of the redcedar.
- A large spacing trial established at the Wind River Experimental Forest in 1982 included one block planted to redcedar. Results have not been reported to date, but the plantation is known to have suffered heavily from elk browsing.
- The Washington Department of Natural Resources established a redcedar spacing trial on the western Olympia Peninsula in 1984. Spacings were 4, 8, and 16 feet (1.2, 2.4, and 4.9 meters). In 2001, there

were large differences in tree diameters among spacings, but the large trees in the wide-spacing plots had been severely damaged by bears.

A well-replicated study installed in 1980 in a 15- to 20-year-old dense poor-site stand on the Olympic Peninsula compared various combinations of precommercial thinning and fertilization (Harrington and Wierman 1990). Five-year results showed very strong response to fertilization and to fertilization combined with thinning, but limited response to thinning only.

Planting of redcedar has increased in recent years. It is a preferred species for use on areas heavily impacted by *Phellinus* root rot, because of its tolerance of root disease. There is also a considerable amount of planting as a secondary component of Douglas-fir-redcedar mixtures, motivated in part by a desire to ensure against root disease, and in part by biodiversity and wildlife concerns. Browsing by deer and elk remain serious problems, and mixed-species plantations are not easily established (Stein 1997).

The principal summary publications are Minore (1983, 1990) and Smith (1987). We will simply list the main points that have been established in reference to silviculture:

- Redcedar is better adapted to imperfectly drained soils than its coniferous associates.
- Redcedar foliage has high concentrations of calcium and may be important in nutrient cycling.
- Redcedar is very susceptible to fire and logging injury.
- Redcedar height growth trends differ from Douglas-fir and hemlock; Douglas-fir commonly overtops redcedar established at the same time.
- European plantation data indicate high potential yields compared to other species; high basal areas tend to offset somewhat lesser height growth.
- Seed production is usually abundant.
- Effective nursery and planting techniques are available.
- Redcedar is resistant to or tolerant of the coastal strain of *Phellinus* root disease.
- Redcedar is a preferred browse species for deer and elk.

## High-Elevation True Fir–Hemlock

The forests above about 2,500 feet (800 meters) in the northern Cascades and Olympics and above about 3,500 feet (1100 meters) in the southern Cascades are composed of various mixtures of Pacific silver fir, noble fir, western hemlock, mountain hemlock (upper elevations), Douglas-fir (lower elevations), and various minor species, collectively referred to as true fir-hemlock. There was little active management of these forests until about 1960. Research has been limited and largely observational in nature; there have been few manipulative experiments.

Much of the silver fir zone and some lower portions of the mountain hemlock zone are quite productive (Franklin and Dyrness 1973). Although we have no U.S. yield tables, it is clear from observation and from European yield information that true fir stands can develop very high volumes. Noble fir in particular is a very impressive species (Franklin 1964a, 1964b) and is widely planted. Pacific silver fir often develops abundant advance regeneration; its behavior resembles that of the silver fir important in Europe. The true firs characteristically have slow early height development followed by a period of acceleration, with rapid growth continuing to advanced ages.

Hanzlik (1925) carried out a study that is probably the first study of noble fir growth, on Larch Mountain east of Portland, Oregon. This study brought out two points that have been confirmed by later work: (1) compared to both Douglas-fir and western hemlock, noble fir makes relatively slow growth in the early years; but (2) in later years it maintains rapid growth to advanced ages, exceeding (on this site) both Douglas-fir and western hemlock in growth rate.

Franklin's (1962) literature review showed that up to about 1960, the existing information on true firs was concerned principally with species distribution, botanical characteristics, and seeding habits. There was little information on applicable silvicultural methods.

Herman and others (1978) and Hoyer and Herman (1989) developed site curves from stem analyses of selected dominant noble fir and silver fir trees in old natural stands.

Murray and others (1991) found that noble fir and silver fir established on clearcuts were making substantially faster height growth than indicated by stem analyses of old trees. Preliminary site curves exist for mountain hemlock. Managers have usually assumed that western hemlock will behave much as it does on the poorer sites at lower elevations.

The extensive ecology program of the Pacific Northwest Region of the USDA Forest Service developed an elaborate plant association classification that is useful in matching species and management practices to site (for example, Brockway and others 1983).

Early management attempts using the clearcut, burn, and plant (often Douglas-fir) practices used in the lowlands frequently failed (Franklin 1964a). The slow development and frequent failure of regeneration (often because of late spring frosts) on harvested areas was a major concern in the 1960 and 1970s, but with improved nursery and planting practices, less burning, better matching of species to site, and consequent higher survival, this was replaced with concern about the overstocking that frequently developed. In the 1980s, the Forest Service undertook an extensive pre-commercial thinning program in true fir-hemlock. Practices were based on experience with Douglas-fir because there were no quantitative stocking standards based specifically on experience with young true fir-hemlock stands.

Over the years 1987–94, an extensive series of spacing trials was established on national forest lands (fig. 33). In time, these trials should produce a basis for estimating yields of young true fir-hemlock stands under a range of stocking levels (Curtis and others 2000). The high values of true fir boughs for Christmas decorations can often cover the costs of precommercial thinning.

The principal available summaries of existing silvicultural information are Oliver and Kenady (1981) and Burns and Honkala 1990.

Prior to Euro-American settlement there were extensive areas of open land in the northern Cascades, maintained in part by burning by Natives. These lands were highly valued by the Natives for huckleberry production, and are now an



Figure 33—A precommercially thinned plot in a noble fir spacing experiment. Noble fir has been widely planted at higher elevations. Concern over some early establishment failures was later replaced with concern about overstocking in many areas.

important recreational resource. Concern over encroachment of forest on these open areas led to a small amount of work on huckleberry management (Minore 1972, Minore and Dubrasich 1978).

Currently, there is only limited formal research on true fir-hemlock in progress in the region. There is more emphasis on silver fir and mountain hemlock research and management in British Columbia, where the species occur at lower elevations and make up a greater proportion of the commercial forest land base.

## **Red Alder**

Interest in silviculture of northwestern hardwoods is a fairly recent development. Examples are red alder, Oregon white oak, and poplars.

### **Red Alder as a Timber Species**

Red alder is the most abundant and economically most important northwestern hardwood. It grows best on moist sites at low elevations, although it occurs on other sites. Alder is an intolerant and relatively short-lived pioneer species that reproduces abundantly on bare mineral soil exposed to direct sunlight. The large clearcuts and fires

common prior to WWII are thought to have considerably increased the amount of alder, compared to presettlement conditions. Conversely, fire protection, the widespread planting of conifers on clearcuts, and conscious efforts in recent decades to convert alder and mixed-species stands to conifers have considerably reduced the area in alder and produced a shortage of young stands.

Prior to WWII, alder was regarded as a low-value weed species. Attitudes began to change after WWII. Causes were (1) increased use of alder for pulp and particle board, (2) increased use of alder for furniture and similar uses with correspondingly higher log prices, (3) recognition that alder's nitrogen-fixing ability had an important role in soil fertility, (4) recognition that rapid juvenile growth and early maturity made alder suitable for management on much shorter rotations than those appropriate for conifers, and (5) interest in the 1980s in short-rotation woody crops as a possible energy source. These factors partially offset the higher volume and value production obtainable with conifers. Interest in the possibilities of alder led to the establishment of the Hardwood Silviculture Cooperative at Oregon State University in 1987.

Two early publications on alder were Johnson (1917) and Johnson and others (1926). The latter was concerned mainly with utilization, but also included some discussion of silvical characteristics, yields, and management possibilities.

Little further work was done with the species until the 1950s. Beginning around 1960, an increasing number of publications appeared, and today there is a growing literature on alder biology and management, a considerable part of which is based on formal experimentation. Major summary publications are Worthington and others 1962, Trappe and others 1968, Briggs and others 1978, Heebner and Bergener 1983, Hibbs and others 1994, and Deal and Harrington 2006. DeBell (2006) gave an overall review of the history of red alder research and changing attitudes. The various papers included in Deal and Harrington (2006) showed that production in managed alder plantations considerably exceeds that in natural stands, and suggested that

financial returns can be competitive with those from conifers.

To summarize the main points established by research:

- Compared to its conifer associates, alder makes much more rapid juvenile height growth but falls behind in later years. Consequently, it offers severe and often lethal competition to intermingled conifers in early life.
- Volume production per year on appropriate rotations is greater for conifers than for alder on most sites, but the rapid juvenile growth and correspondingly shorter rotations for alder reduce the financial advantage of conifers. The current weakness of volume and value yield estimates and of volume and taper functions specifically applicable to intensively managed young alder stands makes financial comparisons somewhat uncertain.
- Alder may have an important role in management of nitrogen (N)-deficient soils because of its N-fixing capability, albeit with recognition of its competitive potential.
- Early thinning trials were unsatisfactory, probably because they were not begun until after the period of rapid height growth. Thinning should be done early.
- Plantations with suitable density control can provide considerable increases over natural stands in volume, height growth, and stem quality. The regular spacing achievable by planting or thinning minimizes the lean and sweep common in unmanaged stands.
- Normal yield tables have been developed for unmanaged stands but are probably not applicable to stands with early density control, and may overestimate yields of older unmanaged stands.
- Site curves and alternative methods of evaluating site quality have been developed.
- Stocking guides for plantations and pure natural stands have been suggested.
- Suitable nursery and planting practices are available.
- Several plantation spacing trials exist, including both pure and mixed species.

- Alder's immunity to *Phellinus* root disease makes it suitable for planting on root-disease-infested areas.

Interest in alder management has been markedly stimulated by recent development of export markets and increasing log prices.

### Red Alder as a Soil Improver

Johnson (1917) produced the first published reference on the role of red alder in the Northwest as a soil-improving species that actively fixes N. He observed apparent relationships between presence of red alder and increased soil fertility, which he interpreted as caused by alder, and referred to an analysis by the Forest Products Laboratory showing that the root nodules on alder contain N-fixing bacteria analogous to those in legumes.

Tarrant and others (1951) compared litter fall and nutrient composition of foliage of the major Northwestern species. They found that alder litter had much higher N content than other species, and suggested that it had value as a soil conditioner.

A severely burned site on the Wind River Experimental Forest was operationally planted to Douglas-fir in 1929. A strip within the plantation was interplanted with red alder in 1933. Tarrant (1961) and Tarrant and Miller (1963) found striking differences in stand growth and soil conditions between the Douglas-fir-alder mixture and the adjacent pure Douglas-fir plantation. The mixed planting had greater total yield, markedly better development of the Douglas-fir, greater soil organic matter content, lower bulk density, and greater N content. Miller and Murray (1978) reported subsequent development of this plantation and findings in other mixed stands, and suggested possible regimes to take advantage of alder N-fixation. The Wind River study had some unique features: (1) the alder was planted 4 years after the Douglas-fir, (2) there was some freeze damage to the alder, and (3) the site was very deficient in N because of previous severe burns. These findings stimulated research interest in alder.

