A Sustained-Yield Scheme for Old-Growth Douglas-fir

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ABSTRACT. From analysis of two Douglas-fir (Pseudotsuga menziesii *[Mirb.] Franco) stands, 120 and 140 years old, we conclude that managed stands can meet established criteria for old-growth Douglas-fir and simultaneously produce near-maximum yields of good-quality timber. With the management approach outlined here, average annual volume growth may approach that of shorter-rotation culture, but in logs of a size and quality normally found only in older stands, and with minimal impact on high-risk watersheds or old-growth habitat. This possibility encourages development of silvicultural systems that can achieve such goals in a variety of timber types.*

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There seems to be a prevailing sense that we can have old-growth timber only by preserving it. This attitude has led to major readjustments in harvest policy on public lands in the Douglas-fir region and to considerable uncertainty about future supplies of mature timber. Planners for the USDA Forest Service and the Bureau of Land Management are considering setting aside large acreages of old growth for wildlife habitat and are also developing plans for long rotations. Our purpose here is to describe some findings that may clarify ways of producing forests that are much like old-growth, yet provide high levels of timber production in reasonable rotations.

The Old-Growth Definition Task Force (1985) has described minimum standards for old-growth Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco var. *menziesii*) as follows:

> On western hemlock sites, there must be two or more species of live trees with a wide range of ages and sizes. There must be 8 or more Douglas-fir more than 32 inches dbh, and there must be tolerant associates of western hemlock, western redcedar, Pacific silver fir, or bigleaf maple. There must be a deep, multilayered canopy, and there must be four or more snags more than 20 inches dbh and 15 feet tall. There must be 15 tons or more of logs on the ground, including four or more pieces 24 or more inches in diameter and 50 feet long.

We infer that any mature Douglas-fir stand may be defined as old growth if it exhibits those understory, log, and snag characteristics, and that the means by which these conditions are achieved is unimportant (except for philosophical reasons).

Managed stands meeting these criteria have not been identified in the literature. Herein we describe some of the features and history of two such stands, and postulate how these data could be used in managing for old-growth-like forests.

METHODS

We identified two natural Douglas-fir stands of fire origin, 120 and 140 yr old, near Corvallis, Oregon (Sec. 3, T11S, R5W, Willamette Meridian). These stands were 2-ac portions of larger (>200 ac) stands, and were selected because of their unique histories of harvest and experimentation. They were selectively logged in 1914; in 1959, 30 to 40 ft^2 basal area/ac of mature bigleaf maple (*Acer macrophyllum* Pursh.) were experimentally removed (Newton 1962). Both stands are on deep (>48 in.) Jory soils at midslope on well-drained north slopes. They appear to fall within the *Pseudotsuga/Holodiscus/Gaultheria* Association within the *Tsuga heterophylla* zone (Franklin and Dyrness, 1973).

In 1984, we inventoried both stands and took 16-in. increment cores from the north sides of 25 sample trees per stand in order to reconstruct the past 70 yr of diameter growth. To establish ratios of pre- to post-treatment diameter increment as a function of treatment, we took similar cores in adjacent stands of the same age and type in which the bigleaf maple remained. Every core showed at least 52 yr of growth, and maple removal occurred at the mid-point of this interval. Because not every core reached the year 1914, we estimated 1914–1932 tree growth by computing growth curves from the 52-yr data and extending them to 70 yr. These estimated curves were then compared to those computed from complete 70-yr data, and were adjusted by the average proportional deviation from estimated diameter 70 yr ago.

The stands from which maples had not been removed had been cut more heavily in 1914 and now are more heterogeneous than the maple-treated stands. Therefore, we did not attempt to analyze total stand growth and yield there. We did compare growth data from both sets of stands to determine the effect of maple removal on the long-term growth patterns of relatively free-to-grow, dominant conifers. Our data on conifer volumes and growth are based only on stands from which the maples were removed.

FINDINGS

Site quality could not be determined accurately because both stands were substantially disturbed during the 1914 entry. Even though logging had been done by horses, felling and skidding caused many broken tops and scars. Currently, top development appears to be recovering; crowns are acutely pointed (a characteristic of trees in excellent vigor). Average height of both 120- and 140-yr-old dominants and codominants in 1984 was 171 ft, and we estimate site index to be about 150+ based on McArdle et al. (1949).

In 1914 the stands were even-aged, 50 and 70 yr old, and residual stump diameters indicate that most of the trees cut at that time were probably 14 to 24 in. dbh. The fact that some trees within this range were not cut suggests that size was not the only criterion. The large trees with large-diameter branches were left, and also small trees, which were presumably of marginal value. Some *Fomes pini* conks were observed.

