Thinning

1. 1987. Impact of intensive forestry practices on net stand values in British Columbia. B.C. Ministry of Forests FRDA-Report 014. 109 p.

Keywords: release treatments
fertilization
thinning
yield
economics

Abstract: Yield responses to major silvicultural treatments (regeneration method, brushing and weeding, spacing and thinning and fertilizer use) are analysed in relation to growth and yield theory, and their translation into operational use of treatments to increase merchantable vol. is considered. Data from coastal Douglas fir (Pseudotsuga menziesii), western hemlock (Tsuga heterophylla) and western hemlock/Abies amabilis stands and interior white spruce (Picea glauca), lodgepole pine (Pinus contorta) and wet belt Douglas fir stands are used to quantify the net present value of treatments in terms of improvement in net stand values and merchantable vol. Potentially viable treatment options are identified for each stand type present.

OSU Link
Non-OSU Link

2. Bailey, J.D. and J.C. Tappeiner. 1998. Effects of thinning on structural development in 40- to 100-year-old Douglas-fir stands in western Oregon. Forest-Ecology-and-Management 108(1/2): 99-113.

Keywords: thinning
commercial thinning
regeneration
tree morphology

Abstract: The composition and structure of the understorey was studied in thinned and unthinned Douglas fir/western hemlock (Pseudotsuga menziesii/Tsuga heterophylla) stands on 32 sites in western Oregon. These stands had regenerated naturally after timber was harvested between 1880 and 1940; they were thinned between 1969 and 1984. Commercially thinned stands had 8-60% of their volume removed 10-24 yr before the study (in 1993-95). Undisturbed old-growth Douglas fir stands were present for comparison on 20 of these paired sites. Conifer regeneration density and frequency were consistently greater in thinned than unthinned stands. For example, average seedling density in thinned stands (1433/ha) was significantly greater than in unthinned stands (233/ha), but very similar to that in old-growth stands (1010/ha). Seedling density and frequency were strongly related to the volume removed and to stand density index (and other measures of overstorey density) just after thinning. In thinned stands, the density of small trees (intermediate crown class overstorey trees and advanced regeneration) was 159/ha, significantly greater than in unthinned stands (90/ha), but not significantly different from that of old-growth (204/ha). The live crown ratio of these trees in thinned stands (66%) was greater than in unthinned (44%) and old-growth (48%) stands. Cover and stem density of shrubs was variable in all 3 stand types. There was significantly less tall shrub cover in unthinned stands than in either thinned or old-growth stands, which did not differ. Thinned stands had the most

low shrub cover. Salal (Gaultheria shallon) and bracken fern (Pteridium aquilinum) cover was greater in thinned stands than in the other stand types, but there was no difference in sword fern (Polystichum munitum) and Oregongrape [Berberis nervosa] cover. Leaf area index in thinned stands (6.6) was not significantly different from that in unthinned (6.8) and old-growth stands (7.1); however, there was more leaf area in shrubs in the thinned stands. Thinning young Douglas-fir stands will hasten the development of multistorey stands by recruitment of conifer regeneration in the understorey as well as by enabling the survival of small overstorey trees and growth of advanced understorey regeneration. Thinning will also help develop the shrub layer by increasing tall shrub stem density and cover of some low shrubs.

OSU Link
Non-OSU Link

3. Barbour, R.J., S. Johnston, J.P. Hayes and G.F. Tucker. 1997. Simulated stand characteristics and wood product yields from Douglas-fir plantations managed for ecosystem objectives. Forest-Ecology-and-Management 91(2/3): 205-219.

Keywords: thinning
yield
wood quality

Abstract: Hundreds of thousands of hectares of Douglas fir (Pseudotsuga menziesii) plantations in coastal forests in the US Pacific Northwest have been established over the past 40 years. Density management regimes designed to increase structural and compositional diversity in these plantations are being tested and implemented on an operational scale, in order to satisfy goals of ecosystem management. These regimes are designed to promote various tree and stand characteristics, such as trees with large limbs, stands with multi-layered canopies, and dense unthinned patches. Changes in forest management policy associated with these types of regimes raise questions about whether it is possible to manage for both ecosystem values and timber production. State-of-the-art growth models were used to simulate stand development and wood product yields under several silvicultural prescriptions. The results indicated that timing and intensity of early thinnings are critical in determining both stand structure and wood quality. It is concluded that it should be possible to manage Douglas fir plantations to provide a high degree of structural diversity, and wood products with a quality similar to that grown in many industrial plantations.

OSU Link
Non-OSU Link

4. Barbour, R.J. and D.L. Parry. 2001. Log and lumber grades as indicators of wood quality in 20- to 100-year-old Douglas-fir trees from thinned and unthinned stands. Pacific-Northwest-Research-Station,-USDA-Forest-Service General-Technical-Report PNW-GTR-510. 22 p.

Keywords: thinning
commercial thinning
wood quality

Abstract: This report examines the differences in wood characteristics found in coastal Pacific Northwest Douglas-fir (Pseudotsuga mensziesii) trees harvested at the age of 70 to 100 years old or at the age of 40 to 60 years from a trial involving multiple thinnings in Seattle,Washington, USA. Comparisons of differences in domestic log grades suggest that the proportion of log volume in the higher grades (Special Mill and No. 2 Sawmill) increased with both stand age and tree size. Simulation of lumber grade yields based on log characteristics suggests that yields of higher grades of lumber increased until about age 60 to 70, and then levelled off over the rest of the age range examined in this analysis. We included structural lumber products in the analysis but not higher value appearance grade products, and some evidence suggests that yields of these products might have begun to increase in the oldest trees. The analysis also showed that the younger trees had larger branches and more juvenile wood, possibly because they had been grown in stands that received a higher level of early stand management than the older trees. If these young trees were grown to the ages of 70 to 100, they likely would not produce the same log and lumber grade yields found in the older trees we examined.