Franklin and others (1968) and Cole and others (1978) compared mineral cycling and N accumulation in young red alder, Douglas-fir, and mixed stands. Soil organic matter and N accumulation were much greater in the alder, and greater in the mixed, compared to the pure Douglas-fir stands. Binkley and others (1994) reviewed the existing information and concluded that average N accumulation rates in pure red alder were generally in the range of 100 to 200 kilograms per hectare per year (88 to 178 pounds per acre per year). Newton and others (1968) measured N accumulations in scarified soils approaching 300 kilograms per hectare per year (267 pounds per acre per year), some of the highest accretion rates reported. They also warned of differences in growth habits of alder vs. conifers that lead to incompatibility in mixed stands.

A number of studies have attempted to evaluate mixtures of alder and conifers, as an alternative to chemical fertilizers. The primary problem encountered is that of keeping early alder competition with the conifers at an acceptable level while maintaining sufficient vigorous alder to provide meaningful amounts of N. Experiments are still ongoing, but it appears that the most feasible approach is either crop rotation (facilitated by the early maturity of alder) or group-wise plantings.

Research has made clear that alder substantially benefits soil productivity where N is deficient, and that N-fixation by an alder component can be an asset in stand management. However, similar benefits can also be obtained by direct application of N fertilizer, and the comparative costs are uncertain. Alder necessarily occupies growing space that could otherwise be used for higher yielding conifers. Potential soil benefits from alder have not generally been a primary consideration by managers who have direct fertilization available as an alternative.

Additional work on the basic biology of N fixation by red alder and on alder's effects on soils and on ecosystem productivity is discussed in symposium volumes edited by Trappe and others (1968), Briggs and others (1978), Hibbs and others (1994), and Deal and Harrington (2006).

## **Oregon White Oak**

Oregon white oak (*Quercus garryana* Dougl. ex Hook), also known as Garry oak, is the only oak native to British Columbia, Washington, and northern Oregon. Other oaks are present in southern Oregon and northern California and may be associated. On most sites, Oregon white oak does not have the growth rates or maximum height potential of associated conifers and is thus overtopped and then succeeded by conifers. It is only considered to be climax on very dry sites.

At the time of initial Euro-American settlement, there were extensive areas of oak woodland and oak savannah and prairie in the Puget Sound region and in the Willamette Valley. These were maintained primarily by frequent burning by Natives, although natural fires were also important. Native Americans set fires to facilitate hunting, to favor food plants associated with the open environments (especially camas (*Camassia quamash* (Pursh) Greene), whose bulbs were an important food source), and to facilitate collection of other foods such as acorns and hazelnuts (Boyd 1999).

The areas of oak woodlands, oak savannas, and associated prairies have drastically declined. Reasons for this decline are (1) conversion to agriculture or urban development, (2) intentional conversion to conifers, and (3) invasion by conifers (primarily Douglas-fir) following fire exclusion. In recent years, interest has developed in the cultural and biological legacies associated with these areas. Although white oak is of negligible importance as a timber species, there are many plant and animal communities associated with these open habitats that are not found in conifer forests and several species considered to be threatened or at risk, including the western gray squirrel, several birds, the Mazama gopher, and various invertebrates. Current interests are in managing oak stands for wildlife habitat, biodiversity, or to keep or create open areas in the landscape.

Stein (1990b) summarized the then-available information on biology and management of Oregon white oak. Harrington and Kallas (2002) provided a more recent

bibliography. Larsen and Morgan (1998) summarized information on the wildlife habitat values of oak and made management recommendations for maintenance and restoration of oak stands, as did Vesely and Tucker (2005) and Campbell (2003).

Most oak habitats are on private land, but some public agencies such as Department of Defense (Fort Lewis Military Reservation near Tacoma, Washington), Bureau of Land Management, U.S. Fish and Wildlife Service Refuges, Natural Resource Conservation Service, Washington Department of Fish and Wildlife, Washington Department of Natural Resources, and Oregon Department of Forestry have programs to preserve, restore, manage, or protect areas of oak and prairie. Nongovernmental agencies such as The Nature Conservancy, the American Bird Conservancy, the Oregon Oak Communities Working Group, and the Garry Oak Ecosystems Recovery Team are also promoting conservation activities. Researchers associated with the USDA Forest Service Pacific Northwest Research Station, University of Washington, and Oregon State University are studying various aspects of oak and prairie biology and management (Peter and Harrington 2002, Regan and Agee 2004, Thysell and Carey 2001, Tveten and Fonda 1999).

There are three key aspects to managing these systems: (1) releasing oaks from the overtopping conifers (and preventing future overtopping), (2) managing the understory to control species composition and development, and (3) establishing oaks and related species in areas where they are currently not present.

Many oak savannas or low-density woodlands have been invaded by conifers (fig. 34). Action to remove the conifers is time critical because the overtopped oaks and other vegetation are often of poor vigor and will not survive much longer. Because conifers will grow well on many of these sites, followup treatments will be needed to prevent future overtopping. Deciding to manage for oaks or open areas is a long-term commitment.

Currently, there are a number of research studies, management trials, and regular forest management activities aimed at improving the condition of the oak and prairie



Figure 34—Fire exclusion has led to widespread conifer encroachment and overtopping of remaining Oregon white oaks.

systems. Prescribed burning is an important tool in managing oak (Agee 1996) and is being used by some agencies to control understory conifers (as well as exotic weeds such as Scotch broom and Himalayan blackberry). However, the danger, cost, and smoke nuisance associated with burning make this a treatment that can only be used in limited areas. Where burning is not feasible, mechanical removal or herbicide treatment can be substituted.

### **Black Cottonwood and Hybrid Poplars**

Several small-scale but successful industrial cottonwood plantings were made along the Willamette and Skagit Rivers by paper companies (fig. 35), the earliest being a 60-acre plantation established in 1893 by Crown Willamette Pulp and Paper Co., the forerunner of Crown Zellerbach Corp. (Brandstrom 1957). However, these remained very small-scale efforts. Major interest in *Populus* is a recent development in the region.

Development of fast-growing *Populus* hybrids had been underway for many years in Europe and the Eastern United States. In 1939, two 1.0-acre (0.4-hectare) hybrid poplar plantations were established at the Cascade Head



Figure 35—T.T. Munger in 1914, in an early cottonwood plantation.

Experimental Forest and on Lady Island, near Camas, Washington (Silen 1947).

The energy crisis of the 1970s produced an interest in short-rotation plantations as a possible source of biomass for energy production. Department of Energy funding stimulated work with red alder and hybrid poplars in the Northwest, with projects at University of Washington, Washington State University, Seattle City Light, and the Olympia Forestry Sciences Laboratory. Clones and cultural information developed in these projects led to industrial investments in growing *Populus* for wood fiber.

With the passing of the immediate energy crisis, interest shifted from biomass energy to fiber production and—recently—to solid wood products. In the 1990s, considerable acreages of *Populus* plantations were established by industrial owners, much of it on former agricultural land (Hibbs and others 2004). Their economic viability is unclear at present.

Recent comprehensive summaries of the subject are Stettler and others (1996) and Dickmann and others (2001).

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## Chapter 12: Changes in Society, Forest Management Objectives, and Supporting Silvicultural Research<sup>1</sup>

Over much of the history of northwestern forestry research, the primary, though not exclusive, interest was in timber production. This has changed markedly in recent decades. In this chapter, we briefly discuss some of the social changes and accompanying changes in public attitudes that have taken place in the Pacific Northwest and that have led to major changes in forest management objectives. We then discuss changes in research direction aimed at supporting current management goals.

### **Social Change and Silviculture**

Many concerns that are today referred to as “environmental” influenced policy from the earliest days of North American forestry. Thus, the writings of Marsh (1864) and Hough (1873) and others warned of the need to do something about the state of the Nation’s forests, and provided the stimulus for early legislation and establishment of the forest reserves (which became the national forests). The Organic Act of 1897 stated as objectives the preservation of the forests, improvement of water flows, and provision of a perpetual supply of timber. Activities and emphasis changed over time with changes in economic and political conditions and the development of transportation. Early efforts included rehabilitation of burns, fire protection, and exploration of regeneration methods after wildfire or harvest. Establishment of wilderness areas and research natural areas in the national forests began in the 1920s.

The selective timber management episode (Kirkland and Brandstrom 1936, Curtis 1998) (chapter 5) was an early—though unsuccessful—effort at a silvicultural alternative to large-scale clearcutting. The subsequent adoption of staggered settings (dispersed moderate-size clearcuts with intervening timber retained as a seed source) was an improvement over previous practices from the environmental as well as the timber standpoint, beneficial to populations of deer and elk and some other species. Efforts were

directed toward control of insects and diseases, enhancement of tree and stand growth, and improvement of wildlife habitat.

Although timber production had been one of several public land management objectives from the beginning, its importance increased greatly during the economic boom following World War II (WWII). Improved transportation and research in logging engineering helped to reduce the impacts of harvest operations on soils and streams, and provided greater flexibility in application of silviculture. With improved access and increased disposable income and leisure time, public concerns about recreation and wildlife assumed increased importance and influence on management of public lands. Many, though not all, of the environmental concerns we hear today were addressed under the name of multiple use (Fedkiw, n.d.). Thus, the emphasis given to the various uses of forest land has been and is continually changing.

Great changes took place in the social and economic structure of the Douglas-fir region over the last half of the 20<sup>th</sup> century. Prior to the 1950s, much of the population lived in rural or small-town settings. Much of it was employed in natural-resource-based industries—agriculture, forestry, and fishing—and had direct contact with practical resource management. Many people were generally supportive of efforts to place timber production on a permanent basis as a mainstay of the economy, and realized that planned management with timber production as a major, though not exclusive, objective was a vast improvement over the forest liquidation and widespread fires of the not very distant past. There was little or no opposition to efforts in this direction. Many people were also keenly interested in management of game fish and wildlife species, although problems with salmon had not yet been generally recognized and nongame wildlife received little attention.

In the post-WWII period, there was a great and continuing influx of people from other parts of the country. Many

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<sup>1</sup> By R.O. Curtis, D.S. DeBell, and M. Newton.

of the new immigrants came from urban backgrounds and had little direct contact with and little understanding of natural resource management or of regional history. Most settled in the expanding cities and found employment in urban-based industries such as aircraft, computers, and supporting services. Many saw little connection between their own well-being and the use of forests for commodity production. With increasing affluence and mobility, many came to value forests primarily for scenery and recreational use and as wildlife habitat. Many did not understand that forests are dynamic entities that are perpetually changing, with or without human intervention, and that it is not possible to perpetuate a given condition indefinitely. A substantial number regarded timber harvests as forest destruction and exerted increasing political pressure for withdrawal of public lands from commodity production and for restrictions on commercial forest operations. To some, large trees and old forests had unique spiritual values. A fringe element found in these attitudes a convenient excuse for disruption and vandalism, including criminal actions such as the arson fires that destroyed the Department of Natural Resources Land Management Center and Animal and Plant Inspection Service facilities in Olympia, Washington, in 2000 and the University of Washington Center for Urban Horticulture in 2001 and caused extensive damage to various facilities elsewhere.