Table 1 illustrates the current relative and cumulative frequency of trees by diameter class in each stand. The 120- and 140-yr-old stands are at 29 and 31 stems/ac, respectively; respective basal areas are 178 and 232 ft^2/ac Neither stand contains bigleaf maple trees larger than sapling size.

Table 2 summarizes changes in diameter and basal area since 1914 as reconstructed by increment cores. Residual stands with only 8 and 13% of normal stand tree numbers (McArdle et al. 1949) and 24 and 28% of normal basal area (total stand basis) in 1914 are rapidly approaching normal yield as they mature. Average diameters are 7.5 and 10.8 in. greater than those of comparable numbers of the largest trees in normal stands. Despite roughness in upper logs due to large branch size, the two butt, 32-ft logs are of higher quality than those in normal stands of the same age because their larger diameters place them in peeler grades. The approach toward normal stocking decreased after the first entry

Table 1. Current relative and (cumulative) frequency distributions by diameter class in 120- and 140-yr-old Douglas-fir stands 70 yr after heavy cutting.

	120-yr-old stand		140-yr-old stand	
Diameter class (in.)	Observed (%)	Normal[a] (%)	Observed (%)	Normal[a] (%)
<24	0 (0)	81 (81)	0 (0)	69 (69)
24	4 (4)	8 (89)	0 (0)	10 (79)
26	8 (12)	5 (94)	4 (4)	8 (87)
28	4 (16)	3 (97)	4 (8)	5 (92)
30	4 (20)	3 (100)	0 (8)	4 (96)
32	8 (28)	0	16 (24)	4 (100)
34	32 (60)	0	12 (36)	0
36	12 (72)	0	8 (44)	0
38	12 (84)	0	4 (48)	0
40	8 (92)	0	8 (56)	0
42	0 (92)	0	8 (64)	0
44	0 (92)	0	12 (76)	0
46	0 (92)	0	8 (84)	0
48	4 (96)	0	0 (84)	0
50	4 (100)	0	12 (96)	0
52	0 (−)	0	4 (100)	0

[a] Frequency distributions from normal yield tables for site III (McArdle et al., 1949).

Table 2. Basal area, diameter, and stocking development in 120- and 140-yr-old Douglas-fir stands that were partially cut 70 yr ago and from which bigleaf maple was removed 26 yr ago. Assumes no conifer mortality.

		Quadratic mean diameter[1] (in.)		Stocking[2] (%)	
Stand age and year	Basal area/ac (ft^2)	Sampled stands	McArdle et al. (1949)	Observed	Predicted[3]
120 yr					
1914	49.7	18.8	—	24	24
1932	72.9	22.8	—	30	38
1958	114.4	28.6	—	40	54
1984	178.0	35.7	28.2	57	68
140 yr					
1914	69.4	22.2	—	28	28
1932	100.7	26.8	—	36	42
1958	158.0	33.5	—	52	58
1984	232.0	40.8	30.0	71	71

[1] Largest 31 trees/ac.
[2] Percentage of normal basal area for SI_{100} 150 at given age, total stand (McArdle et al. 1949).
[3] From McArdle et al. (1949), Table 28.

and is now accelerating somewhat more rapidly than McArdle et al. (1949) predicted.

Table 3 summarizes growth rates during those intervals in stand development for which we have information. The remarkable feature of this summary is the clear picture of increasing absolute diameter and basal area growth during an age span when both are expected to decline after a period of normal stocking. Both stands are accelerating in diameter growth, which means that basal area growth is increasing even faster. Current volume growth rates are higher than mean annual growth. Together, these findings indicate that neither periodic nor mean annual growth have culminated; yet the stands contain 72 and 83% of normal Scribner volume for their ages in addition to the intermediate harvest (McArdle et al. 1949). This is not an abnormal pattern for young understocked stands, but we know of no other reports of mature forests exhibiting such acceleration in growth. If the trends continue as in Figure 1, normal yield may be exceeded in a few decades.

Although growth data indicate that Douglas-fir trees grew more rapidly after maple removal than before, core samples from untreated stands demonstrate the same degree of acceleration during the same period. The maples apparently were not a major factor controlling growth of the dominant, free-growing conifers. The maple experiment was not designed as a study of interspecific competition, rather, it was a completely successful test of a control method. Untreated stands were initially stocked at a lower level than treated stands, and therefore were not subjected to the same level of intraspecific crowding. Nevertheless, mature dominant Douglas-fir continued to accelerate in diameter growth in both situations up to age 140. Although our evidence is limited, it appears that, at 31 Douglas-fir trees/ac or less, the existence of *some* residual bigleaf maples is neither a threat nor a benefit to growth of clearly dominant overstory Douglas-fir.