OSU Link
Non-OSU Link

5. Barclay, H., H. Brix and C.R. Layton. 1982. Fertilization and thinning effects on a Douglas-fir ecosystem at Shawnigan Lake: 9 year growth response. Pacific-Forestry-Centre, Canadian-Forest-Service Information-Report BC-X-238. 35 p.

Keywords: fertilization
thinning
growth

Abstract: Further results are given for a trial established in 1970 in a 24-yr-old stand in British Columbia, last measured 6 yr after treatment. Volume increments over 9 yr for heavy thinning alone, heavy fertilizer (urea) treatment alone, or both together, were 46%, 75% and 120%, respectively.

OSU Link
Non-OSU Link

6. Barclay, H.J. and H. Brix. 1984. Effects of urea and ammonium nitrate fertilizer on growth of a young thinned and unthinned Douglas-fir stand. Canadian-Journal-of-Forest-Research 14(6): 952-955.

Keywords: fertilization
thinning
growth
tree physiology
tree/stand health

Abstract: The effects were studied of 2 sources of nitrogen fertilizer applied at rates of 224 and 448 kg/ha N on growth of thinned and unthinned plots established in 1970 in a 24-yr-old stand on southern Vancouver Is., British Columbia. Ammonium nitrate yielded higher growth of diam. and vol. than urea over a 9-yr period, particularly with thinning. Ht. growth was not affected by nitrogen source. The efficiency of nitrogen fertilizing in terms of stem vol. response per kilogram of nitrogen applied was

greatest with ammonium nitrate in thinned plots. Tree mortality increased substantially with fertilizing for both sources, and decreased markedly with thinning.

OSU Link
Non-OSU Link

7. Barclay, H.J. and H. Brix. 1985a. Effects of high levels of fertilization with urea on growth of thinned and unthinned Douglas-fir stands. Canadian-Journal-of-Forest-Research 15(4): 730-733.

Keywords: fertilization
thinning
growth
tree physiology
tree/stand health

Abstract: Diameter height and volume growth were documented for 9 yr after thinning and fertilizing in a 24-yr-old stand on a poor site on southern Vancouver Is. The treatments involved 3 thinning treatments (0, 1/3, and 2/3 b.a. removed) and 6 fertilizer treatments (0-1344 kg/ha N) with urea. Increments for both diameter and gross volume increased with the rate of fertilizer application and responses were still apparent 9 yr after treatment. For unthinned plots, the 9-yr volume growth responses were 30, 50, and 80% with fertilizer rates of 224, 448, and 896 kg/ha N, respectively. The efficiency of fertilizer use, measured as stem volume response per unit of nitrogen applied, decreased with rate of fertilizer application, but this result may change over a longer response period. There was a positive interaction between fertilizing and thinning such that high amounts of both mutually enhanced growth. Mortality increased with fertilizing, but only noticeably in unthinned plots.

OSU Link
Non-OSU Link

8. Barclay, H.J. and H. Brix. 1985b. Fertilization and thinning effects on a Douglas-fir ecosystem at Shawnigan Lake: 12-year growth response. Pacific-Forestry-Centre, Canadian-Forest-Service Information-Report BC-X-271. 34 p.

Keywords: fertilization
thinning
growth

Abstract: [See FA 45, 2316] Further results are given from the study established in 1970 in a 24-yr-old stand in British Columbia. Fertilizers (urea) and thinning both increased vol. increments over 12 yr. Refertilization 9 yr after initial treatment has produced substantial increases in vol. increment.

OSU Link
Non-OSU Link

9. Barclay, H.J. and C.R. Layton. 1990. Growth and mortality in managed Douglas fir: relation to a competition index. Forest-Ecology-and-Management 36(2-4): 187-204.

Keywords: fertilization
thinning
growth
tree/stand health

Abstract: Twelve-year increments of diameter at breast height (DBH), height, and volume in thinned and fertilized 45-year-old Douglas fir (Pseudotsuga menziesii) stands on Vancouver Island, Canada, were related (by regression) to degree of thinning, amount of fertilizer (3x3 factorial), initial DBH, and a competitive stress index (CSI). The ability of the CSI to predict growth after treatment was examined. Causes of tree death, and CSI data, are presented, and the relationship between them discussed. The CSI was found to be only moderately good at predicting Douglas fir growth and mortality: initial DBH provided a better predictor. Most mortality in unthinned plots resulted from suppression, and correlated reasonably well with CSI; mortality in thinned plots was not correlated with CSI, and resulted principally from snow damage. Tree height variability generally became less over the 12 years following treatment, which is more consistent with two-sided than one-sided competition predictions, a result which is contrasted to that of many other species.

OSU Link
Non-OSU Link

10. Barclay, H.J., P.C. Pang and D.F.W. Pollard. 1986. Aboveground biomass distribution within trees and stands in thinned and fertilized Douglas-fir. Canadian-Journal-of-Forest-Research 16(3): 438-442.

Keywords: fertilization
thinning
carbon allocation

Abstract: Nine years after heavy thinning and fertilization with urea, 34-yr-old Douglas firs at Shawnigan Lake (British Columbia) were destructively sampled. Dry wt. of seven aboveground components (wood, bark, dead branches, new or old foliage, new twigs and live branches) were determined and regression equations from d.b.h. were developed. Differences among treatments were shown for all biomass components and for the proportion of the total biomass allocated to each component. Thinning reduced the proportion of wood, bark and dead branches while increasing the proportion of foliage and live branches. Fertilization increased the proportion of branches but had negligible effects on the proportions of other components.

OSU Link
Non-OSU Link

11. Barclay, H.J. and J.A. Trofymow. 2000. Relationship of readings from the LI-COR canopy analyzer to total one-sided leaf area index and stand structure in immature Douglas-fir. Forest-Ecology-and-Management 132(2/3): 121-126.