Several developments in Douglas-fir silviculture exacerbated the conflicts among groups interested in the regions's forests. The shift to planting (primarily of Douglas-fir) as the primary regeneration method meant that it was no longer necessary to limit the size of clearcuts and retain seed blocks. Many owners used larger clearcuts to save on road and logging costs. Concurrently, there was a progressive reduction in rotations by many industrial and other private owners, motivated primarily by the desire to maximize net discounted timber values. The combined effect was creation of landscapes with extensive areas of unsightly recently cut land, with the rest of the landscape largely occupied by uniform young stands of a single species that are the least productive condition for many

species of wildlife and that are regarded as unattractive by many people. Public reaction to these visual effects was an important factor in the developing opposition to clear-cutting as a silvicultural system and to forestry operations in general.

The rise of the environmental movement in recent decades as a factor in Northwestern forestry is associated with these social and management changes. It has exerted an increasing influence on public policies, and has had major effects on both forest land management and silvicultural research. It has stimulated silviculturists and land managers to adopt broader perspectives, including increased consideration of social and ecological values. It has been a significant factor in directing more research toward management for multiple objectives including wildlife habitat, scenic values, biodiversity, and long-term sustainability, in addition to traditional commodity production goals. On the other hand, increased pressures and considerable sensational and often misleading propaganda from activist groups and individuals have at times overshadowed the efforts of more moderate groups. Conflicts and extreme positions often receive more attention in the news media than do constructive accomplishments. Contributing factors include (1) the difficulty that many people have in grasping the range of management options that exist and the timescales involved in forest development, (2) the increasing and sometimes exclusive public emphasis on wildlife, often directed at single species—as exemplified by the spotted owl recovery effort (mandated by court decisions); and (3) a romanticized and unrealistic view of “untouched nature” as an ideal condition, necessarily degraded by any human intervention. To some degree, the differences in viewpoints, values, and underlying philosophy extend into the scientific community, (for example, Salwasser and others 1997 vs. Noss 1995) and have been accentuated by lack of communication and mutual understanding between specialized disciplines.

Namkoong (2005) provided a wide-ranging discussion of the historical and cultural origins of the different conceptions of the nature and role of forests and the differing

objectives, which range from short-rotation plantation forestry aimed exclusively at wood production at one extreme, to restoration of a mythical untouched nature at the other.

The tunnel vision evident in many land management disputes is not limited to the usual pressure groups and segments of the public. We like to think that “science” is unbiased, and no doubt it is, in the long run. But individual scientists have their own biases, whether they be silviculturists, ecologists, wildlife biologists, or whatever. They also can become preoccupied with pet topics, and are often unaware of existing knowledge and historical experience outside their immediate and sometimes narrow range of expertise. Also, the behavior of forests is influenced by the wide variations that exist within the region in soil and local climate, and by short-term weather fluctuations. Therefore, generalizations derived from individual studies that are not replicated in space and time can easily be misleading. Answers to many forestry questions are dependent on well-designed and well-replicated long-term experiments, which are expensive (and therefore few in number), dependent on continuity in funding and personnel, subject to disruption by pests and climatic events, and likely to be lost to the pressures for quick answers to the question of the moment. There is therefore, at best, considerable uncertainty in interpretation of existing science.

Incomplete knowledge and conflicting viewpoints and objectives have resulted in land management policies that are increasingly driven by political considerations and judicial decisions, some of which have had considerable effects on research.

Several factors affecting research on federal lands are associated with the Northwest Forest Plan (FEMAT1993), Record of Decision (ROD) (USDA FS 1994) These include:

- Inadequate funding and other limitations to conducting large-scale manipulative research over a sufficient range of conditions and practices.
- The near-failure of the adaptive management areas (AMAs) of the Northwest Forest Plan. The AMAs were intended to encourage federal land managers

to try new and bold approaches, but have not generally been effective. Obstacles have resulted from lack of organizational support and from an institutional and regulatory environment that stymies innovation and makes managers unwilling to accept risks of failure and unwilling to try nonstandard practices that may provoke conflicts with segments of the public (Haynes and Perez 2001; Stankey and others 2003, 2006).

- Single-purpose set-asides or constraints that have curtailed or shut down ongoing research and negated the very purposes for which long-time research areas were dedicated. For example, inclusion of the Wind River and Cascade Head Experimental Forests in late-successional reserves.

Allied to these problems is the difficulty and frequent inability to conduct experiments on federal lands because of delays and disruptions associated with the regulatory and appeals processes (which can destroy the validity of an experiment), exclusion of large areas from any manipulation, and reluctance of managers to allow treatments that might provoke opposition or that conflict with existing guidelines. These difficulties are manifestations of what has been variously termed the “process predicament” and “analysis paralysis,” in which the multitude of overlapping and sometimes conflicting laws, regulations, and court decisions render timely and effective action on anything almost impossible (Thomas 2000, USDA Forest Service 2002). One result is that some researchers in the Pacific Northwest, have abandoned attempts to work with the national forests in favor of state agencies and industrial owners.

Contributing factors include the general tendency of regulations, guidelines, and policies—necessarily based on incomplete knowledge and often influenced by political factors and judicial decisions—to become fixed dogma. Likewise, the tendency under the Endangered Species Act to direct effort toward individual species to the exclusion of other considerations, including the habitat needs of many other species.

The current prohibition on most uses of herbicides on most federal lands in the Pacific Northwest is an example of a policy driven by public attitudes that has had serious effects on land management and considerable impacts on silvicultural research. Segments of the public are opposed to any use of “chemicals,” an attitude that initially stemmed from harmful effects on wildlife of widespread use of the persistent insecticide DDT and was reinforced by the military use of “Agent Orange” as a defoliant and crop destruction tool in the Vietnam War. Negative perceptions have been reinforced by the tendency of the public and the media to lump all such materials under the generic term “pesticide,” without recognizing that there are a wide variety of such materials, and that these differ in persistence, mode of action, environmental effects, and uses.

Alleged human health effects from use of 2,4,5-T on the Siuslaw National Forest (Newton and Young 2004, US EPA 1979, Wagner and others 1979) led to suspension of use of herbicides on most federal lands in the Pacific Northwest in 1983. Subsequent development of herbicide technology and herbicide use continued elsewhere. Despite convincing evidence that currently used herbicides are often less expensive and more effective, safer, and more benign in their effects on the environment than alternative methods of controlling unwanted vegetation, that amounts used in forestry are very small compared to those routinely used in agricultural and other applications (Kimmins 1999: 129–138), and that currently used herbicides have not been shown to have harmful effects, advocacy groups opposed to any herbicide use have been successful in preventing nearly all use of herbicides on federal lands. This is a major limitation in cost-effective restoration of forests on burns and other nonstocked areas and in the control of invasive species and vegetative competition.

Dogmas do not all originate outside the forestry community. Historically, one may cite the clearcut-burn-plant-Douglas-fir regime that was nearly universal from about 1950 to the 1990s, as an example of silvicultural dogma. This regime was highly successful as a means of establish-

ing prompt regeneration, and came to be accepted by a generation of foresters as **the** regime for management of Douglas-fir. But, its near-universal application in combination with progressively shortened rotations has had undesirable effects on public attitudes, scenic values, and many species of nongame wildlife. And, because of its very success in the context of the timber-oriented needs of the time, very little research was done on possible alternative regimes until quite recently.

Another forestry dogma was the goal of total elimination of wildfire, almost universally accepted until quite recently. This had only limited effects in the northern portion of the Douglas-fir region, but considerable effects in the drier climate of southwest Oregon and northern California.

There are older examples of historical interest. Thus, Fernow’s 1903 attempted application of practices widely accepted at the time in his native Germany was halted, and the Cornell forestry program terminated, because of public reaction to visual effects (Dana 1953, Rodgers 1991). Lesson: public attitudes can and often do override science and economics and must be considered in silvicultural decisions.

Ernst (1998) recounts the conflicts over early introduction of block clearcutting and regeneration in Germany, which was prohibited by a court decision in one jurisdiction in 1764. Despite conflicts, it was widely adopted and was highly successful in rehabilitating extensively degraded forests, though considerably modified in more recent times. Lesson: the clearcutting furor of the recent past is nothing new!

The environmental historian Radkau (1996), reviewing the changes in German attitudes to forestry over the past several centuries, concluded with the statement:

. . . even those foresters who have the good will to think ecologically do not find a common basis with environmental fundamentalists who want to ban economic considerations from the woods. . . If environmental history is able to produce any practical benefit, it could do so by overcoming the

estrangement between forestry and the environmental movement. . . by criticizing dogmatic tendencies on both sides and arguing against the trend of playing off ecology against economy.

Lesson: North American problems are not unique.

### **Sustained Yield, Multiple Use, Ecosystem Management, and Sustainable Forestry**

By the 1990s, differences in attitudes and understanding had created a degree of polarization that drastically impacted forest management and the economy of many small timber-based communities. It also produced marked changes in direction of research by public agencies. These changes included a great expansion in wildlife- and wildlife-habitat-related research, and initiation of research—most of it necessarily long-term—on silvicultural practices and regimes designed to promote scenic and wildlife values. Particularly, on those characteristics commonly associated with late-seral conditions and old-growth-dependent wildlife. There was also renewed interest in selection systems, natural regeneration, and species other than Douglas-fir.

Traditional commodity-oriented areas of research such as regeneration, pruning, fertilization, and tree improvement continued, but were now carried out primarily by the various landowner-supported research cooperatives at the universities. There was also considerable research by major industrial owners, some of it in cooperation with the universities and public agencies.

In this period, a number of new terms were added to traditional forestry terminology, ostensibly to describe changing management objectives.

**Sustained yield** is a long-established term for a management objective that dates from the early 19<sup>th</sup> century or earlier in Europe, and was increasingly adopted in the United States from the 1930s on. Originally, it denoted organization and management of a forest property for continuous timber production with the aim of achieving—at the earliest practicable time—an approximate balance between growth and harvest. By the late 20<sup>th</sup> century, the larger ownerships in the region were far along in conversion to

continued production, although attainment of a balance between growth and harvest was often delayed by unbalanced stand age distributions and by disruptions associated with ownership changes in the private sector and land use allocation changes in the public sector.

The historical definition of sustained yield was broadened in its application to the national forests by the Multiple Use-Sustained Yield Act of 1960, which stated (Sec. 4):

Multiple use means the management of all the various renewable surface resources so that they are utilized in the combination that will best meet the needs of the American people; . . . and harmonious and coordinated management of the various resources. . . without impairment of the productivity of the land, with consideration given to the relative values of the various resources, and not necessarily that combination of resources that will give the greatest dollar return or greatest unit output.

Sustained yield of the several products and services means achievement and maintenance in perpetuity of a high-level annual or regular periodic output of the various renewable resources without impairment of the productivity of the land.

**Ecosystem management** and **sustainable forestry** are terms of recent origin. To us, they appear little different in meaning from the 1960 definitions given above. These terms appear to have come into use as an attempt to distinguish between certain past practices (particularly, large-scale clearcutting) and current practices and proposals, and to offset the perceptions of some to whom “sustained yield” and “multiple use” have connotations of a primary emphasis on timber production. Shifts in emphasis include de-emphasis of timber production in favor of a more holistic view emphasizing—in addition to the traditional multiple-use concerns for game animals and recreation—maintenance of biodiversity and ecosystem function, visual effects, and avoidance of hypothesized deleterious long-term effects from some forms of management (Hobbs and others 2002b).

