Silvicultural Research in the Douglas-Fir Region[1]

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Abstract

This paper reviews the history of silvicultural research in the Douglas-fir region from circa 1900 to the present, emphasizing long-term studies that had a major influence on the development of Douglas-fir forestry. Silvicultural practices have evolved from the combination of formal research, observation and experience of managers, and changing social and economic conditions. Although much of the older work is unfamiliar to the present generation of foresters, it still has value and its history provides perspective on present problems and trends. This paper discusses recent changes in emphasis and experimental design.

Introduction

This brief history of Douglas-fir research in the coastal Pacific Northwest will emphasize long-term studies and their influence on the development of forest practices. It should remind us that silvicultural research is far from new, and that there is a large body of past work that is still relevant. The timber industry in the region began in the 1850s and soon became the dominant industry. In the early years, these were strictly liquidation operations, carried out without regard to the future.

Silvicultural research in the Douglas-fir region dates roughly from 1900. Initial work, mostly descriptive, began in the old Bureau of Forestry in the 1890s. The first published work was a series of monographs on the important timber species (e.g., Allen 1902, Frothingham 1909), based on field observation. It was early recognized that Douglas-fir was a moderately intolerant species and that most of the region's forests owed their origin and characteristics to periodic fires.

Silvicultural Systems and Regeneration

Long-term silvicultural research began with the 1908 arrival of Thornton Munger in the district forester's office in Portland, OR. He and others recognized that the most crucial, immediate problems were (1) fire protection and (2) regeneration methods. Munger undertook extensive measurements in existing second-growth stands, published the first volume and yield tables and much other information, and recommended "clean" cutting with retention of seed trees, followed by slash burning and protection from fire (Munger 1911). More elaborate silviculture was not feasible at that time.

Seed and nursery production research began at Wind River Nursery in 1911, initially by C.P. Willis and Julius Hofmann. The Wind River Experiment Station was established in 1913 (combined with the Division of Silvics in 1924 to form the present Pacific Northwest Research Station [PNW]). In 1915, a tract was set aside for experimental purposes; this tract was later greatly expanded in 1932 to form the present Wind River Experimental Forest. (Two other experimental forests on national forest land were established later: Cascade Head Experimental Forest on the Siuslaw National Forest in 1934, primarily for work with spruce and hemlock, and H.J. Andrews Experimental Forest on the Willamette National Forest in 1948.)

Julius Hofmann (director of the Wind River Experiment Station from 1913 to 1924) conducted extensive surveys of the distribution of regeneration on burned and logged areas. He established a series of plots along extensive transects in then unstocked areas; remeasurements in later years documented gradual restocking by seed windborne over long distances. He also established the first precommercial thinning study in the region in 1920, was the first to link humidity and fire risk, and worked with Munger on the early heredity trials.

Leo Isaac began work in 1924 and devoted most of his working life to the problems of natural regeneration. He became the lead-

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ing authority on Douglas-fir regeneration (Isaac 1943) and was an early advocate of tree improvement programs in the 1950s.

Abortive efforts at "selective timber management" in the 1930s (Curtis 1998, Isaac 1956, Kirkland and Brandstrom 1936) led many to conclude that there was no alternative to clearcutting. In the 1940s, there was general adoption of dispersed moderate-sized clearcuts, first with natural regeneration and later with planting. The clearcut/burn/plant regime was highly successful for a timber production goal and was almost universal until the 1990s. Most silvicultural research was devoted to refining the system, although there were a few trials of shelterwood on problem sites.

In the early 1950s, PNW and Oregon State University (OSU) began extensive work on the control of shrub competition. This work was later concentrated at OSU and continues to the present. In recent years, environmental concerns, public pressures, and endangered species considerations have revived interest in alternative silvicultural systems, and these issues are a major aspect of current silvicultural research. These alternatives involve a wider range of species, harvest methods, silvicultural systems, management regimes, and regeneration methods (e.g., Curtis et al. 1998).