Keywords: fertilization
thinning
tree morphology

Abstract: Estimation of leaf area is important in predicting potential growth. This estimation is often done by means of a photometer, such as the LI-COR plant canopy analyser, but such instruments generally give biased estimates. Consequently, conversion factors are required to convert output from the photometer to the actual leaf area index (LAI). Foliar biomass was estimated in a 52-year-old Douglas fir (Pseudotsuga menziesii) stand at Shawnigan in British Columbia, Canada, which had been treated with 3 levels of thinning and 3 levels of fertilizer 28 years previously. The 4 treatment extremes (no thinning or fertilizing, no thinning and heavy fertilizing (448 kg N/ha as urea), heavy thinning (to 1/3 basal area) and no fertilizing, and heavy thinning and heavy fertilizing) were sampled for foliage. Projected leaf areas were calculated from these biomass samples using specific leaf areas derived in a previous biomass sampling. Total one-sided leaf area was then computed by dividing the projected leaf areas by 0.9 to allow for lateral leaf curvature. In addition, LAI-2000 readings were taken in the same plots and then factors were derived to convert LAI-2000 readings to total one-sided LAI. These conversion factors were found to vary strongly with quadratic mean diameter, stand density, mean diameter at breast height, mean height and stand basal area. The effect of live crown height was minimal. These should allow the prediction of the conversion factor based on 2 or 3 of these highly correlated factors.

12. Beddows, D. 2002. Levels-of-growing-stock cooperative study in Douglas-fir: Report No. 16 - Sayward Forest and Shawnigan Lake. Pacific-Forestry-Centre, Canadian-Forest-Service Information-Report BC-X-393. viii + 67 p.

Keywords: thinning
growth
tree morphology

Abstract: Results from the two levels-of-growing-stock installations at Sayward Forest and Shawnigan Lake on Vancouver Island, British Columbia, Canada, are summarized. Volume growth at both the site-III Sayward Forest installation to age 51 and the site-IV Shawnigan Lake installation to age 52 has been strongly related to level of growing stock. Basal area growth followed a similar, though weaker, trend. Thinning has affected stand development through tree size distribution and live crown development. Periodic annual increments in volume at both installations are still two to three times the mean annual increment, indicating the potential for productivity gains as the treated stands age. Results to date from both installations are similar to results from other cooperative installations, generally differing from the more productive sites only in the rate and degree of response associated with a lower site quality.

13. Bettinger, P., K.A. Bettinger and K. Boston. 1998. Correlation among spatial and non-spatial variables describing a cut-to-length thinning site in the Pacific Northwest, USA. Forest-Ecology-and-Management 104(1/3): 139-149.

Keywords: thinning

commercial thinning
tree/stand health

Abstract: Variables describing the pre- and post-logging conditions of a thinning site in 47-yr-old naturally regenerated stand of second-growth Douglas fir (Pseudotsuga menziesii) and western hemlock (Tsuga heterophylla) in western Oregon, were examined for correlation, and subsequently used to develop models to estimate residual stand damage levels. A cut-to-length harvesting system was utilized to perform the thinning operation, which used a single-grip harvester and a forwarder, and marked logging trails. Several of the variables were measured in an intensive field survey; other variables were developed using geographic information system (GIS) processes. An analysis of correlations among the site variables showed several obvious, and a few interesting, results that describe the operation. Most of the variables provided negative, or inconclusive, assistance in describing the variation in stand damage levels. Only one variable, the number of original trees/hectare, was significantly correlated with residual stand damage levels, and was represented in the models that were developed to estimate residual stand damage levels. The resulting models are of limited practical value, however, since they explain little of the variability in damage levels. Most of the variation in residual stand damage levels may well be explained by random chance, operator error, other unmeasured operational variables associated with this harvesting system, or interactions among variables. The main conclusion from the study is that although both spatial and non-spatial data were utilized in describing the logging operation and in developing models to estimate stand damage levels, the importance of using spatial data was inconclusive.

OSU Link
Non-OSU Link

14. Bettinger, P. and L.D. Kellogg. 1993. Residual stand damage from cut-to-length thinning of second-growth timber in the Cascade Range of western Oregon. Forest-Products-Journal 43(11/12): 59-64.

Keywords: thinning
commercial thinning
tree/stand health

Abstract: Residual stand damage was measured on 25% of an area that had been thinned with a cut-to-length logging system. Total damage (scar area) per acre was less than in any similar study in the Pacific Northwest, although 39.8% of the residual trees sustained some damage. Only 0.8% of the trees, however, sustained significant damage. Western hemlock (Tsuga heterophylla) was more susceptible to damage than Douglas fir (Pseudotsuga menziesii). Most of the damage occurred within 15 feet of a trail centreline and originated within 3 feet of the groundline. Early summer logging may have resulted in more damaged trees than might occur during other seasons. Future volume loss due to decay is likely to be minimal because a low percentage of scars were considered vulnerable to wood-decaying fungi.

OSU Link
Non-OSU Link

15. Binkley, D. 1984. Importance of size-density relationships in mixed stands of Douglas-fir and red alder. Forest-Ecology-and-Management 9(2): 81-85.

Keywords: thinning
growth
tree/stand health

Abstract: Pairs of Douglas-fir, and Douglas-fir and red alder (Alnus rubra) stands were examined at four locations (in Oregon, Washington and British Columbia) for patterns in average tree size as a function of stand density. On fertile sites, the mixed stands experienced higher mortality than the pure conifer stands. On infertile sites, the pure conifer stands were well below the maximum tree size and density relationship compared to fertile sites or mixed stands, suggesting under-utilized site resources were available for nitrogen-fixing alder.

OSU Link
Non-OSU Link

16. Binkley, D. and P. Reid. 1984. Long-term responses of stem growth and leaf area to thinning and fertilization in a Douglas-fir plantation. Canadian-Journal-of-Forest-Research 14(5): 656-660.

Keywords: fertilization
thinning
tree morphology
carbon allocation
growth

Abstract: Replicated thinning and nitrogen fertilization plots in a 53-year-old plantation in Washington State were examined for repsonses in stem growth, leaf area, and stem growth per unit leaf area. Although measurements occurred 20-30 yr after plot installation, substantial effects from the various treatments were still present. Thinning reduced leaf area of the stands but increased stem growth per unit leaf area, resulting in little difference in stem growth per ha over the 5-yr measurement period (1977-81). Fertilization increased both stand leaf area and stem growth per unit leaf area, and more than doubled 5-yr stem growth per ha. Consideration of the role of leaf area and stem growth per unit leaf area in determining stand treatment responses may account for much of the variation found among replicates of treatments or between studies on different sites.