This collection of ideas is also associated with the closely related term “new forestry,” common in the 1990s.

There remains a wide gulf between those environmental groups philosophically opposed to any form of active management, and more moderate environmental groups who believe that “do nothing” policies are neither biologically nor economically feasible in the long run. Unfortunately, concentration for the past half century on a single form of management—clearcutting, planting one species, and steadily decreasing rotation lengths—has provided the public with few on-the-ground examples of the long-term effects of alternative practices.

Over the past 15 years or so, there has been a great increase in research by ecologists and wildlife biologists on the relations between forest conditions and populations of small mammals, birds, lichens, and other organisms (Bunnell and others 1997). The main conclusions appear to be (1) large woody debris and large snags have a role in maintaining populations of certain small vertebrates and birds, (2) large trees and snags have value as refugia for organisms such as lichens that may have difficulty in recolonizing large open areas, and (3) different species have different requirements, and no one condition is favorable to all. Quantitative relationships between amounts of woody debris, snags, residual trees, and size and distribution of openings on the one hand, and their effects on the various wildlife and plant species on the other, are not well defined. Because species differ in their habitat requirements, maintenance of all species also requires provision of a wide range of habitat conditions (DeBell and Curtis 1993, Kohm and Franklin 1997). The current emphasis on “biodiversity” does not necessarily require diversity within each stand; biodiversity may be better achieved by a mosaic of diverse conditions at the landscape level (Boyce 1995, Kimmins 1999).

The emphasis on development of stands with late-seral characteristics arose in part because old growth was perceived as in short supply. In turn, this implies that on some portion of the land base, management should strive to create conditions with some of the attributes of late-seral

stages—large trees, large snags, down wood, and layered structure (McComb and others 1993). Silviculture can accelerate the rate of development of these characteristics to a degree that is not generally realized. Much current silvicultural research is directed at accomplishing this acceleration, through changes in thinning regimes, harvest and regeneration practices, and rotations. This includes both new work and reinterpretation of work done in the past.

Curtis and others (1998) synthesized existing knowledge related to silviculture for multiple objectives and showed that the knowledge base is far greater than generally known outside the field of silviculture. Several papers included in Monserud and others (2003) and in Hobbs and others (2002b) also reviewed knowledge and ongoing research in multiple objective management, including specifically the promotion of biodiversity.

The change in emphasis has increased interest in silviculture of Northwestern hardwoods, associated in part with the new concerns with biodiversity. There is also more emphasis on the visual effects on the landscape, on public perceptions of silvicultural practices, and on the possibilities of using alternative silvicultural systems.

## Visual Effects and Public Perceptions

The conflicts that have developed in recent years between the perceptions and desires of an urbanized public primarily interested in scenic, recreational, and wildlife values, and the economic needs for efficient commodity production and support of the rural economy, constitute the most serious problem in Northwestern forestry today. To a considerable extent, these conflicts arise from the high visibility of forestry operations on the landscape. There is thus a growing interest in silvicultural measures that may reduce conflicts while maintaining some reasonable level of commodity production. Such measures include different sizes, shapes, and arrangements of harvest areas; different amounts of green-tree retention on harvest areas; and extended rotations combined with increased emphasis on thinning. A number of studies over the past two decades have addressed the questions of (1) visual acceptability of

alternative practices and (2) the costs involved (Clausen and Schroeder 2004).

Visual acceptability questions are often addressed by surveys in which respondents are asked to rate examples of typical practices, presented either as on-the-ground examples or—more frequently—as photographs or pictorial images. Typical examples are work by Brunson and Shelby (1992), Shelby and others (2003), Bradley and others (2004), and Ribe (2005). An important aid in such studies is visualization software (McGauhey 1998), which can create images of anticipated conditions. In general, results indicate that acceptability decreases with increased size of openings, with decreased number of retained trees in partial cuts, and with increased amounts of slash and down wood.

A drawback of many visual acceptability studies is that they tend to concentrate on conditions shortly after harvest rather than average condition over the life of the stand, or the landscapes produced by application of a regime over an extended period. Unfortunately, we have at present no concrete examples of the landscapes that can be expected from long-term application of regimes (including “do-nothing”) other than conventional short-rotation even-age management.

## Green-Tree Retention

Retention of scattered overstory trees, either as groups or scattered individuals, for presumed, though largely unquantified, wildlife and ecological benefits (Aubry and others 2004, Franklin and others 1997, Mitchell and Beese 2002) is now a common and in part a legally mandated practice, superimposed on even-age management (fig. 36). As amount of growing stock retained increases, there is a transition from more-or-less conventional even-age management to uneven-age management with either two-aged (reserve shelterwood) or patch- or group-wise uneven-aged structures.

There have been several attempts to evaluate the effect on timber production of retention of overstory trees (green-tree retention). Lacking permanent-plot data, most studies have been retrospective in nature (examples: Wampler



Figure 36—It is now common practice to leave scattered green trees or groups of trees and snags on harvest areas for wildlife and other purposes. Although superficially resembling past seed-tree cuts, the trees are not retained for regeneration purposes.

1993, Zenner and others 1998) or simulations (example: Birch and Johnson 1992). These indicate—as would be expected—that green-tree retention reduces growth of the understory, with reduction increasing as number of trees retained increases. It may also increase the difficulty of controlling competing vegetation.

The recently established DEMO study (Demonstration of Ecosystem Management Options) is a large regional study with six replications, designed to examine the ecological effects of several amounts and physical arrangements of green-tree retention after a single harvest operation (Aubry and others 2004, Franklin and others 1999). As originally planned, it made no provision for postharvest vegetation management or density control and therefore

does not mesh well with other research and applications aimed toward sustainable management regimes.

## Nontraditional Thinning

The LOGS (Levels-of-Growing-Stock) study in Douglas-fir (Curtis and others 1997) and a variety of other less elaborate thinning trials have shown that early and repeated uniform thinning can produce dramatic increases in individual tree growth and understory development. On good sites, large trees can be produced at relatively young ages.

Retrospective studies of operationally thinned and unthinned mid-age stands, and of age distributions and stand structures in old-growth and young-growth forests, have shown that appropriate thinning of mid-aged stands hastens the development of multistory stands (Bailey and Tappeiner 1998, Poage and Tappeiner 2002) and that many existing old-growth stands were established at much lower densities and with a much greater range in ages than young growth established following harvest. The marked differences in developmental trends suggest that in the absence of active management, many existing young stands will not develop into stands similar to existing old growth (Tappeiner and others 1997). Muir and others (2002) provided a comprehensive review on the potential of thinning for shaping stand development and suggested general guidelines for thinnings in young Douglas-fir forests to promote biodiversity and development of late-seral characteristics.

Most older thinning studies in Douglas-fir have applied uniform thinning to uniform even-aged stands. Treatments have usually been either low thinning or crown thinning, differing only in amount of growing stock retained and frequency of thinning. Several thinning studies have been established recently to examine techniques for promoting development of diverse stand structures through unconventional irregular thinning. Associated with these trials are efforts to maintain or establish secondary species.

One such study in young Douglas-fir plantations compares development of unthinned stands with stands treated with regular thinning, irregular thinning to create gaps, and with and without supplemental planting of other species in the gaps (Reutebuch and others 2004) (fig. 37). The first block was installed in a large area of uniform plantation in the Mount St. Helens blast zone.<sup>2</sup> An additional block was subsequently installed on the Willamette National Forest, and a very similar trial was established by Washington Department of Natural Resources<sup>3</sup> in the Forks area.

A second large-scale study involves irregular thinning in several mid-aged stands on the Olympic National Forest (Harrington and others 2005). A third study is in mid-aged stands on the Fort Lewis military reservation (Carey and others 1999). A fourth somewhat similar study was established at about the same time by Oregon State University and the Willamette National Forest. All recent studies use much larger treatment areas than the small plots (0.4 hectare or less, 1 acre or less) typically used in early thinning studies.

A large study at Oregon State University is designed to evaluate silvicultural practices to promote understory structure and diversity combined with overstory maturation, as stands mature in a two-story system. Several reports have described overstory effects on understory (Brandeis and others 2001a, 2001b, 2002) and damage to understory in rethinning (Newton and Cole 2006). Several other trials with broadly similar objectives, recently established by a number of organizations, are listed in Hunter (2001).

It has been commonly thought that old trees will not respond to thinning, a belief that probably stems in part from the unfavorable results of early selective cutting (chapter 5), in which choice of residual trees was largely dictated by immediate economic rather than silvicultural considerations. Recent work (Latham and Tappeiner 2002) has shown that, in many cases, removal of understory and less vigorous

<sup>2</sup> Lead scientist is Connie Harrington, Forestry Sciences Laboratory, Olympia, WA.

<sup>3</sup> Lead scientist is Richard Bigley, Washington Department of Natural Resources, Olympia, WA.



Figure 37—Experimental thinning in a plantation in the Mount St. Helens blast zone, aimed at creating irregular stand structure to enhance biodiversity: (A) uniform plantation, (B) uniform stand created by conventional precommercial thinning, and (C) irregular thinning.

trees accelerated growth of trees 200 or more years old. This not only promotes development of larger trees, but can be expected to reduce susceptibility to bark beetle attack, and possibly somewhat reduce the risk of stand-replacing fires.

## Forest Health Issues

Sporadic minor damage from weather, insects, and diseases is a normal part of stand development, and in recent years the Douglas-fir region has been largely free from catastrophic damage. This is due at least in part to the prevalence of vigorous young stands, in contrast to the overstocked and low-vigor stands that are currently a major problem in forests east of the Cascade crest. Silviculture is the principal means of preventing or controlling a variety of damaging agents (Curtis and others 1998: 67–72). Recent changes in silvicultural practices and management policies may have effects on west-side forest health, which have as not yet been well evaluated.

The most serious diseases are the endemic root rots. Control consists in removal of infected trees followed by planting of resistant species (or removal of infected stumps). Recent interest in use of resistant species such as redcedar, red alder, and white pine to increase species diversity is consistent with control of root rots.

Extensive damage by Swiss needle cast (*Phaeocryptopus gaeumanni*), an organism formerly considered innocuous, has occurred recently on Douglas-fir plantations within or near the Sitka spruce zone. Causes are uncertain, but a plausible hypothesis is that the needle cast problem is associated with extensive planting of pure Douglas-fir (perhaps from nonlocal seed sources) on sites formerly dominated by hemlock and spruce.

In the past, the most serious insect problem has been the Douglas-fir bark beetle (*Dendroctonus pseudotsugae*). Losses to bark beetles are usually a minor factor in young vigorous stands, but large and very damaging outbreaks have occurred at intervals in the past, usually triggered by extensive blowdown or fire events (Furniss and Carolin 1977). Control is by prompt salvage of infested trees, and by appropriate thinning to maintain vigor and windfirmness. This is no longer possible on some public lands because of conflicts with reserve status and opposition by segments of the public. Hence the risk of future major outbreaks is increased.

