Wood Productivity of Pacific Northwest Douglas-Fir: Estimates from Growth-and-Yield Models

David D. Marshall and Eric C. Turnblom

With increases in harvest of forests in the Pacific Northwest during the late 1800s and early 1900s came a concern for future timber supplies. Unsuccessful attempts at selective logging in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) *France*) and a better understanding of requirements for natural regeneration led to the adoption of moderate-sized clearcuts with adjacent uncut timber as a seed source (Curtis and Carey 1996). As a response of the need for more dependable regeneration, the 1950s saw a shift to artificial regeneration methods and the establishment of state forest practice regulations to insure prompt reforestation. This eliminated the need for leaving onsite seed sources, making further increases in cut unit size possible. Through the 1960s and 1970s, research improved the quality and survival of planted seedlings through the selection of genetically appropriate trees for individual sites, better nursery practices, site preparation, and early control of competing vegetation. Miller and others (1993) compared paired plots in naturally regenerated and planted Douglas-fir stands 35 to 38 years after harvest at seven locations in the Cascades of Oregon and Washington and found 40 percent more volume per acre and an 8 percent greater average diameter in the planted stands. The authors attributed the volume differential to differences in the pattern of stand development, e.g., planted stands reached breast height an average of 3 years sooner.

An important factor in the development of forest management in the Pacific Northwest has been research demonstrating the productive potential of the abundant Douglas-fir forests in the region. Bulletin 201 (McArdle et al. 1961), first published in 1930 and revised in 1949 and 1961, summarized yields from 2,052 plots in 261 *naturally regenerated* tracts of near maximum stocking in western Washington and Oregon. By the 1970s, however, reliance on plantations and more intensive management practices made traditional yield tables, such as Bulletin 201, obsolete. One of the early growth models for Douglas-fir was DFSIM (Curtis et al. 1981), which included data from 1,434 research plots at 203 installations in the region. This model projects growth in natural and planted stands and allows for thinning and fertilization. By the 1990s, the need for information on individual trees (e.g., wood quality) and the need to project development of mixed-species stands led to the creation and widespread use of individual tree models, such as the various variants of FVS (Donnelly 1997) and ORGANON (Hann 2003).

Each of these models represents a step in advancing our understanding of the productivity of coastal Douglas-fir forests and in the ability to incorporate the impact of more intensive management treatments in yield assessments. Although each model takes a different approach and uses different data, they provide a means for estimating the impacts of evolving stand management practices on yield.

Yields at age 45 for a well-stocked natural stand or a plantation (begun by planting 435 trees per acre) are compared in Table 1 for average regional estimates of three models developed over the past 60 years. Both the natural stand and the plantation were grown on a site index of 118 ft (50-year base), an average site index for private lands in western Oregon and Washington.

Bulletin 201, which assumes a well-stocked naturally regenerated stand, estimates a merchantable volume (6-inch top diameter inside bark) of 4,150 ft^3/acre for the 1930s, whereas the DFSIM model predicts a merchantable volume of 6,035 ft^3/acre for a plantation of the 1960s and early 1970s. Although DFSIM predicts a 45 percent increase in yield over Bulletin 201, a difference similar to the one found by Miller and others (1993), it was developed with data collected prior to 1975 and thus represents estimates of yields from early plantations in the region. Pittman and Turnblom (2003) used data from the Stand Management Cooperative at the University of Washington (which represents 66 Douglas-fir research installations in plantations established from the 1960s until now throughout western Washington, Oregon, and British Columbia) to develop the TreeLab model. This model provides up-to-date yield estimates for Douglas-fir plantations, representing more current management levels. Its estimate of merchantable volume is 8,599 ft^3/acre at total age 45, which is more than a twofold increase in the yield estimated for the natural stand by Bulletin 201 and 40 percent

Table 1. Douglas-fir yield projections to total age 45 years from three different models for naturally regenerated stand or planted stands on a 118-foot (50-year breast height age) site index.

Model	Stand origin	Trees per acre at harvest	Basal area (ft^2/ac)	Quadratic mean dbh (in)	Total stem volume (ft^3/ac)	Merchantable volume (ft^3/ac)[a]	Merchantable MAI[b] (ft^3/ac/yr)	Board foot volume (bf/ac)[a]
Bulletin 201[c]	Natural	464	194.3	8.8	6,475	4,150	92	13,859
DFSIM[d]	Planted	237	191.4	12.2	6,897	6,035	134	23,559
TreeLab[e]	Planted	276	219.6	12.1	10,077	8,599	191	33,014

[a] Merchantable cubic volume is to a 6-inch top diameter inside bark and board foot volume is Scribner in 32-foot logs to a 6-inch top diameter inside bark.
[b] MAI = mean annual increment.
[c] Bulletin 201 (McArdle et al. 1961) yields were adjusted to fit the site curves of King (1966), using the methods of Curtis (1992), because of errors in the original curves.
[d] Curtis et al. 1981.
[e] Pittman and Turnblom 2003. Total stem volumes for tree lab were computed from an equation developed from the Stand Management Cooperative database: $V = N \times [0.00185584 \times (Dq^{1.889135669}) \times (H40^{1.08502379})]$, where N is trees per acre, Dq is the quadratic mean diameter at breast height (inches) and H40 is average height (feet) of the 40 largest trees by diameter. Merchantable volumes were computed using the equations of Williamson and Curtis (1980).

greater than estimated by DFSIM for early plantations. Much of this increase can be attributed to the almost 20-foot greater heights estimated at age 45 for current plantations (i.e., a higher exhibited site index) when compared with the expected site index estimated from traditional natural stand-based site curves.

The TreeLab model estimates a maximum mean annual increment (MAI) in merchantable cubic feet for a site index of 118 ft of 221 ft^3 /acre/year at about age 70 for plantations studied by the Stand Management Cooperative, compared with its estimate of 191 ft^3/acre/year at age 45. Although age 70 is beyond the range of the current database used to construct the TreeLab model, it does suggest that a harvest at age 45 would capture about 85 percent of total merchantable yield measured in cubic feet—consistent with the growth patterns of Douglas-fir, which reach peak average growth at a relatively late age. For comparison, the TreeLab model predicts MAIs of 93 and 243 ft^3 /acre/year at age 45 for a lower site (93 ft) and high site (143 ft) stand, respectively.

Although some of the differences in these comparisons are due to the differences in data sets, modeling techniques, and the assumptions made (e.g., the resulting stocking from natural regeneration is highly variable and can impact future yields), they demonstrate the gains in potential wood production achieved over the past 60 years in managing coastal Douglas-fir stands. Although the TreeLab model is based on the most current data sets and represents plantations of improved seed and more intensive establishment practices, it also represents data from a range of owners whose vegetation management practices vary in intensity. It also does not represent advanced generation genetics. Furthermore, this analysis did not consider fertilization, which would make the potential for yields even greater. With continued improvements in the genetics of planting stock, seedling quality, vegetation management, and initial spacing guidelines, one can expect further gains in productivity in future Douglas-fir plantations in the Pacific Northwest (Talbert and Marshall 2005).

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