OSU Link
Non-OSU Link

17. Bodner, J. 1984. Effect of thinning and fertilization on wood properties and intra-ring characteristics in young Douglas-fir. Holzforschung-und-Holzverwertung 36(1): 5-11.

Keywords: fertilization
thinning
wood quality

Abstract: Studies were made on samples from a total of 21 trees (felled in 1982) from 42-yr-old control and thinned/[N] fertilizer-treated stands near Sweet Home, Oregon, and a 48-yr-old thinned stand near Corvallis. Wood properties, studied between and within treatments, included ring density (analysed by X-ray densitometry), earlywood and latewood density, min. earlywood density,

max. latewood density, and ring width. There was n.s.d. in av. wood density between treatments. There were significant between-treatment differences in MOE and MOR. Heavy thinning (during the juvenile wood formation phase) reduced latewood fibre length by 26.5%. Min. earlywood density and max. latewood density were the most important components of ring density.

OSU Link
Non-OSU Link

18. Brandeis, T.J., M. Newton and E.C. Cole. 2001. Underplanted conifer seedling survival and growth in thinned Douglas-fir stands. Canadian-Journal-of-Forest-Research 31(2): 302-312.

Keywords: planting operations
thinning
commercial thinning
site preparation
chemical preparation
release treatments
chemical release
growth
tree/stand health
regeneration

Abstract: In a multilevel study conducted at the Oregon State University's McDonald-Dunn Research Forest, Oregon, USA, to determine limits to underplanted conifer seedling growth, Douglas-fir (Pseudotsuga menziesii), grand fir (Abies grandis), western redcedar (Thuja plicata) and western hemlock (Tsuga heterophylla) seedlings were planted in January 1993 beneath second-growth Douglas-fir stands that had been thinned in 1992 to basal areas ranging from 16 to 31 m2/ha. Understorey vegetation was treated with a broadcast herbicide (glyphosate + imazapyr) application prior to thinning, a directed release herbicide (glyphosate, plus triclopyr for tolerant woody stems) application 2 years later, or no treatment beyond harvest disturbance. Residual overstorey density was negatively correlated with percent survival for all four species. Broadcast herbicide application improved survival of grand fir and western hemlock. Western redcedar, grand fir and western hemlock stem volumes were inversely related to overstorey tree density and this effect increased over time. There was a strong indication that this was also the case for Douglas-fir. Reduction of competing understorey vegetation resulted in larger fourth-year stem volumes in grand fir and western hemlock.

OSU Link
Non-OSU Link

19. Brandeis, T.J., M. Newton and E.C. Cole. 2002. Biotic injuries on conifer seedlings planted in forest understory environments. New Forests 24:1-14.

Keywords: planting operations
site preparation
chemical preparation
release treatments
chemical release

thinning
tree/stand protection
growth
tree/stand health

Abstract: The effects of partial overstorey retention, understorey vegetation management, and protective Vexar(R) tubing on the frequency and severity of biotic injuries in a two-storied stand underplanted with western redcedar (Thuja plicata), Douglas-fir (Pseudotsuga menziesii), grand fir (Abies grandis), and western hemlock (Tsuga heterophylla) were investigated. The most prevalent source of damage was browsing by black-tailed deer (Odocoileus hemionis columbiana); deer browsed over 74% of Douglas-fir and over 36% of western redcedar seedlings one or more times over the four years of this study. Neither the spatial pattern of thinning (even or uneven) nor the density of residual overstorey affected browsing frequency. Spraying subplots may have slightly increased browsing frequency, but the resulting reduction of the adjacent understorey vegetation increased the volume of all seedlings by 13%, whether or not they were browsed. Vexar(R) tubing did not substantially affect seedling survival, browsing damage frequency, or fourth-year volume. Greater levels of overstorey retention reduced frequency of second flushing. Chafing by deer and girdling by rodents and other small mammals began once seedlings surpassed 1 m in height. Essentially all grand fir seedlings exhibited a foliar fungus infection.

OSU Link
Non-OSU Link

20. Brix, H. 1984. Effects of thinning and nitrogen fertilization on growth of Douglas-fir: relative contribution of foliage quantity and efficiency. Canadian-Journal-of-Forest-Research 13(1): 167-175.

Keywords: fertilization
thinning
growth
carbon allocation
tree morphology

Abstract: [See FA 43, 1948, 3839] On Vancouver Island, aboveground biomass and annual production over 7 yr was studied in relation to thinning and nitrogen fertilization at 24 yr old. Biomass yield of both treatments increased during the first 3-4 yr then decreased for fertilization but not with thinning. Treatments doubled biomass production of individual trees over the study period when applied separately and quadrupled it when combined. Annual biomass production per unit of foliage (E) increased during the first 3-4 yr, but was at or below control level after 7 yr. E accounted for 20, 37, and 27% of the stemwood dry matter response to thinning, fertilization and the combined treatments, respectively; the remainder was attributed to an increase in foliage biomass. Thinning, but not fertilization, influenced distribution of radial growth along the stem, increasing growth only below the top one-third of the stem. This pattern was related to crown development.

OSU Link
Non-OSU Link

21. Brix, H. 1993. Fertilization and thinning effect on a Douglas-fir ecosystem at Shawnigan Lake: a synthesis of project results. B.C. Ministry of Forests FRDA-Report 196. X + 64 p.

Keywords: fertilization
thinning
growth
tree morphology
tree/stand health
carbon allocation
wood quality
tree physiology
photosynthesis
economics

Abstract: Treatments were initiated in 1970-71 in a 24-year-old Douglas fir (Pseudotsuga menziesii) near Shawnigan Lake, Vancouver Island, British Columbia, to determine the effects of 3 intensities of thinning (removing none, one-third and two-thirds of basal area) and 3 levels of urea fertilizer (0, 224 and 448 kg N/ha) on the growth and biology of the trees. Subsidiary experiments were established during 1972-87 to examine the effects of high doses of urea (672-1344 kg N/ha), ammonium nitrate as an N source instead of urea, understorey response to thinning and fertilizer, and responses to P and S fertilizer.