Dwarf mistletoe (*Arceuthobium tsugense*) can be seriously damaging in hemlock. The older practices of clear-cutting and broadcast slash burning were effective in controlling the problem. The shift to green-tree retention and efforts to develop multilayered stands have the potential to increase future infestations through spread from the retained trees to regeneration.

Understory development, layered stands, and increased amounts of coarse woody debris—although desirable from the standpoints of wildlife habitat and visual effects—can also increase fire risk through increased fuel loads and creation of fuel ladders that can carry fire into tree crowns. This is of particular concern in the southern and drier part of the region, where the presettlement pattern was one of relatively frequent light burns in contrast to the stand-replacing fires that occurred at long intervals farther north (Agee 1993). Appropriate thinning (followed by underburning in some situations) can reduce fuel loads and minimize the risk of intense fires.

Stand density control (initial spacing, thinning) can markedly reduce the risks of wind and snow damage (Wilson and Oliver 2000) and also enhance resistance to bark beetle attack, by lowering height/diameter ratios and increasing tree vigor.

Animal damage is often serious. With the general shift to planting rather than natural regeneration, seed consumption is no longer as critical as it once was. But browsing of seedlings by deer and elk, mountain beaver damage to seedlings and saplings, and bark stripping by bear are all serious problems. Deer and elk browsing is the principal obstacle to wider use of redcedar, otherwise silviculturally and ecologically desirable. There has been extensive research on animal repellents, physical barriers to browsing, use of large planting stock, and supplemental feeding in efforts to overcome the problems (for example, Black 1992, Newton and others 1993, Nolte and Otto 1996). Success has been limited, and animal damage remains a serious problem in many areas.

## Nontimber Forest Products

Commercial harvest of nontimber forest products, although not new (Adams 1960, Isaac 1945), has become an economically important activity in recent years. These products include Christmas trees, floral greens (swordfern, salal, Oregon grape, boughs, moss), beargrass, mushrooms, huckleberries, and medicinal plants. To some extent, productivity can be influenced by silviculture, most notably through stand density control. Christmas tree and bough production can be a part of precommercial thinning. Development of understory species is influenced by stand density and by stand age.

Research is in progress on management of nontimber forest products, which necessarily involves silviculture, and which we do not review here. General discussions and extensive references are given by Duncan (2003), Kerns and others (2003), and Molina and others (1997).

## Growth Trends, Rotations, and Carbon

Important research and policy questions are involved in choice of management regimes and rotations and their possible effects on carbon sequestration and climate change.

Reexamination of permanent-plot data from past experiments has shown that culmination of mean annual increment in Douglas-fir is later than commonly thought, and is probably delayed by repeated thinning. Considerable extension of commonly used rotations is possible without loss of volume production (Curtis 1995, Newton and Cole 1987), and possibly even with some increase in value production. Moderate extension of rotations combined with greater use of thinning could markedly reduce visual and environmental effects of harvest operations while increasing employment, long-term timber yields, tax revenues, carbon sequestration, wildlife values, and flexibility to respond to future unknown social and economic changes (Curtis and Carey 1996).

Carey and others (1999) simulated three alternative management strategies for an area on the Olympic Peninsula—no management with protection, maximization of net present value of timber (clearcutting on 40- to 50-year

rotations, with required riparian buffers), and a “conservation of biodiversity” strategy (Carey and Curtis 1996) using a mix of treatments including extended rotations. They concluded that the “conservation of biodiversity” strategy developed a target proportion of late-seral stands much sooner than did the protection-only alternative; produced nearly as much timber as the “maximum net present value” alternative; minimized area in the stem-exclusion stage (Carey and Curtis 1996), in which development of understory vegetation is prevented and some trees become suppressed and die; and was generally more desirable from the ecological and wildlife standpoints. Although the cost in terms of reduced net present value of timber was higher for the “conservation of biodiversity” strategy than for the maximum net present value strategy, the differences were not large. Lippke and others (1996) concluded that the benefits in enhanced employment, tax revenues, and carbon sequestration were sufficient to justify some form of publicly funded incentives to compensate landowners for the added financial costs.

In recent years, there has been much public concern about climatic warming and its possible consequences, the marked increase in atmospheric CO<sub>2</sub> (attributed to use of fossil fuels), and the possibility that the latter is a major causal factor in climatic change and is subject to some degree of human control. Forests store large amounts of carbon, and both afforestation and modified silvicultural regimes are potential means of increasing carbon sequestration. There is also a future possibility of plantation-based biomass energy production, without the net CO<sub>2</sub> production inherent in the use of fossil fuels (Larson and Johanssen 2001). A goal of increasing carbon storage has at least two aspects that affect silviculture and needs for silvicultural research:

- Change in growth conditions associated with predicted warmer climate and increased atmospheric CO<sub>2</sub> could affect species and family adaptation and susceptibility to insects and disease. It could also require modification of growth functions and simulation programs used to predict development of forests.

- The most obvious silvicultural regime changes for the purpose of increasing carbon sequestration are an increase in rotation length with an associated increase in growing stock (Harmon and Marks 200, Haswell 2000, Peterson and others 2004), combined with minimal slash removal. Longer rotations would also benefit long-term wood production, wildlife habitat, and scenic values.

The principal difficulties in any extension of rotations are (1) temporarily reduced cash flow for those owners currently lacking older stands; (2) reduced net present (discounted) value of future timber yields, which in the absence of other incentives is an overriding consideration for those owners whose primary objective is maximum percentage return on their timber investment; and (3) recent conversion of many mills to processing small logs, with resulting loss of price premiums and markets for large logs. The potential benefits of extended rotations are primarily public benefits that do not accrue to the individual owner. Thus, extended rotations are at present primarily an option for public ownerships. This situation could change if present and predicted climatic trends lead to active public programs that encourage carbon sequestration via carbon credit trading or other forms of direct or indirect subsidy.

## **Riparian Silviculture**

West-side stream conditions have been markedly changed since the first European settlement. Factors involved include extensive urbanization with attendant changes in runoff, stream temperatures, and stream pollution; logging; dams that obstruct the passage of fish; agricultural operations; and clearance of stream channels to facilitate transportation (including early-day log transport and fish passage). Marked declines in salmonid populations have occurred in the past several decades. The decline is at least partially attributable to the off-shore fishery. Nevertheless, the decline is widely perceived as having its origins in declining quality of freshwater habitat. Salmon recovery has been a major public concern for a couple of decades,

leading to restrictions on forest operations in riparian zones. At present, such restrictions not only limit forest operations in riparian zones for either harvest or stand improvement, but also complicate efforts intended to enhance spawning and survival.

Forests are not static, and presettlement conditions included periodic large-scale disturbances (fire, windfall) and debris flows that influenced stream productivity (Reeves and others 2002). Timber harvest has in part replaced fire as a major influence, analogous to but not the same as presettlement disturbances. Low-elevation riparian zones, especially those characterized by significant terraces, are frequently occupied by red alder, a species with a limited life expectancy leading to shrub-dominated communities as overstories senesce (Newton and others 1968). The dilemma today is how to create a level of disturbance that ensures establishment of coniferous stands as characterized in the Oregon criteria for desirable future conditions (Oregon Department of Forestry 2003).

In the 1950s and 1960s, governmental programs favored removal of wood from streams in the belief that this would facilitate passage of fish (Reeves and others 2002). It was subsequently recognized that large woody debris is important in forming pools essential to spawning and survival, and current policies aim to provide such material together with streamside shading to maintain low water temperatures.

Recent research on riparian silviculture includes efforts to provide cover needed for cool streams and productive aquatic communities, to ensure production of large, durable conifer wood to enhance stream habitat (Bilby and Bisson 1998), and to enhance development of late-seral conditions. Several events, beginning with reports by Brown (1969) and Brown and Krygier (1970), led to concerns with streamside cover and water temperature interactions. This was reinforced by the Forest Ecosystem Management Assessment Team report (FEMAT 1993). The recent listing of many strains of salmon as threatened has stimulated interest in how riparian forests can be managed to ensure the future of the salmon resource.

Much of this research is concerned with determining effects of streamside buffers vs. no buffers, and occasionally with buffer characteristics; with techniques for promoting desired conditions; and with the possibilities of combining limited timber production from riparian areas with stream protection. Extremely restrictive buffer requirements have major economic impacts, and the future of stands without maintenance is uncertain. Stream-side vegetation changes over time, and some stream-side conditions present today as a result of previous disturbance are unlikely to develop desirable characteristics in the long run. Producing large conifer material for stream channel improvement has been identified as an important value of mature forests adjacent to streams (FEMAT 1993, Oregon Department of Forestry 2003). Much research in the last 20 years has been devoted to active management measures aimed at establishment and maintenance of conifers and multilayered canopies in the riparian zone. Salo and Cundy (1987) provided a major work on interaction of aquatic and terrestrial systems that led to both regulatory activity and research to resolve issues on influence of streamside forests. Walsh (1996) provided some of the first insights on how buffers and their arrangements influence aquatic insects that are a major prey base for fish. Newton and Cole (2005) expanded this to include concepts of establishing several species of conifers as long-term streamside cover following conversion from red alder.

Several major initiatives have emerged in the past decade that illustrate the cooperative nature of programs within Oregon to resolve conflicts and illuminate some unresolved questions in riparian management. The Coastal Oregon Productivity Enhancement (COPE) program brought together federal, state, and private resources in a major 10-year effort to improve understanding of the roles of terrestrial and aquatic portions of the stream environment and how these influence stream biota. Hobbs and others (2002a) summarized the findings of this program, which mostly dealt with stream processes and ecological assessment of coastal forests. Very few manipulative experiments were conducted, and the need for quantitative analysis of the specific impacts of forest practices remains.

Concurrently with COPE, several other cooperative efforts between the university and state and industrial forest landowners have led to improved understanding of the effects of harvest practices on water temperatures (Zwieniecki and Newton 1999) and of opportunities to improve streamside stand composition while maintaining stream productivity. Newton and Cole (2005), for example, discussed rehabilitation of riparian hardwood forests and the size of overstory openings needed to secure satisfactory juvenile growth of conifers. They also observed that riparian reforestation depends heavily on protection from ungulate browsing and beavers. Zwieniecki and Newton (1999) and Newton and Cole (2005) have shown that harvesting close to streams while leaving narrow buffers or strategically designed residual shade can maintain cool streamwater, while providing opportunity to establish large durable conifers close to streambanks. Their work and that of Rutherford and others (1999) also showed that stream productivity can often be increased by allowing diffuse light to reach the stream. Skaugset<sup>4</sup> provided evidence that timber harvest along non-fish-bearing headwater streams did not have a warming influence on downstream waters, although some unbuffered streams warmed appreciably within units. These reports reinforce the hypothesis that streamside harvests, at least in small headwaters streams, would not lead to cumulative warming.

Chan and others (2004) reported a current large-scale stand management experiment on Bureau of Land Management lands in western Oregon that includes comparisons of stream-buffer widths and within-buffer silvicultural treatments. Early results suggest that differences in residual thinning densities and buffer widths result in relatively small changes in the riparian environment, and that these effects are not associated with detectable changes in riparian-dependent organisms. Clearcutting is not a factor in this study; all streams were buffered by stands thinned to various densities. Long-term renewal of the streamside coniferous cover was not evaluated.