Stand Density Control

Plantation Spacing

Leo Isaac established a Douglas-fir plantation spacing test at Wind River Experiment Station in 1925, on a relatively poor site. This spacing test was remeasured at intervals through 1990 (Miller et al. 2004, Reukema 1979). Results showed that the 10- by 10-ft and 12- by 12-ft (3- by 3-m and 3.7- by 3.7-m) spacings were markedly superior to the close spacings and led owners to abandon the close spacing that had been the prevailing practice.

The University of British Columbia established a series of spacing trials in 1957 and following years on an excellent site, with generally similar results (Reukema and Smith 1987). In the 1960s, additional trials were established by several companies and by the British Columbia Ministry of Forests, and, in 1980, a much more extensive trial using five species was established at Wind River Experimental Forest. There was also some use of the Nelder design in spacing trials by the University of British Columbia, Washington Department of Natural Resources, and OSU, although most of these trials have never been published. All these trials showed markedly greater diameter growth at wide spacings. Some showed effects on height growth, mostly on poor sites.

Thinning Research: Pre-World War II (WWII)

Thinning was long regarded as impractical under northwest conditions because of the low value of small material and the abundant supply of large timber. Despite the prevailing opinion of thinning, a number of—at the time—visionary studies were established in the 1920 to 1940 period. In 1920, Hofmann established a precommercial thinning trial in a 9-year-old stand at the Wind River Experiment Station. Walter Meyer established an additional trial in 1933, thinned at ages 31 and 50. The Schenstrom thinning plots on Vancouver Island were established in 1929 in an 18-year-old stand on an excellent site. These plots have been thinned repeatedly, although the originally planned differences in treatment were more or less lost. The Mt. Walker thinning study was established in a 60-year-old poor site stand on the Olympic National Forest from 1934 to 1937. Response was poor in the early years, but, when remeasured in 1991, the thinned plots were in excellent condition and had not reached peak mean annual increment despite their age (Curtis 1998).

Thinning Research: Post-WWII to Present

In addition to earlier trials in Douglas-fir, two extensive precommercial thinning trials were installed in hemlock at Cascade Head, OR, and Clallam Bay, WA, in 1963 and 1971, respectively (Hoyer and Swanzey 1986). These trials showed striking response. Trials and observation of existing young stands showed that many young stands were too dense for optimum growth and resistance to wind and snow breakage. With the changed economic outlook that followed WWII, precommercial thinning became common from the late 1960s onward.

Interest in commercial thinning was stimulated by the economic revival after WWII, the increasing acreage of second-growth stands, and the foreseeable end of old-growth timber. The PNW undertook several operational-scale commercial thinning experiments on industrial lands, under cooperative agreements with landowners. Three experimental forests were established for the primary purpose of thinning research: the Hemlock Experimental Forest near Hoquiam, WA; the Voight Creek Experimental Forest near Orting, WA; and the McCleary

Experimental Forest near McCleary, WA. These forests were midage, previously unmanaged stands of natural origin. Repeated thinnings included different thinning cycles. Growth and mortality were measured over a period of about 20 years.

Results showed some increase in diameter growth and reduced mortality but little or no volume gain from thinning in these midage, previously untreated stands (Reukema 1972, Reukema and Pienaar 1973). Together with higher logging costs and the continued availability of mature timber, these results markedly dampened interest in commercial thinning. Concurrently, a number of industrial owners established other thinning studies. Most have not been published. Two long-term studies in older stands (e.g., Williamson 1982) found little difference in gross volume growth but a large reduction in mortality on thinned plots. Allen Berg of OSU established an extensive series of thinning trials in the 1950s. These trials have had considerable use as demonstration areas, but no formal report has ever been published. Most of these studies were begun comparatively late, after extensive crown reduction had occurred. The marked differences between initially overstocked stands and those established with early spacing control showed the need for thinning experiments begun at much younger ages. Several large-scale regional studies attempted to address these and related concerns.