22. Brix, H. and A.K. Mitchell. 1983. Thinning and nitrogen fertilization effects on sapwood development and relationships of foliage quantity to sapwood area and basal area in Douglas-fir. Canadian-Journal-of-Forest-Research 13(3): 384-389.

Keywords: fertilization
thinning
tree morphology
tree physiology

Abstract: A 24-yr-old stand in British Columbia was treated in 1971-72 with various intensities and combinations of N fertilization and thinning. For 5-9 yr after treatments, trees were sampled to determine effects on foliage quantity and sapwood characteristics at varying stem ht. together with their relationships. Sapwood width remained relatively constant up the stem where heartwood was present, but the number of annual rings it contained decreased with ht. The sapwood width at b.h. increased with stem diam.; treatments had little effect on % sapwood at b.h. The ratio of foliage mass to sapwood cross-sectional area changed for different portions of the crown and was lower when based on sapwood area at b.h. than at base of live crown. Significant linear relationships of foliage mass and area to sapwood area at b.h. were found, but relationships of foliage to b.a. were just as close for all treatments; treatments significantly affected these relationships with control trees having the lowest regression slopes.

23. Brix, H. and A.K. Mitchell. 1986. Thinning and nitrogen fertilization effects on soil and tree water stress in a Douglas-fir stand. Canadian-Journal-of-Forest-Research 16(6): 1334-1338.

Keywords: thinning
fertilization
soil properties
tree physiology

Abstract: Soil and tree water potentials were studied for 10 yr in a Douglas fir stand near Shawnigan Lake, British Columbia that was treated when 24 yr old with heavy thinning (removing superscript 2/3 of b.a.) and/or fertilization with 448 kg N/ha as urea. Control plots were not thinned or fertilized. Throughout the 10 yr, thinning increased soil water potential during the dry summer periods (July-early Oct.) by as much as 1 MPa. The effect of fertilization on soil water potential was slight and nonsignificant, and only apparent towards the end of the study in spite of large increases in leaf area (50% after 7 yr). Fertilization increased water use efficiency. The favourable soil water conditions produced by thinning led to improved shoot water potential only during predawn and early morning. Removal of understorey in a thinned and fertilized plot did not affect soil or shoot water potential.

OSU Link
Non-OSU Link

24. Buermeyer, K.R. and C.A. Harrington. 2002. Fate of overstory trees and patterns of regeneration 12 years after clearcutting with reserve trees in Southwest Washington. Western-Journal-of-Applied-Forestry 17(2): 78-85.

Keywords: thinning
regeneration
tree/stand health

Abstract: Changes in management objectives for some forestlands in the Pacific Northwest have spurred interest in the creation of multistoried stands and the use of natural regeneration systems, but data on such systems are lacking. We assessed the status of the overstory trees and the regeneration 12 yr after a clearcut harvest with reserve trees in an even-aged, 145-yr-old Douglas-fir stand on a moderately productive site (site class 3) in southwest Washington. The 15 ha harvest unit was superimposed over two areas differentially thinned 15 and 34 yr before clearcutting. The clearcut harvest retained 18 trees/ha with a mean diameter of 63 cm. The reserved overstory trees had a 93% survival rate after 12 yr; most dead trees had been windthrown. Diameter growth for the reserved trees averaged 3.3 cm and was greatest during the most recent 3 yr period, which also had the highest growing-season precipitation. In a 1 ha mapped area, there were 5,854 seedlings/ha, and more than 99% of the regeneration was Douglas-fir. Most seedlings were less than 2 m tall. Seedling density was somewhat clumped (value of 2.1 for Pielou's index of nonrandomness), but 79% of randomly located 4.04 m2 (mil-acre) plots and 98% of 5x5 m grid cells had at least one conifer seedling. There was no obvious pattern of regeneration based on direction from the reserved trees, but both seedling density and seedling size within the drip lines of reserved tree crowns were less than in the rest of the area. The number of seedlings was similar on the two halves of the plot corresponding to the original thinning blocks, but seedling size and age differed. In the half of the study plot that had been twice lightly thinned, only 14% of the seedlings were >0.5 m tall; however, 41% of the seedlings were >0.5 m in the block that had been thinned more heavily. There was no difference between the thinning blocks in the ages of seedlings

<less or =>0.5 m tall (mean age of 5 yr). This example of clearcutting with reserve trees resulted in reasonable survival of the overstory trees and adequate stocking but slow growth rates in the naturally regenerated Douglas-fir. Heavier thinning before harvest was associated with more advance regeneration, more shrub cover, and less windthrow of the reserved trees than in the more lightly thinned block. If an abundance of tree species other than Douglas-fir was desired on this site, interplanting would be required.

OSU Link
Non-OSU Link

25. Busing, R.T. and S.L. Garman. 2002. Promoting old-growth characteristics and long-term wood production in Douglas-fir forests. Forest-Ecology-and-Management 160(1/3): 161-175.

Keywords: thinning
yield
wood quality

Abstract: Trade-offs among wood production, wood quality and ecological characteristics in the management of harvested forest stands are explored through model simulation of various silvicultural regimes. Long-term production of merchantable wood, production of various types of high-quality wood, and the level of certain quantitative ecological indicators are projected for coniferous forests of Pacific Northwestern USA. The set of ecological indicators used is based on the species composition and physical structure of old, unlogged forest stands. Simulations are performed with an ecological model of forest stand dynamics that tracks the fate of live and dead trees. Short rotations (<50 years) produce the least amount of high-quality wood over the multi-century simulation period. They also fail to generate ecological attributes resembling those of old forest stands. Production of high-quality wood is moderate to high under all rotations of 80 years or more; however, most ecological indicators require longer rotations unless alternatives to clear felling are applied. Alternatives examined include retention of 15% cover of live tree canopy at each harvest in combination with artificial thinning between harvests. Thinning from below can expedite the development of large live and dead trees, and canopy height diversity without greatly diminishing wood quantity or quality. Proportional thinning retains understorey stems, thereby expediting the recruitment of shade-tolerant trees. A possible drawback to thinning, particularly proportional thinning, is the diminished production of clean-bole wood at rotations of 150 and 260 years. It is concluded that most wood quantity, wood quality and ecological objectives can be met with long rotations (approximately 260 years). Certain objectives can be met with shorter rotations (80-150 years) when treatments of thinning and canopy tree retention are applied.