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<sup>4</sup> Skaugset, A. Processes that influence the downstream propagation of stream temperatures. Manuscript submitted to *Forest Science*.

Integration of stream treatments with fish-biology research is now recognized as crucial. The Watershed Research Cooperative at Oregon State University and the Headwaters Research Cooperative, a consortium of landowners and agencies, has been formed to conduct research on managed watersheds and to collect and disseminate monitoring data on stream systems. One major company (Roseburg Forest Products) has contributed a 5,000-acre (2000-hectare) watershed plus considerable infrastructure in support of the Watershed Research Cooperative's Paired Watershed Study, which is a long-term initiative to evaluate the effects of intensive management on fishery resources. Two more paired watersheds on industry and state lands are currently under evaluation. Collectively, results from these studies will likely have a major effect on policies affecting streamside silviculture.

Good general discussions on riparian silviculture with extensive references are Hayes and others (1996), Hobbs and others (2002b), and Cunningham (2002).

## **Comparisons of Silvicultural Systems and Management Regimes**

Silvicultural research in the past was typically carried out on small plots selected for uniformity and comparability of initial conditions and with close control of treatments. Given suitable experimental designs, statistical tests were easily applied. Although small-plot experiments have provided much valuable information on forest biology and on development of trees and stands, their results are often not directly applicable to the larger and more heterogeneous areas that a manager must deal with. And they cannot provide information on variables that cannot be evaluated on small areas, such as wildlife and visual effects.

A few recently established long-term studies are designed to compare results and costs of alternative management regimes that aim to combine timber production with reduced visual and ecological impacts (Arnott and Beese 1997; Maguire and Chambers 2005; McComb and others 1994; Monserud 2002, 2003). As one example, a

large replicated study involving the Pacific Northwest Research Station, Washington Department of Natural Resources, and the British Columbia Ministry of Forests compares costs and yields for conventional clearcutting, two-age management, repeated small-patch cutting with repeated thinning of the matrix, group selection with repeated entries, and continued thinning on an extended rotation (Curtis and others 2004, DeBell and others 1997, De Montigny 2004) (figs. 38 through 44). The treatments are expected to produce widely different stand structures with corresponding differences in visual effects, wildlife effects, and acceptability to the public. This study differs from DEMO in that it is a comparison of regimes rather than of results from a single entry. Conversion of the large units used will extend over the next half century, and a variety of intermediate growth-enhancing treatments will be applied.

Several other long-term operational-scale experimental trials of alternatives to conventional clearcutting are in progress in the United States and western Canada (Monserud 2002, Peterson and Maguire 2005). Large treatment areas are required to provide realistic evaluations of operational timber yields, costs, stand structural changes, and scenic and wildlife effects. These cannot be provided by the small-plot experiments common in the past.

Large-scale long-term experiments involve some major challenges:

- It is difficult to find large treatment areas that can be considered comparable. At best, there is much uncontrolled variation that reduces the power of statistical tests.
- Variation in soils and local climate make replication in time and space important for valid generalizations of results.
- The variety of questions and likelihood of future unforeseen questions make an interdisciplinary structure highly desirable.
- They require close cooperation and coordination between the research and land managing organizations.

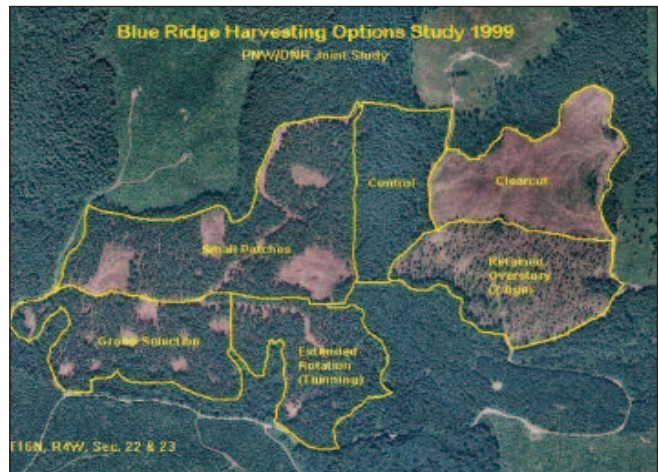


Figure 38—The Blue Ridge replication of the Silvicultural Alternatives for Young-Growth Douglas-Fir Forests study, established in 1998 in a stand of 1929 natural origin after cutting and fire. Several other experiments of similar nature are in progress in the region.



Figure 39—Control unit at Blue Ridge, with abundant understory of suppressed hemlock. It was thinned about 1970 prior to study, with no subsequent treatment.

- They must be continued over a long period if they are to answer questions about the long-term results of alternative regimes. Consistency over time in treatments and procedures is necessary and difficult to obtain.



Figure 40—Clearcut treatment at Blue Ridge at year 6 after planting: (A) planted Douglas-fir with some naturally seeded hemlock, and (B) leader growth of Douglas-fir in full light.



Figure 41—Two-age treatment at Blue Ridge, intended to develop a two-storied stand, 6 years after underplanting with Douglas-fir. Considerable natural hemlock regeneration is present. Overstory left after cut was 16 trees per acre (39 trees per hectare) with a stand basal area of 46 square feet per acre (11 square meters per hectare).



Figure 42—Patch cut treatment at Blue Ridge, six seasons after planting.

- They are expensive to establish and maintain, and are therefore in competition with activities aimed at quick answers to the question of the moment.
- They are heavily dependent on continuity in personnel and on support by both the research and administrative organizations.



Figure 43—Group selection treatment at Blue Ridge after six growing seasons.

- Like all long-term experiments, they are liable to disruption by unplanned events (fire, pests, political changes, interrupted funding).

Nonetheless, such experiments are sorely needed to address many important questions. Lacking long-term experimental data, present estimates of long-term results of alternative silvicultural regimes are necessarily based



Figure 44—Continued thinning treatment at Blue Ridge.

on extrapolations and simulations that become increasingly suspect as they are extended to ages, treatment regimes, and stand conditions outside the range of existing data. And, on-the-ground demonstrations showing the feasibility of alternative regimes may be more important in a practical sense than statistical significance of small differences.

## Chapter 13: Evolution of Applied Forest Management Practices<sup>1</sup>

Forest management practices have been and are continually evolving. Formal forestry research has been an important factor in the process, but it is only one of the factors involved. Progress in applied silviculture comes from the interaction of research results, observation and experience of managers and silviculturists, changes in harvesting and manufacturing technology, and a continually changing economic and social environment. Flora (2003) provided a good account of these changes from an economist's viewpoint.

In the following sections we briefly review the historical changes in forest management that parallel and were influenced by the development of silvicultural research.

### **Forest Management Changes: 1900–1925**

Establishment of the U.S. Forest Service in the Department of Agriculture, by merger of the former Bureau of Forestry with the forest reserves, provided an effective organization for management of federal forest lands (Steen 1977) and for forestry research (Steen 1998). The U.S. Forest Service also played a very important role in promoting forest protection and management activities by the states and by nongovernmental organizations.

The greatest advance in this period was the introduction of effective efforts for fire control and fire prevention, stimulated by the disastrous fire years of 1902 and 1910. The states passed legislation requiring burning of slash on freshly cut areas, fire patrol of such areas, provision of spark arresters on equipment, and firefighting tools. The Washington Forest Fire Association was formed in 1908, and the Oregon Forest Fire Protective Association in 1910. The Weeks Act of 1911 included authorization for federal participation in the organization and maintenance of cooperative fire control organizations. The newly formed

Western Forestry and Conservation Association, established in 1909 under leadership of E.T. Allen and George Long, became an active and effective organization promoting fire control legislation, public education, and the formation of cooperative fire control associations among landowners (Allen 1926, Martin 1945). (In later years, it also became an effective advocate of improved silviculture and of sustained yield management.) Concurrently, the national forests developed their own fire control capabilities.

The Clarke-McNary Act of 1924 expanded Forest Service authority to cooperate with and provide financial aid to states for fire protection. It also provided similar authority for aid to states in providing seed and planting stock for reforestation of denuded lands.

The great Yacolt Fire of 1902 (Felt 1977) and others of that period had left large areas of land unstocked. A large and continuing effort was mounted to replant the national forest lands involved. This necessarily included the establishment and operation of forest nurseries, beginning with the Silverton Nursery in 1909 and the Wind River Nursery in 1910 (Cameron 1979).

Timber harvesting on national forest lands was generally on a small scale, because industry controlled huge amounts of timber and had little immediate need for purchases of federal timber. Most commonly, national forest harvests used the scattered seed tree method for regeneration, with a rough standard of at least 2 seed trees per acre (5 per hectare), in line with recommendations of Munger and others. A beginning was made on working plans providing for sustained yield management.

In this period, private owners rarely made any specific provision for regeneration other than the fire protection and slash disposal required by law. However, defective trees and inaccessible groups of trees were often left and frequently approximated the seed tree method. On most areas,

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<sup>1</sup> By R.O. Curtis and M. Newton.



Brubaker Aerial Surveys

Figure 45—Railroad logging operation some time in the 1930s. Such areas frequently reseeded naturally, but it was often a slow process and sometimes led to conversion to brush species or alder.

the only feasible logging method available at the time was the logging railroad and steam donkey, and there was therefore no feasible alternative to large clearcuts or at best leaving a few scattered seed trees (fig. 45).

Several of the more far-sighted industrial landowners acquired large timber holdings beyond their immediate needs as insurance for future supplies for long-term operation. By the 1920s, a number of large owners undertook survey and classification of their cutover lands. The largest of these efforts was that by Weyerhaeuser Timber Co., which in 1924 established a new corporation—the Weyerhaeuser Logged-Off Land Co.—to take over management of the parent company’s cutover lands, with lands suitable only for timber-growing to be managed for that purpose (Brandstrom 1957).

This period also saw the beginning of a long-running controversy over proposals for federal regulation of forest practices on private lands. Legislation to this end was proposed in Congress, and supported by Pinchot (after his departure as Chief Forester) and by Graves. Graves’ successor, William B. Greeley, took the position (strongly supported by E.T. Allen) that more progress could be made

through cooperation between government and industry. The controversy continued and was not laid to rest until about 1950, by which time a number of states (including Washington and Oregon) had passed legislation regulating forest practices.

### Forest Management Changes: 1925–1950

During this period there was a continuing increase in the effectiveness of fire prevention and control, aided by partial federal funding under the Clarke-McNary Act (1924).

The Knutson-Vandenberg Act of 1930 provided additional federal funding for nurseries and planting programs on national forest timber sale areas. The contribution of the national forests to regional timber supply was still relatively small, although steadily increasing (except for the Depression period).

During the 1920s, a number of companies (notably Crown Zellerbach and Long-Bell) undertook forest planting and seeding on a limited scale (Brandstrom 1957). Long-Bell Lumber Co. established a nursery near Ryderwood, Washington, in 1926. The company planted 13,330 acres to conifers until the Depression halted work in 1931, although about half of the planted area was subsequently lost to fire. These private reforestation efforts came to an abrupt end with the onset of the Great Depression.