The cooperative Levels-of-Growing-Stock (LOGS) study in Douglas-fir was conducted jointly by several organizations (Curtis et al. 1997). Begun in 1961, it was installed in stands in the precommercial thinning stage and included a wide range of sites. Nine installations followed a common design originated by George Staebler and Richard Williamson, consisting of 27 plots with 3 replicates of 8 thinning treatments plus control. Principal results included the following:

- Gross volume increment was greatest at the highest growing stock levels, contrary to a belief widely held at the time the study was initiated.
- Volume increment was much more closely related to growing stock level than was basal area increment.
- Net volume increment of unthinned controls exceeded that of thinned plots, although there are indications that the relationship may be reversing with advancing age.
- All thinning treatments markedly increased diameter growth and had striking effects on understory composition and development.

The Stand Management Cooperative (SMC) is a large cooperative effort headquartered at the University of Washington (Chappell et al. 1987). Its formation in 1985 stemmed from the realization that existing data (1) did not provide adequate coverage of young stands with early density control, (2) did not cover a sufficient range of initial plantation spacings, and (3) were often of poor quality and inconsistent in measurement standards. SMC involves many larger landowners and uses standardized design and measurement procedures. Its activities include work on timber quality and fertilization as well as work on stocking control per se. The data are rapidly becoming the major source of information on young stand development of Douglas-fir and western hemlock. The Hardwood Management Cooperative at OSU is a somewhat similar but smaller program.

Forest Fertilization and Long-Term Site Productivity

Stimulation of tree growth by added nitrogen was first demonstrated in the late 1940s. Several organizations began research on forest fertilization (Chappell et al. 1992). The Regional Forest Nutrition Research Project was established in 1969 under the leadership of Stanley Gessel of the University of Washington. This initiative was a cooperative program (that has since merged with SMC) financed by many major landowners in the region. Over the years, this program established a very extensive series of long-term field trials that are now the principal source of information on the subject. In general, results showed that Douglas-fir response to nitrogen (N) is inversely related to site index and is greater in combination with density control. N fertilization is a widely adopted practice on industrial lands and some State lands. Response to nutrients other than N has been highly variable. Response of hemlock to N fertilization has also been erratic.

It has often been hypothesized that soil compaction and the removal of nutrients and organic matter associated with timber harvest may reduce site productivity. Attempts to examine the question by retrospective studies have yielded no clear generalizations. There are two major ongoing long-term experiments in the Pacific Northwest that attempt to address the question: (1) the Long-Term Ecosystem Productivity Study and (2) the Long-Term Site Productivity (LTSP) Study. These studies are affiliates of the National Long-Term Soil Productivity Study

(Powers et al. 2005) but differ considerably from that study and from each other in design and component treatments. Treatments are replicated within each of several installations in each study. Both studies are still in the early stages and many years will be required for conclusive results, although some preliminary results from one installation of the LTSP study are available (Ares et al. 2007).

Tree Improvement

In 1912, Munger established the Douglas-Fir Heredity Study, a pioneering provenance trial maintained until 1993, which clearly demonstrated the importance of seed source. He also established the Wind River Arboretum as a long-term trial of exotic species. Although some exotics showed initial promise, their long-term survival and growth proved far inferior to the native species.

From 1950 to the 1960s, several programs in tree improvement were established. John Duffield and Roy Silen were prominent in the early work. Several tree improvement cooperatives have been established. Additional provenance trials were established, seed collection zones were defined, breeding programs were undertaken, and a large number of field trials were established. This work continues.

Growth and Yield Research

In 1910, Munger began a program of establishing permanent growth plots in second-growth stands, which continued until 1940 (Williamson 1963) and formed the basis for a number of publications over the years.

In 1930, McArdle and Meyer published an elaborate normal yield table for Douglas-fir (McArdle and Meyer 1930), which had a great influence. The yield table served for half a century as *the* guide to stand development and management planning (Curtis and Marshall 2004). Like all normal yield tables, however, it represented well-stocked natural unmanaged stands and could not provide the information needed for intensive management.