OSU Link
Non-OSU Link

26. Carter, R. and R. Scagel. 1989. The effects of stand density and fertilization on stand development in immature coastal Douglas-fir. B.C. Ministry of Forests FRDA-Report 094. i + 15 p.

Keywords: fertilization
thinning
growth
tree morphology

Abstract: The effects of urea fertilizer were studied in Pseudotsuga menziesii stands spaced to 500, 750 and 1000 stems/ha in coastal British Columbia.

OSU Link
Non-OSU Link

27. Chen, J.M. and T.A. Black. 1992. Foliage area and architecture of plant canopies from sunfleck size distributions. Agricultural-and-Forest-Meteorology 60(3/4): 249-266.

Keywords: thinning
pruning
tree morphology

Abstract: A Poisson model is developed to describe sunfleck or gap size distributions beneath clumped plant canopies. This model is based on the assumption that foliage clumps are randomly distributed in space and foliage elements are randomly distributed within each clump. Using this model, the foliage clumping index, leaf area index (L), clump area index, element area index in each clump, and element and clump widths were successfully derived for two artificial canopies and a thinned and pruned Douglas-fir (Pseudotsuga menziesii) forest stand. It is shown that existing theories for deriving L from measurements of canopy gap fraction have limitations, and use of canopy architectural information derived from canopy gap size distribution can substantially improve the technique for indirectly measuring L of plant canopies.

OSU Link
Non-OSU Link

28. Christiansen, E.C. and S.G. Pickford. 1991. Natural abatement of fire hazard in Douglas-fir blowdown and thinning fuelbeds. Northwest-Science 65(4): 141-148.

Keywords: thinning
precommercial thinning
tree/stand health

Abstract: The changes over time in fuelbed loading and depth in precommercially thinned and windthrown low altitude stands of Douglas fir (Pseudotsuga menziesii) were investigated in the Bull Run Watershed, Oregon, using standard fuel inventory techniques. Non-linear least squares regressions were fitted to the resulting data. Slash from precommercial thinning lost half of its original loading and depth within 2 yr. No foliage was retained on twigs and branches after 1 yr. Changes in fuels from windthrown trees were similar to those in slash, except that more material was present initially. Fine fuels (<3 inches in diameter) decreased to background levels within 2-4 yr, but large fuels persisted for longer. Sound logs became rotten after about 80 yr. The study confirmed that the fire hazard after precommercial thinning slash and wind throw was abated after 3 yr.

OSU Link
Non-OSU Link

29. Cole, D.W., M.L. Rinehart, D.G. Briggs, C.L. Henry and F. Mecifi. 1984. Response of Douglas fir to sludge application: volume growth and specific gravity. *In* Proceedings of the Technical Association of the Pulp and Paper Industry 1984 Research and Development Conference, Appleton, Wisconsin, September 30-October 3. pp. 77-84.

Keywords: fertilization
thinning
growth
wood quality

Abstract: In 1977 and 1980 municipal sludge was applied to a 60-yr-old lowland Douglas fir stand in Washington State. Application procedures and rates and suitable sites for treatment are described. There was a 6 yr av. diam. growth response of 93% in unthinned and 48% in thinned stands treated with 142 t/ha sludge and a vol. growth response of 53 and 42%, respectively. The accelerated rate of growth has not shown signs of decreasing since treatment. Relative density of sludge-grown wood was 10-15% less than that of untreated wood, but within the range for Douglas fir grown on higher land. This is thought to be a result of the change in forest site produced by the sludge treatment.

OSU Link
Non-OSU Link

30. Collier, R.L. and E.C. Turnblom. 2001. Epicormic branching on pruned coastal Douglas-fir. Western-Journal-of-Applied-Forestry 16(2): 80-86.

Keywords: pruning
thinning
wood quality
tree morphology

Abstract: The Stand Management Cooperative (SMC 1998) at the University of Washington, USA, conducted live crown reduction experiments in the Pacific Northwest regions of the USA, to better understand the dynamics of the response of coastal Douglas fir (Pseudotsuga menziesii) to pruning. A detailed report on how frequently epicormic branches occur, where they occur on the bole, whether or not their occurrence is related to stand density or the amount of crown removed, and how epicormic sprouting may affect log grade, is presented. The experiments include fifty-six 0.08 ha pruning plot in 18 installations in British Columbia, Oregon and Washington. As part of the monitoring process, a subset of 38 plots in 12 installations was examined for the occurrence and size of epicormic branches 4 years after the initial pruning treatments. Results showed that epicormic branching was most severe on the south and west sides of trees. When epicormic branching was severe, sprouts occurred both at nodes (or whorls) and along internodes. Less severe or moderate sprouting tended to originate mainly in nodes. The risk of epicormic branching is minimal as long as the pruning treatment does not reduce the live crown by more than 40% and the stand has 500 or more stems/ha. The highest risk of epicormic branching was found to be when the live crown is reduced by more than 40%, and the stand carries less than 500 stems/ha.

OSU Link
Non-OSU Link

31. Cruickshank, M.G., D.J. Morrison and Z.K. Punja. 1997. Incidence of Armillaria species in precommercial thinning stumps and spread of Armillaria ostoyae to adjacent Douglas-fir trees. Canadian-Journal-of-Forest-Research 27(4): 481-490.