DISCUSSION

The 70 yr of recorded tree removals and growth responses in these stands provide useful insights into what may be required for producing old-growth-like forests.

It is difficult to make a precise evaluation of the yields achieved in the 1914 entry because, at that time, these stands apparently contained fewer stems and larger trees than normal. On the basis of our increment-core data, we estimate that the residual stands, then 50 and 70 yr old, with the observed average diameters adjusted for height according to McArdle et al. (1949), contained 2,088 and 3,613 ft^3 and 11,368 and 21,700 bd ft Scribner/ac (assuming negligible losses since then). We may surmise that 40 to 50% of each stand (i.e., 9,300 and 17,750 bd ft Scribner) was removed 70 yr ago.

Distribution and quality of the residual stand suggest that a planned entry, perhaps several over a period of 20 yr, would have resulted in better distribution of the residual trees, fewer scars, and greater tree vigor. Nevertheless, in spite of a ragged start, these stands have produced an average of 700 to 800 bd ft Scribner/ac/yr for the past 70 yr, and this average continues to increase rapidly (Figure 1). Current trends indicate that growth will probably stay at or above present levels for 3 to 5 more decades, which will lead to volumes substantially greater than 100,000 bd ft/ac by ages 170 to 190 yr (Figure 1), and to average diameters of 50 to 52 in. Total yield to date, including estimated first-entry harvest, for the 120-yr-old stand is 71,160 bd ft Scribner and for the 140-yr-old stand is 96,178 bd ft Scribner, or 593 and 687 bd ft/ac/yr

Table 3. Basal-area growth since 1914 and current volume growth in 120- and 140-yr-old Douglas-fir stands.

	Annual basal area growth								Current volume		Current annual volume growth	
	1914–1932		1932–1958		1958–1984		1984					
Stand age	ft^2/ac	%	ft^2/ac	%	ft^2/ac	%	ft^2/ac	%	ft^3/ac	bd ft/ac (Scribner)	ft^3/ac	bd ft/ac (Scribner)
120 yr	1.29	2.10	1.60	1.71	2.45	1.68	2.90	1.63	8,837	61,859	143	1,001
140 yr	1.74	2.04	2.20	1.70	2.85	1.46	3.51	1.52	11,204	78,428	164	1,148