Staebler combined McArdle's net yield table with mortality data from the permanent plot series begun by Munger and developed estimates of gross yield. He then used these estimates to produce estimates for thinned stands under the then-current assumption that gross yield would be little affected by differences in stocking (Staebler 1960). These estimates represent an early example of stand simulation (albeit not computerized). Staebler recognized that the hypothesized constant gross increment over a range of stocking had never been demonstrated for Douglas-fir, and that existing data did not cover a wide range of stocking and did not allow a test of this hypothesis. He went on to design the LOGS study referred to previously.

Following WWII, a number of organizations (including major industrial landowners) began installing permanent plots. By the 1970s, a large number of permanent plots were in existence, including natural unmanaged stands, some fertilized stands, thinned stands, and some young plantations. The advent of the computer made it possible to handle large amounts of data and to construct stand simulators that summarized the results of many studies. There were efforts to assemble existing data and construct simulation programs that could produce estimates of stand development under a variety of management regimes (e.g., Curtis et al. 1981).

It quickly became apparent that, although large quantities of remeasured plot data existed and although some data from work begun before the war covered quite long periods of time, there were major limitations on its usefulness. The data were not well distributed geographically, were primarily from stands of natural origin without early stocking control, and did not include extreme treatments. A considerable part of the existing data was of little value because of inconsistent measurement standards and procedures, poor quality control, inadequate documentation, and frequent use of excessively small plots.

These deficiencies led to the establishment of the SMC (referred to previously) and to associated efforts to improve long-term experimental plot procedures. Efforts to improve simulation programs continue. These programs provide the best means of summarizing the results of the numerous existing silvicultural experiments. The objective is a suite of models that can integrate the results of all aspects of silvicultural research into a coherent framework for predicting stand dynamics, treatment response, and forest productivity.

Changes in Experimental Designs

Early (pre-WWII) field experiments commonly used large plots (0.5 to 1.0 acre), usually without replication or randomization. Statistical designs were introduced from agriculture in the late 1930s. Following WWII, many but not all field studies were designed for statistical analysis, with replication and randomization. The scarcity of uniform areas that could accommodate the necessary numbers of plots, plus cost considerations, led many researchers to use quite small plots—often 1/10 acre and sometimes as small as 1/20 acre. This practice severely limited the usefulness of the data for many purposes and made the extension of results to larger and more heterogeneous areas problematic. In recent years, the problems associated with very small plots have been commonly recognized.

Social Change and Silvicultural Objectives

Until quite recently, most silvicultural research was directed at timber production as the major objective. For some 40 years after WWII, the standard regime was to clearcut, burn, and plant, usually to Douglas-fir, with or without later thinning. There was a progressive reduction in rotations, while the replacement of natural regeneration by planting eliminated the need to limit the size of clearcuts. The result was large areas in the unsightly early regeneration stage, with most of the remainder in uniform young stands that much of the public regarded as not particularly attractive and that are the least productive condition for wildlife. These factors combined with widespread urbanization and the associated rise of the environmental movement to produce conflicts between public perceptions and attitudes versus economic objectives, with associated constraints on management. These conflicts are the most serious forestry problem we have in the Northwest today.

There are now considerable differences in objectives among public, industrial, and small private owners. Much current silvicultural research is concerned with efforts to minimize conflicts between diverse resource management goals, economics, and social considerations that include public attitudes and various legal constraints such as the National Environmental Policy Act, Endangered Species Act, and State forest practice rules. This work includes efforts to develop stand structures with some of the characteristics found in old-growth forests. In addition, defining relationships between increment, growing stock, management regimes, and rotations seems pertinent to current concerns about global warming and carbon sequestration. Douglas-fir is a long-lived species that maintains good growth to advanced ages and lends itself to a variety of management strategies and objectives (Curtis and Carey 1996).

There is also much interest in wildlife habitat, biodiversity concerns, and scenic effects that cannot be evaluated on small plots. This interest has led to a number of long-term studies using large, operational-scale treatment units (Poage and Anderson 2007) on the order of 20 to 80 acres. Compared to traditional small-plot studies, they have major advantages and major disadvantages, including the following.