The introduction of the motor truck and crawler tractor opened new possibilities for more flexible logging methods. Much of the silvicultural knowledge needed for long-term management was now available (Munger 1927). McArdle and Meyer (1930) had shown the enormous productivity of Douglas-fir and had provided a quantitative basis for management planning. It seemed that the stage was set for conversion from an industry engaged in liquidating a wasting asset to one engaged in growing timber on a permanent basis.

Then came the Great Depression. Mill capacity, which had greatly expanded in the boom years of the 1920s, was now far in excess of plummeting demand. The forest industries descended into chaos, as did many others.

One result was the rise of “selective cutting” (chapter 5). This was a silviculturally destructive practice, driven by the short-term economics of survival under conditions where only the biggest and best trees could be handled at a profit.

Congress passed the National Industrial Recovery Act (NRA) in 1933. This act provided for formation of industry associations with power to set minimum wages and prices and control production levels (Robbins 1981). The Code of Fair Competition for the Lumber and Timber Products Industries (Dana 1953: 254–257) also included a provision, Article X, requiring the industry to formulate a Forest Conservation Code, including enforceable rules of forest practice. Such a code was formulated by industry leaders in association with state and federal officials, and adopted in 1934. Then, in 1935, the Supreme Court struck down the entire NRA program.

Although no longer operative, the NRA Conservation Code had a considerable educational effect (Recknagel 1938). The West Coast Lumberman’s Association and Pacific Northwest Loggers Association subsequently (1937) issued a forest practice handbook, based on the NRA Forest Conservation Code. This publication summarized existing knowledge and recommendations on fire prevention and control, called for natural reseeding of cut areas, and advocated transition to sustained yield as the eventual industry goal. It reflected changing attitudes in the industry and formed a part of the groundwork for the shift in direction of the industry during and following World War II (WWII).

In the late 1930s, a number of large timber holdings were placed under sustained yield programs, including the St. Helens Sustained Yield Unit of Weyerhaeuser Co. and the Oregon and California Railroad (O&C) land grant lands under the General Land Office of the Interior Department (which later became the Bureau of Land Management).

With the recognition that the seed tree method was frequently ineffective and that “selective cutting” had been a silvicultural fiasco, there was a general shift to the use of so-called “staggered settings”—block clearcutting in units

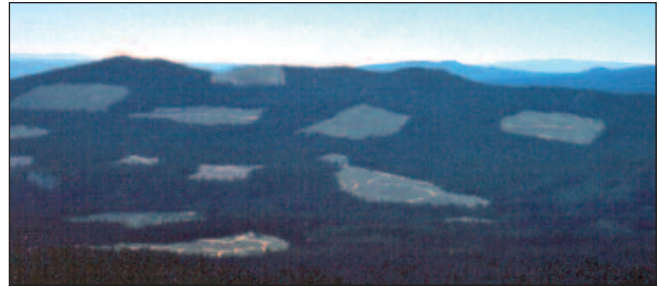


Figure 46—Unsatisfactory regeneration from the seed-tree method and from “selective cutting” led to adoption of “staggered settings” in the 1940s—moderate size clearcuts interspersed with uncut timber that served as a seed source.

of moderate size interspersed with blocks of uncut timber that served as a seed source (fig. 46).

By 1940, the economic upturn associated with the war in Europe and rearmament in the United States was being felt. Markets and prices improved, and the outlook for timber and other manufacturing industries brightened. Emphasis shifted to increased production to meet wartime needs. There was a corresponding shift in industry attitudes from gloom to optimism.

Nineteen-forty-one brought the birth of the industry-sponsored tree farm movement, with dedication of the Clemons Tree Farm of Weyerhaeuser Co. as the first such unit. Over subsequent years, this movement became an important vehicle for encouraging improved forest management. An industry-wide forest tree nursery was established in 1941 at Nisqually, Washington, to supply seedlings for tree farm planting, an activity that expanded rapidly.

The Oregon Forest Conservation Act of 1941 was the first in the Nation requiring regulation of cutting practices by the state. Washington passed a similar act in 1945. Although the Washington act was contested by a group of timberland owners as an infringement on private property rights, it was upheld by a 1949 Supreme Court decision.

The great Tillamook Fire of 1933, and subsequent reburns (1938, 1944, 1951) created a huge area of unstocked land in northwestern Oregon. The State of Oregon eventually acquired most of the land involved, and undertook a massive program of timber salvage followed

by seeding and planting, extending through the 1950s. This effort created the present Tillamook State Forest. The reforestation problems involved provided a strong stimulus to research in artificial regeneration.

World War II was followed by a strong and continuing expansion of the general economy, and by a steady rise in demand and prices for the timber industries. Improved markets and improved transportation meant much more complete utilization of harvested timber, with reduced slash accumulations. The end of old-growth timber was visible on the horizon. Second-growth stands took on a new value. Operations such as thinning, that had previously been considered uneconomic, now seemed feasible.

In the changed economic climate and the new optimistic view of the future, most of the stronger companies undertook the transition to permanent sustained-yield management. Concurrently, there was a sharp increase in the cut from federal lands. This served both to help meet the soaring demand for timber, and to facilitate the transition to sustained yield of companies that had badly unbalanced age distributions or insufficient land base to make sustained-yield operation feasible without supplemental supplies of federal timber.

Brandstrom (1957) provided an excellent historical account of industry developments in this period.

### **Forest Management Changes: 1950–1985**

Over the years from about 1950 to 1985, change continued in the directions foreshadowed in the immediate postwar period. Demand for timber products was high. Timber supplies, although not yet seriously limiting, clearly required foresight and planning. Old-growth timber on private lands was largely replaced by young stands. Harvests on national forest lands greatly increased and became a major supply source, and planning envisioned the gradual conversion of much of the large amount of old growth remaining on federal lands to managed young growth.

There were major and continuing improvements in wood utilization. Markets developed for much material that

had previously been unusable. Harvesting equipment became more efficient and more flexible. With steadily increasing timber prices and the prospect of future supply problems, owners were ready to invest in cultural measures that promised to increase growth rates and value of young stands.

The standard regeneration practice over most of the region was now to clearcut, burn, and plant, usually to Douglas-fir. The shift to planting as the preferred regeneration method was driven by (1) the frequently unsatisfactory results of natural regeneration methods, (2) the availability of Knutson-Vandenberg funds for planting on Forest Service lands, and (3) the increasingly stringent restocking requirements under the Washington and Oregon forest practices acts. Improved nursery and planting procedures and improved vegetation control provided a steady increase in survival. With planting rather than natural seeding as the primary regeneration method, it was no longer necessary to retain seed blocks. Some owners therefore chose to use very large clearcuts to reduce logging costs.

With more complete utilization and the gradual shift to young growth—which had much less defect than old growth—less slash was left on the ground. Less slash, better fire control, and public objections to smoke led to a gradual decrease in the formerly nearly universal practice of broadcast burning.

Precommercial thinning became common practice in naturally seeded stands and in plantations, especially those with substantial additions from natural seeding.

Commercial thinning was now feasible, although there were differing opinions as to its desirability. Early trials in mid-aged stands had not shown the growth response that many people had anticipated, and some questioned the benefits of thinning on the short rotations that many owners were adopting. Others—particularly the public agencies with their somewhat longer rotations—did a considerable amount of thinning.

Nitrogen fertilization of young stands was widely adopted by industrial and state owners.

Both public agencies and the larger companies established tree improvement programs, and operational plantings used selected seed as this became available. The combination of genetic improvement with improved nursery and planting practices produced plantations that—at least in their early years—clearly outperformed natural stands.

These changes were accompanied by a general shortening of rotations used by industrial and some private owners, in some cases to as short as 40 years. Shortening of rotations was sometimes motivated by need to compensate for unbalanced age distributions, but primarily by financial considerations without much attention to other biological, social, or political effects.

Forest management on federal lands (and to a considerable extent on industrial and state lands) became more centrally planned and controlled. Forest planning became a major activity on national forests, and forest practice regulations began to affect private operations.

This was also a period of burgeoning population growth—centered in the urbanized areas around Puget Sound and the Willamette Valley—and growing affluence and mobility. The expanding road system made much formerly remote forest land readily accessible. Recreational use exploded, particularly on the national forests. Increasing areas were designated as wilderness. Conflicts between user groups intensified. It became increasingly difficult to reconcile the desires and demands of the various interest groups. The problems and policy responses on the national forests, which had a great impact on silviculture from about 1985 on, are well presented in Fedkiw (n.d.), which is also one of the best available histories of the Forest Service.

## **Forest Management Changes: 1985 to the Present**

Several major trends are apparent in this period:

- Controversy and conflicts associated with the Endangered Species Act (and its emphasis on individual species) and the opposition of segments of the public and some influential environmental

groups to any form of active management nearly halted management activities on the national forests. There was a drastic decline in harvests and associated economic damage to forest-dependent industries and communities. Federal lands ceased to be a major factor in the regional timber supply. Management emphasis shifted to recreation and perceived biodiversity issues.

- Other public ownerships were affected by the same factors although, so far, to a much lesser degree. Legal requirements that state lands be managed to provide income for educational and other institutions provided continued incentives for timber production. There was a marked increase in thinning and a willingness to consider somewhat longer rotations in management planning.
- Another result of environmental concerns was the increasing complexity of state forest practice regulations. Although these regulations have undoubtedly been beneficial on the whole, they sometimes impose considerable burdens on landowners and can have unintended negative consequences. Substantial amounts of private land were withdrawn from production to protect riparian and other areas thought to be important to wildlife and fish or other environmental considerations. Restrictions were imposed on clearcut size, leaving of “green trees” was mandated, etc. Although probably justified from the larger environmental standpoint, many of these requirements were viewed as a burden by the landowner.
- Although the adaptive management area component of the Northwest Forest Plan has been a near failure on federal lands, collaborative approaches to management of state and private forest lands have been considerably more successful. Beginning with the Timber-Fish-Wildlife Agreement of the mid-1980s and continuing through the current Forest and Fish Policy, forest practices in Washington State have been guided by consensus-building processes. Although

there has been some litigation on some aspects of the Timber-Fish-Wildlife Agreement, this has been minor compared with that associated with federal land management. Adaptive management projects are undertaken along with cooperative monitoring and evaluation. Participants include the state, tribes, large and small forest landowners, local governments, and the environmental community. Such efforts receive peer review and are used in decisionmaking and regulation by the Forest Practices Board.

Faced with a reduced and uncertain public timber supply, increasing regulatory restrictions on portions of an ownership, and increased global competition, industrial owners managed their remaining lands for maximum short-term timber production. This often included intensive site preparation, improved planting stock, control of competing vegetation, stand density control, fertilization, and short

rotations. It also included extensive corporate mergers, transfer of operations to lower cost regions both within and outside the United States, sale of some lands to financial institutions (insurance firms, retirement funds, etc.), or real estate development with attendant forest fragmentation.