Keywords: thinning
precommercial thinning
tree/stand health

Abstract: The frequency of Armillaria species in precommercial thinning stumps and the interaction at root contacts between Douglas fir (Pseudotsuga menziesii) crop trees and stumps colonized by A. ostoyae were investigated at sites in four biogeoclimatic zones along a transect from the coast through the southern interior of British Columbia. The frequency of stumps colonized by A. ostoyae and A. sinapina varied among lower, mid, and upper slope transects. On coastal sites, A. sinapina dominated fresh hygrotopes and A. ostoyae dominated slightly dry hygrotopes, and the frequency of both fungi was low on moist hygrotopes. On interior sites, A. ostoyae was found over all hygrotopes, but with lower frequency on the driest sites. The distribution of the two Armillaria species on sites is apparently determined by anoxia associated with periodic soil saturation, by drying of the soil, and by host response limiting spread of pathogenic species. At root contacts between colonized stump roots and crop tree roots, transfer and infection by A. ostoyae occurred more frequently in moist biogeoclimatic zones than dry ones. Lesion size on crop tree roots was related to inoculum volume at some sites and to stump root diameter at others. The percentage of lesions on roots at which crop trees formed callus was associated with tree bole volume. The results indicate that there will be crop tree mortality following precommercial thinning, especially where inoculum levels are high in the Interior Cedar-Hemlock and Interior Douglas fir biogeoclimatic zones.

OSU Link
Non-OSU Link

32. Curtis, R.O. 1987. Levels-of-growing-stock cooperative study in Douglas-fir: Report No. 9 - some comparisons of DFSIM estimates with growth in the levels-of-growing stock study. Pacific-Northwest-Research-Station,-USDA-Forest-Service Research-Paper PNW-RP-376. 34 p.

Keywords: thinning
commercial thinning
growth
tree/stand health
computer modeling

Abstract: Initial stand statistics for the 9 levels-of-growing-stock (LOGS) study installations in Oregon and Washington, USA, and Vancouver Island, British Columbia, Canada, were projected by the Douglas fir (Pseudotsuga menziesii) stand simulation program (DFSIM) over the available periods of observation. Thinnings were simulated by use of observed top height trends, actual residual basal areas, and actual ratios of cut tree diameters to stand diameter before cutting (d/D). Estimates were compared with observed gross and net volumes and basal area growth, net change in quadratic mean diameter, and change in number of trees. Although the LOGS installations included regimes quite different from those in most of the data used to construct DFSIM, overall agreement was reasonably good. Results indicated some density-related bias in the thinned stands and a need for revision in the method used to control the maximum density in the DFSIM program and in the associated mortality estimates.

OSU Link
Non-OSU Link

33. Curtis, R.O., G.W. Clendenen and D.J. DeMars. 1981. A new stand simulator for coast Douglas-fir: DFSIM user's guide. Pacific-Northwest-Forest-and-Range-Experiment-Station,-USDA-Forest-Service General-Technical-Report PNW-GTR-128. ii + 79 p.

Keywords: planting operations
thinning
precommercial thinning
commercial thinning
fertilization
yield
computer modeling

Abstract: A description of a computer program, written in FORTRAN IV, for simulating managed stands. The program has been developed from remeasured plot data contributed by many organizations in the Pacific Northwest USA. It can produce yield tables which include estimates of effects of initial spacing, precommercial and commercial thinning and addition of N fertilizer. Topics discussed include program limitation and potential for further development. Appendices include operating instructions and notes on testing. The program is available from the authors on request.

OSU Link
Non-OSU Link

34. Curtis, R.O. and D.D. Marshall. 1986. Levels-of-growing-stock cooperative study in Douglas-fir. Report no. 8 - The LOGS study: twenty-year results. Pacific Northwest Research Station, USDA Forest Service Research-Paper PNW-RP-356. v + 113 p.

Keywords: thinning
commercial thinning
growth

Abstract: A further report in a series on 9 study areas in Oregon, Washington and British Columbia. The programme aimed to determine relations between growing stock and vol., b.a. and diam. growth for 8 thinning regimes. Results presented are mainly from 5 site class II installations. Growth was strongly related to growing stock. Thinning treatments produced marked differences in volume distribution by tree sizes. There were considerable unexplained differences in productivity between installations, beyond those attributable to site quality. During the 4th treatment period (32-42 yr old in site class II sites) c.a.i. was approx. twice m.a.i. An evaluation is given of the LOGS study design.

OSU Link
Non-OSU Link

35. Curtis, R.O. and D.D. Marshall. 2002. Levels-of-growing-stock cooperative study in Douglas-fir: report no. 14 - Stampede Creek: 30-year results. Pacific-Northwest-Research-Station,-USDA-Forest-Service Research-Paper PNW-RP-543. xi + 77 p.

Keywords: thinning
commercial thinning
growth
yield
tree morphology
tree/stand health

Abstract: Results of the Stampede Creek installation of the levels-of-growing-stock (LOGS) study in Douglas-fir (Pseudotsuga menziesii) are summarized. To age 63 (planned completion of 60 feet of height growth), volume growth on the site III natural stand has been strongly related to level of growing stock, but basal area growth-growing stock relations were considerably weaker. Marked differences in tree size distributions have resulted from thinning. Periodic annual volume increments at age 63 are two to three times greater than mean annual increment; this stand is still far from culmination. Results for this southwest Oregon installation are generally similar to those reported from other LOGS installations, although development has been slower than on the site II installations that make up the majority of the series.

OSU Link
Non-OSU Link

36. Curtis, R.O., D.D. Marshall and J.F. Bell. 1997. LOGS: a pioneering example of silvicultural research in coast Douglas-fir. Journal-of-Forestry 95(7): 19-25.