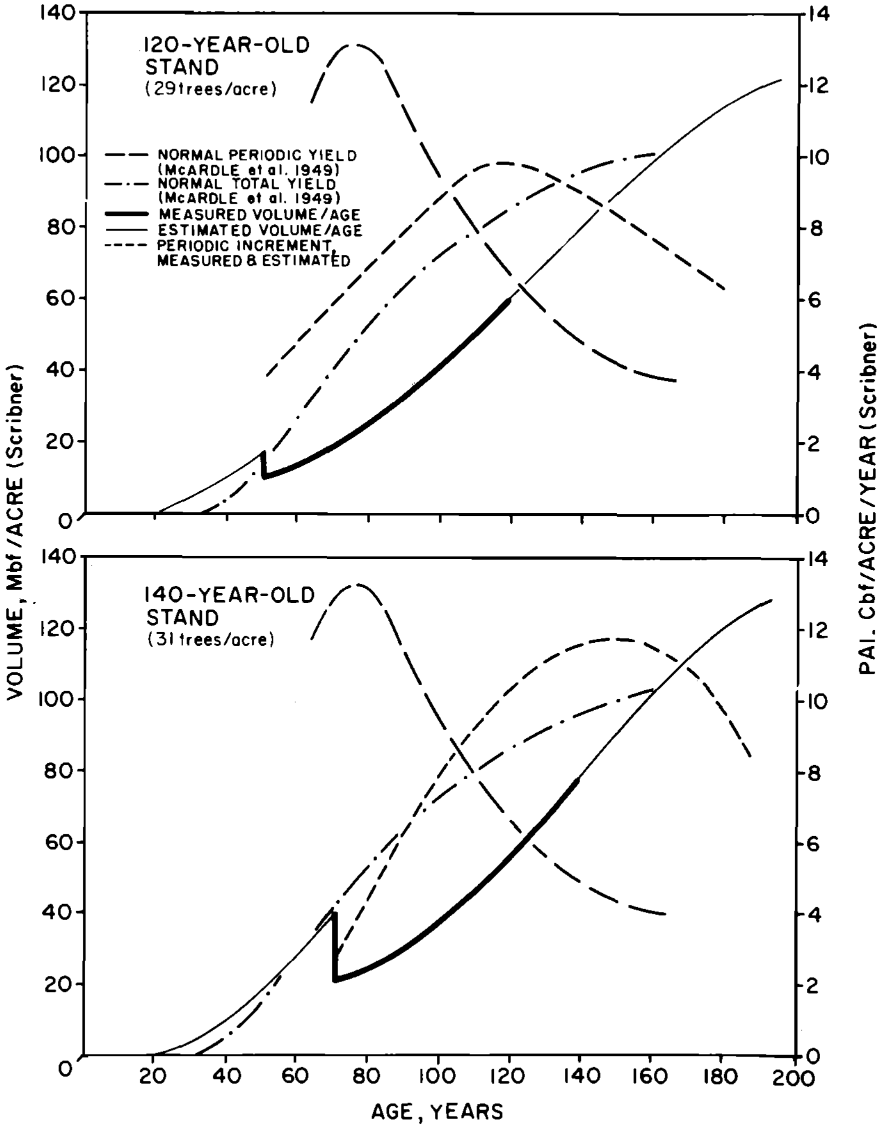

Fig. 1. Observed and estimated volume development in 120- and 140-yr-old Douglas-fir stands after heavy cutting at ages 50 and 70 yr, respectively.

(MAI). This compares with maximum MAI of about 724 bd ft/ac/yr for the same site in 100-yr rotations, the culmination of MAI (McArdle et al. 1949).

Quality of the stands for solid wood products is very good, although there are some rough trees and some defects induced by old logging injuries, heavy crowns, and *Fomes pini*. A high percentage of the first 64 ft is in veneer-grade logs, and nearly all trees are in the size range for peeler-grade logs. Ring width and knot indications point to excellent wood quality in the lower logs. The current growth rate of 7 rings/in. in the outer inch would normally suggest that earlier growth was faster, but in these stands, 7 rings/in. at the outside of the tree is associated with 8 rings/in. 6 in. into the log and 10 rings/in. at the 50% volume point (i.e., at 71% of total radius). It is difficult to visualize a silvicultural regime that could produce large timber with more favorable ring widths. Presumably, control over the loggers' choices and methods would have led to higher (branching) quality in the residual stand.

Wood quality considerations are always of interest in a silvicultural regime. Senft et al. (1985) identified quality deficiencies in young second growth in which the core of juvenile wood influences most of the solid-wood cuttings. In the large trees of our study, the wood in a 7-in. conical core contains less than 3% of the gross volume of the first 64 ft of logs in a 34-in. tree. Every tree in these stands has enough high-quality wood on the exterior to avoid juvenile-wood problems when sawing.

Amenity values of these stands approach those of old-growth. Size distributions, numbers of trees, and frequency of damaged tops are well within the range proposed by the Old-Growth Definition Task Force (1985). There are fewer downed logs and softwood snags than proposed, but these can be augmented or removed in the course of management. Damaged tops, rotten knots (such as those from *Fomes pini* infection), and downed logs are habitat components that favor various cavity-nesting birds and rodents. The area of our stands was too limited for a useful inventory of these features, but their occurrence in stands with these histories is evidence that such conditions could be reproduced under deliberate management according to quantitative standards.

The stands in which hardwoods remain contain enough bigleaf maple to constitute a tolerant understory. In the treated stands, very few maples have recolonized since removal, but large shrubs are common. Grand fir (*Abies grandis* Lindl.) also are slowly entering the stands where they are forming a scattered, tolerant conifer understory. Tolerant shrubs and ferns include western hazel (*Corylus cornuta* Marsh.), western dewberry (*Rubus ursinus* C. and S.), and western sword fern (*Polystichum munitum* [Kaulf] Presl.). Where killed and left standing, the maples have left snags up to 24 in. in diameter for more than 20 yr. The maples have also contributed numerous downed logs which are mostly <24-in. diameter but tree length. Maple removal in several entries would have provided for continuity of snags and downed logs and an increase in the sizes of both with increasing stand age. There are enough damaged or defective conifers[1] to provide for some snags and downed logs in the future, but probably at a lower rate than that defined for "true" old growth. One stand had two very large windfalls; the other has had no unsalvaged windfall conifers in the last 40 yr.

MANAGEMENT FOR OLD-GROWTH PRODUCTION

This "accidental" achievement, in 120 to 140 yr, of stands resembling old growth can probably be improved on if forest managers make early decisions on what they eventually want in their stands. Given adequate time, Douglas-fir clearly has the ability to occupy growing space after thinning from below, and this can be used to advantage in producing high-quality, productive stands that have most of the features of old growth.