Thus, the current picture is a division into three broad management classes by ownership:

- On most federal lands, timber production has become a secondary objective, subordinate to recreation, wildlife, and amenity values.
- On state lands timber production remains a major objective although management practices are modified to reduce conflicts.
- On industrial and many other private lands, the primary objective is usually maximum return on the timber investment. Other objectives are likely to be pursued only in response to regulatory or public relations pressures, prospective land use changes, or possible public provision of incentives.

## Chapter 14: In Conclusion<sup>1</sup>

The preceding pages have traced the history of silvicultural research in the Douglas-fir region and its applications in forest land management. We have made no attempt to discuss the burgeoning literature on forest ecology and tree physiology, extensive topics that form the foundation of silviculture. We have touched only lightly on the important role of silviculture in prevention and control of insect and disease problems and in reducing the risks of catastrophic windfall and fire. We have briefly sketched the concurrent evolution of management practices, which reflect the combined influence of research, operational experience and observation, and changing economic and social factors.

We have confined ourselves largely to the means of manipulating stand establishment and stand development, many of which have been developed in a somewhat empirical manner although guided by considerable knowledge of the underlying biology. Our lengthy list of citations includes most of the important research before 1950, but only a fraction of the large literature that has developed since then. Although incomplete, these citations should suffice to indicate the scope of the subject and to provide entry points to the literature for readers without detailed prior knowledge.

It should be apparent that a large part of our present knowledge has come from long-term silvicultural experiments. These are expensive; difficult to maintain through changes in personnel, budgets, and short-term political priorities; and are often unattractive to researchers because of long lead times between establishment and the publishable results that are the main criterion for advancement in the research community. But, long-term experiments provide information obtainable in no other way. Their results are far more convincing to field foresters, landowners, and managers than any amount of extrapolation from theory and short-term observations.

Looking back over the history of silviculture-related research in the coastal Pacific Northwest, one can see a number of long-term trends:

- Prior to the 1950s, forestry research was almost exclusively carried out by the U.S. Forest Service. In the early years, silvicultural research was done by a very small number of people of outstanding ability and motivation. In general, they were keen observers and far-seeing individuals with a broad outlook, who operated with a high degree of independence on very low but fairly stable funding. A number of them devoted their working lives to one area of primary interest, and developed an unparalleled knowledge of their subject. Much of their work remains valuable. Despite limited resources, these few established and maintained a number of long-term studies that have had major influences on management.
- As the Forest Service research organization expanded, it necessarily became more highly structured. The Research Station Director became primarily an administrator (although usually with a scientific background). With increased numbers of people and increased specialization, team efforts and formal research organization became more important. There was more emphasis on interdisciplinary research.
- There was a great expansion in university research after World War II (WWII). Most of this was funded by grants from various sources, including the McIntire-Stennis Act, National Science Foundation, other organizations (including the Forest Service), and (in Oregon) a harvest tax. In general, dependence on short-term grants and graduate student research assistants, conflicts with staff teaching duties, and university reward systems did not encourage continuity of effort or long-term studies (although some were undertaken, usually as cooperative efforts supported in part by federal agencies and industry).

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<sup>1</sup> By R.O. Curtis and D.S. DeBell.

- Considerable industrial research was undertaken after WWII. Much of this was aimed at solving short-term management questions, but there were also some long-term studies. Some of these were disrupted or destroyed in the course of various reorganizations and ownership changes. Most data are not publicly available.
- From around 1970 onward, the Forest Service also had difficulties in maintaining long-term silvicultural research. Long-term research was in competition for funds with short-term studies, which were often prompted by politically “hot” questions of the moment.
- Overall, efforts and funding devoted to silvicultural research increased rapidly after WWII, peaked sometime in the 1970s, and steadily declined thereafter. Some of the decline resulted from a mistaken perception in some quarters that we already knew everything we needed to know about silviculture. More of it resulted from diversion of public agency effort and funding into the politically more popular though related fields of forest ecology, wildlife, and associated environmental questions. The decline also reflected the relatively low priority given natural resource management compared to other national concerns.
- The need for continuity combined with the limited personnel and funding resources available in individual organizations has led in the last several decades to an increased emphasis on cooperative efforts, which combine the resources of several organizations.
- There has been a revival of long-term silvicultural studies in the last few years, stimulated by the evident need for management regimes that can maintain commodity production from forest lands while simultaneously providing aesthetic, recreational, and wildlife values. Many of the questions involved can only be answered by long-term multidisciplinary studies.

It should be apparent that silviculture and silvicultural research have a much longer history than most people—both the general public and natural resource specialists in other fields—realize. There is a great amount of existing information available for those with the time, inclination, and expertise to seek it out. Because of the long-term nature of forestry and the timescales involved in forest development, public attitudes and desires may change faster than the forest can respond to changes in management, and faster than research can provide definitive answers.

Knowledge can never be complete, and information needs will continue to change with changes in the biological, economic, and social environment. There is a continuing need for silvicultural research in both traditional areas such as intensive wood production, and in alternative silvicultural systems and management regimes directed at integrated management for multiple objectives (National Research Council 1990, 2002). The latter includes the relatively new and potentially important goal of carbon sequestration.

One has only to read the media coverage of various forestry issues to realize that much of the public and the media that shape public opinion have little understanding of the long history of Northwestern forestry, the nature of forests, possible management options, or the existence of a large body of research-based information. Unfortunately, much of the existing information is only available in specialized publications that are not ordinarily seen by workers in other fields, and that are often both inaccessible and unintelligible to the general public. There is a great need for synthesis of existing information and its presentation in forms understandable by nonspecialists and by people in other natural resource-related disciplines.

We hope that this publication will contribute toward that end.

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## Appendix

**Table 1—Common and scientific names of European species referred to in text**

Common name	Scientific name
Beech	<i>Fagus sylvatica</i> L.
Birch	<i>Betula pendula</i> Roth., and <i>B. pubescens</i> Ehrh.
Maritime pine	<i>Pinus pinaster</i> Ait.
Oak	<i>Quercus petraea</i> (Mattuschka) Liebl., and <i>Q. robur</i> L.
Scots pine	<i>Pinus sylvestris</i> L.
Silver fir	<i>Abies alba</i> Mill.
Spruce	<i>Picea abies</i> (L.) Karst.

**Table 2—Common and scientific names of North American trees referred to in text**

Common name	Scientific name
Alaska yellow-cedar	<i>Chamaecyparis nootkatensis</i> (D. Don) Spach
Bigleaf maple	<i>Acer macrophyllum</i> Pursh
Black cottonwood	<i>Populus trichocarpa</i> Torr. & Gray
Canyon live oak	<i>Quercus chrysolepis</i> Liebm.
Chinkapin	<i>Castanopsis chrysophylla</i> (Dougl.) A. DC.
Douglas-fir	<i>Pseudotsuga menziesii</i> (Mirb.) Franco var. <i>menziesii</i>
Engelmann spruce	<i>Picea engelmannii</i> Parry ex Engelm.
Grand fir	<i>Abies grandis</i> (Dougl. ex D. Don) Lindl.
Incense-cedar	<i>Libocedrus decurrens</i> Torr.
Jeffrey pine	<i>Pinus jeffreyi</i> Grev. & Balf.
Lodgepole pine	<i>Pinus contorta</i> Dougl. ex Loud.
Madrone	<i>Arbutus menziesii</i> Pursh
Mountain hemlock	<i>Tsuga mertensiana</i> (Bong.) Carr.
Noble fir	<i>Abies procera</i> Rehd.
Oak, Oregon white	<i>Quercus garryana</i> Dougl. ex Hook.
Pacific silver fir	<i>Abies amabilis</i> Dougl. ex Forbes
Ponderosa pine	<i>Pinus ponderosa</i> Dougl. ex Laws.
Red alder	<i>Alnus rubra</i> Bong.
Sitka spruce	<i>Picea sitchensis</i> (Bong.) Carr.
Sugar pine	<i>Pinus lambertiana</i> Dougl.
Tanoak	<i>Lithocarpus densiflorus</i> (Hook & Arn.) Rehd.
Western hemlock	<i>Tsuga heterophylla</i> (Raf.) Sarg.
Western redcedar	<i>Thuja plicata</i> Donn ex D. Don
Western white pine	<i>Pinus monticola</i> Dougl. ex D. Don
White fir	<i>Abies concolor</i> (Gord. & Glend.) Lindl. ex Hildebr.

**Table 3—Common and scientific names of non-tree plants mentioned in text**

Common name	Scientific name
Beargrass	<i>Xerophyllum tenax</i> (Pursh) Nutt.
Bitterbrush	<i>Purshia tridentata</i> (Pursh) DC.
Camas	<i>Camassia quamash</i> (Pursh) Greene
Hazelnut	<i>Corylus cornuta</i> var. <i>californica</i> (A. DC.) Sharp
Himalayan blackberry	<i>Rubus armeniacus</i> Focke
Huckleberries	<i>Vaccinium</i> (various species)
India mustard	<i>Brassica juncea</i> (L.) Czern
Oregon grape	<i>Berberis aquifolium</i> Pursh
Manzanita	<i>Arctostaphylos columbiana</i> Piper
Rhododendron	<i>Rhododendron macrophyllum</i> D. Don ex G. Don
Salal	<i>Gaultheria shallon</i> Pursh
Salmonberry	<i>Rubus spectabilis</i> Pursh
Scotch broom	<i>Cytisus scoparius</i> (L.) Link
Snowbrush	<i>Ceanothus velutinus</i> Dougl. ex Hook.
Swordfern	<i>Polystichum munitum</i> (Kaulfuss) K. Presl
Vine maple	<i>Acer circinatum</i> Pursh

**Table 4—Common and scientific names of insects and diseases mentioned in text**

Common name	Scientific name
Annosus root disease	<i>Heterobasidium annosum</i> (Fr.) Bref (formerly <i>Fomes annosus</i> )
Douglas-fir bark beetle	<i>Dendroctonus pseudotsugae</i> Hopkins
Dwarf mistletoe	<i>Arceuthobium tsugense</i> (Rosendahl) G.N. Jones
Laminated root rot	<i>Phellinus weirii</i> (Murr.) Gilb.
Seed chalcid	<i>Megastigmus spermotrophus</i> Wachtl
Swiss needle cast	<i>Phaeocryptopus gaumanni</i> (Rohde) Petrak
White pine blister rust	<i>Cronartium ribicola</i> Fischer

**Table 5—Common and scientific names of wildlife species referred to in text**

Common name	Scientific name
Bear	<i>Ursus americanus</i> Pallas, 1780
Beaver	<i>Castor canadensis</i> Kuhl, 1820
Deer	<i>Odocoileus hemionus</i> Rafinesque, 1817
Deer mouse	<i>Peromyscus maniculatus</i> Wagner, 1845
Elk	<i>Cervus elaphus</i> Linnaeus, 1758
Mountain beaver	<i>Aplodontia rufa</i> Rafinesque, 1817
Mazama gopher	<i>Thomomys mazama</i> Merriam, 1897
Northern spotted owl	<i>Strix occidentalis caurina</i> Merriam, 1898
Western gray squirrel	<i>Sciurus griseus</i> Ord 1818

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