Advantages:

- Results are representative of the real world, without the uncertainties involved in applying results from highly selected small plots to the more heterogeneous conditions that managers must deal with.
- Large treatment units make it possible to evaluate a variety of response variables, in addition to the traditional variables of stand and tree volume and increment. These variables include the following:
  - Visual effects and public perceptions.
  - Wildlife habitat.
  - Harvesting costs.
  - Economic returns.
  - Biodiversity.
- Large treatment units are extremely valuable as demonstration areas, where forest managers and interested segments of the public can see the results of alternative management regimes.

Disadvantages:

- Large treatment units are expensive to install and maintain.
- They are dependent on common interests and continued close cooperation between research and land management organizations.
- They require continuity in personnel and funding.
- The scarcity of reasonably homogeneous areas of sufficient size to accommodate such studies limits the number of treatments that can be included and the possible number of replications.

- The greater inherent variability within and between treatment areas reduces the power of statistical tests.
- Over a long timeframe, serious disruptions are likely to arise from weather events, insect infestations, and political factors.

These studies are generally joint efforts between a land management organization(s) and a research organization(s). (As an example, our Silvicultural Options Study at Olympia is a joint effort of the Washington Department of Natural Resources [the land manager], PNW, and the University of Washington, with Canadian replications installed and maintained by the British Columbia Ministry of Forests). Joint responsibility provides facilities and expertise not otherwise available and helps cushion the fluctuations in funding and priorities that occur within individual organizations. There are considerable differences in design and emphasis among the existing studies that reflect the particular interests and priorities of the designers. These differences frequently offer opportunities for superimposed supplementary studies, given the necessary personnel and funding.

Conclusions

Most past research has been on Douglas-fir, the economically most important species in the region. Secondary species (hemlock, true firs, and hardwoods) are also important economically and ecologically, and a lesser but increasing amount of research has been done on these species. In the early years, most silvicultural research was conducted by the Forest Service on Forest Service lands, much of it on dedicated experimental forests such as Wind River. Much of our research is now conducted on State or private lands, as cooperative efforts of PNW, the universities, and industrial owners. This shift is partly a matter of efficiency in using sources of funding and expertise. It also is partly a result of changing national forest policies and priorities. The Northwest Forest Plan effectively halted manipulative silvicultural studies on the long-established Wind River and Cascade Head Experimental Forests, although we are still remeasuring some existing studies. Reduced staffing and changing priorities have sharply reduced National Forest System capabilities and interest, and managers are reluctant or unable to allow treatments that might arouse opposition or that conflict with established guidelines. The sales and appeals process can involve lengthy delays. All these factors can disrupt schedules and experimental designs.

Formal silvicultural research in the Douglas-fir region can be roughly divided into three periods with differing emphases:

1. 1908 to circa 1945: Primary research emphasis was on the regeneration of logged areas and unstocked burns and on yield tables; research was also begun on thinning. Most research was conducted by the Forest Service.
2. 1945 to circa 1990: Research emphasis was on questions and practices directly related to timber production. There was a shift to intensive silviculture in the 1960s, with a concomitant expansion in research. The universities assumed a major role. Several companies (Weyerhaeuser, Crown Zellerbach, MacMillan-Bloedel) developed strong in-house research programs.
3. Circa 1990 to present: Research aimed at timber production as a primary goal is deemphasized by the Federal agencies. The primary emphasis of public agencies is now on environmental, scenic, and biodiversity goals, with efforts to reconcile these goals with some level of timber production. Funding for Forest Service silvicultural research of any sort progressively declined. In-house industrial research declined sharply (partly because of reorganizations and timber land divestitures by several large companies), although it was replaced in part by various landowner-supported research cooperatives (usually at universities).

The Douglas-fir region has a long history of long-term silvicultural observation and experimentation. Much of our present knowledge is derived from this work. Data from these experiments have often been found useful for a variety of purposes, in addition to those purposes envisioned at the time the experiments were established. Experience has shown that ultimate conclusions from long-term experiments can be considerably different from initial indications, and that objectives and available techniques can be expected to change over time.

This has been a very sketchy account of a large subject. Much more thorough presentations are available in Curtis et al. (2007) and Herring and Greene (2007).

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