The subject stands of this study are not the only instance of sustained growth in mature timber. Berntsen (1960) reported that 250-yr-old Douglas-fir sustained excellent peri-

[1] We did not record numbers of specific defects because data of a random hit or cluster nature could not be extrapolated from such localized stands. We estimate that more than 20% of the observed trees had *Fomes pini* conks, logging scars, or broken tops in mid-crown.

odic growth rates (226 ft^3 and 1,582 bd ft Scribner/ac/yr) on an average site in Oregon.

The existing pattern in the literature also suggests that the response of large trees to thinning or release, although slower than that of small trees or young stands, will continue for a longer period, especially if thinning results in low densities. Williamson and Price (1971) observed that Pacific Northwest conifers would fully occupy average sites in 70 to 150 yr if no more than 60% of basal area were removed at once and if residual trees had good crowns. They noted (1) the importance of spacing and distribution of residual trees, (2) that long measurement periods were helpful in evaluating growth patterns, and (3) that the largest trees exhibited the highest growth rates. Farr and Harris (1971) found that thinning in 96-year-old stands of Alaska Sitka spruce (*Picea sitchensis* [Bong.] Carr.) and western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) resulted in rising growth rates that were still increasing 16 yr after entry, whereas unthinned stands were decreasing in growth rate during the same interval.

Achieving the large sizes and high quality desirable in old stands requires preparation that begins with well-spaced, good-quality, vigorous trees. Examples have been noted in which thinning to 50 Douglas-fir/ac at age 37 leads to full site occupation by low-density stands of high quality and yield by age 50 (Berg 1970). The final intermediate harvest can be at any age, but 50 yr appears to be early; the nature of our stands suggests that 70 yr or later will lead to high yields from thinning and to development of good quality in residual dominant trees. Thinning to the desired density might be done in several entries, depending on terrain and specific quantitative criteria.

During the next-to-last thinning, understory conifers could be introduced as reported by Berg (1970) with planted western hemlock. These would take their place in the lower canopy after the final thinning and would provide a multilayered effect (as defined for old growth) as well as an increase in total yield. A conifer understory would be silviculturally desirable as an alternative to sprouting hardwoods; the latter would prove troublesome after final overstory harvest, and the conifers would add value as well as deeper canopy development. However, our data (Newton 1962) suggest that removal of maples is permanent if done with herbicide applications to standing trees in understories. We are not aware of any reason for selecting hardwoods rather than other species as understory components of conifer stands; the traditional criteria for aesthetic and biological diversity are undoubtedly met by both types of understory, but preferences could vary for different observers or wildlife species. In any event, short-lived species such as red alder (*Alnus rubra* Bong.) should not be relied on for this role because they cannot persist through the rotation.

Although growth would be slower in response to these treatments on poorer sites, true old growth would also generally be smaller on such sites. We expect the overall development of any stand to be proportional to site quality, but management regimes that emphasize thinning and the maintenance of low densities appear to increase both height and diameter growth of stands in early years, and thus improve *apparent* site quality.

We postulate that old-growth and production objectives could be achieved simultaneously through management of three large, adjacent units. One would be in the regeneration to 50- or 60-yr stage, under intensive, full-scale, visible management; one would be in the 50–100- or 60–120-yr stage, in which final entries would be made and visibility of the last entry would fade; and one would be in the 100–150- or 120–180-yr stage, in which no entries would occur, and very few signs of entry would be visible. All roads would be of minimum width and, after use, would be allowed to become overgrown until they were nearly indistinguishable (a process that appears to take 30 to 40 yr in low elevations of the Douglas-fir region). At any time, the snags and large debris that are needed to meet habitat criteria could be created by felling, girdling, or injecting a selection of low-value trees.

This approach allows at least one-third of the managed area to be maintained in a structurally diverse, old-growth-like condition at all times, and another one-third to be free of disturbance for half of its mid-life cycle, ensuring the continuity of species that rely on such habitat. Rotations would be 150–180 yr, followed by repetition of the cycle. Management would reduce the risk of catastrophic loss and maximize yield in the highest grades. Low frequency of clearcutting would minimize adverse impacts on watersheds, which would make this scheme suitable for unstable areas. In addition, low stand densities would make cable yarding feasible for intermediate harvests on steep slopes. Cutting stumps very short would reduce visible evidence of management; very high stumps would serve as habitat for certain birds.

It is apparent that high yields of high-quality timber can be achieved with no sacrifice of old-growth habitat and with minimal impact on high-risk watersheds. Our data offer an incentive to develop research and silvicultural systems that can achieve such goals in a variety of timber types. Deliberate programs for old-growth management and replacement may be appropriate for those entities that cannot be preserved forever. □

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