Keywords: thinning
commercial thinning
growth
yield

Abstract: A regional levels-of-growing-stock (LOGS) study of young Douglas fir (Pseudotsuga menziesii) stands in western Oregon and western Washington, USA and Vancouver Island, British Columbia, Canada, was conducted between 1961 and 1970. The objective was to determine how the amount of growing stock retained in repeatedly thinned stands of P. menziesii affects cumulative wood production, tree size and growth:growing stock ratios. Nine LOGS installations were established during the study period, each consisting of 27 one-fifth acre plots, with 8 thinning treatments (and controls). All plots received initial calibration thinning. After the first 10 feet of height growth and at intervals of 10 feet thereafter, 5 subsequent thinning treatments were made. As of 1994, all installations on site class II, and most installations on site classes III and IV had completed the planned thinning sequence over 60 ft of height growth. Periodic annual increment of both basal area and volume was clearly related to basal area of growing stock and several measures of density. Thinning accelerated diameter growth, and diameter and volume distributions differed greatly among treatments. Mean annual increment and periodic annual increment showed no sign of approach to culmination in either total or merchantable cubic volume. Cumulative volume production (live stand plus thinning) of the controls exceeded all thinning treatments to date when measured in total cubic volume of all trees, although when volume was measured in merchantable cubic feet several thinning treatments exceeded net volume production of the controls. A discussion of the results includes: a comparison with other thinning studies; an analysis of application of the Langsaeter hypothesis (that the same cubic volume production could be obtained over a wide range of stand densities); growth trends and rotations; thinning gains; non-timber

values; and critical analysis of the study design. The continuing value of the demonstration stands is discussed.

OSU Link
Non-OSU Link

37. Curtis, R.O., D.D. Marshall and D.S. DeBell. 2004. Silvicultural options for young-growth Douglas-fir forests: the Capitol Forest study - establishment and first results. Pacific Northwest-Research-Station,-USDA-Forest-Service General-Technical-Report PNW-GTR-598. xi + 110 p.

Keywords: thinning
commercial thinning
economics
soil properties

Abstract: This report describes the origin, design, establishment and measurement procedures and first results of a large long term cooperative study comparing a number of widely different silvicultural regimes applied to young-growth Douglas-fir (Pseudotsuga menziesii) stands managed for multiple objectives. Regimes consist of (1) conventional clear felling followed by intermediate thinning; (2) retention of reserve trees to create a two-aged stand; (3) small patch cuts dispersed within a thinned matrix, repeated at approximately 15-year intervals to create a mosaic of age classes; (4) group selection within a thinned matrix on an approximate 15-year cycle; (5) continued thinning on an extended rotation; and (6) an untreated control. Each of these regimes is on operation-size units (approximately 30 to 70 acres each). A LIDAR system was used to scan the surface of the 2 miles2 that encompass the Blue Ridge study site on the Capitol State Forest, near Olympia, Washington, USA. This measurement technology emits laser pulses that are reflected by vegetation, buildings, or the ground surface. Output variables from the study to be evaluated include conventional timber growth and yield statistics, harvest costs, sale layout and administration costs, aesthetic effects and public acceptance, soil disturbance, bird populations, and economic aspects. Descriptive statistics and some initial results are presented for the first replicate, established in 1997-98.

OSU Link
Non-OSU Link

38. Dangerfield, J. and H. Brix. 1981. Comparative effects of ammonium nitrate and urea fertilizers on tree growth and soil processes. *In* Proceedings: Forest Fertilization Conference, University of Washington, Seattle, Washington, USA. *Eds.* S.P. Gessel, R.M. Kenady and W.A. Atkinson. pp. 133-139.

Keywords: fertilization
thinning
growth
tree physiology

Abstract: Growth response of Douglas-fir to ammonium nitrate and urea, applied at rates of 200 and 400 pounds per acre (224 and 448 kilograms of nitrogen per hectare), was studied over a 7-year period at Shawnigan Lake, B.C. Diameter growth was 21 and 9 percent better, respectively, for the two rates

with ammonium nitrate than with urea in unthinned plots and 7 percent better for plots that had been thinned and received 400 pounds per acre (448 kilograms nitrogen per hectare). Foliar nitrogen concentrations also increased most with ammonium nitrate fertilzization during the first 2 years, indicating that nitrogen from this source was initially more readily available to the trees. This is explained in part by the greater mobility of nitrate supplied by ammonium nitrate and by nitrogen immobilization in buildup of bacterial populations with urea.

OSU Link
Non-OSU Link

39. DeBell, D.S., C.A. Harrington and J. Shumway. 2002. Thinning shock and response to fertilizer less than expected in young Douglas-fir stand at Wind River Experimental Forest. Pacific-Northwest-Research-Station,-USDA-Forest-Service Research-Paper PNW-RP-547. ii + 20 p.

Keywords: fertilization
thinning
precommercial thinning
growth

Abstract: Three thinning treatments (thinned to 3.7 by 3.7 m, thinned to 4.3 by 4.3 m, and an unthinned control treatment with nominal spacing averaging 2.6 by 2.6 m) were installed in a 10-year-old Douglas-fir (Pseudotsuga menziesii) plantation growing on a low-quality site at the Wind River Experimental Forest in southwest Washington, USA. Two years after thinning, two fertilizer treatments were superimposed on the design (0 and 224 kg per ha of nitrogen applied as ammonium nitrate). Diameter growth increased with increasing spacing throughout the 6-year study period, and it was also increased by fertilizer in both the thinned and unthinned (control) treatments. Thinning shock, a reduction in height growth after thinning, was expected at this study site because severe thinning shock had been documented in earlier nearby trials. Height growth was initially reduced slightly by thinning, but by the third 2-year period after thinning, height growth in thinned, unfertilized treatments was equal to or greater than height growth in the unthinned, unfertilized treatment. Fertilizer application increased height growth on average by 13 per cent in the first 2 years after fertilizer application. In the third and fourth years after fertilizer application, however, fertilizer increased average height growth by 9 per cent, but the increase was substantial (16 per cent) only in the unthinned control treatment. The mild, ephemeral nature of thinning shock in our study was in contrast to the severe, long-lasting shock in earlier studies at Wind River. The milder shock in our study could be related to one or more of the following: (1) thinning was done at an early age, (2) impacts of fire (natural or prescribed) preceding planting were minor, and (3) seed source of the planted stock was appropriate for the location. Based on comparisons with other studies at Wind River and elsewhere, we suspect that use of nonlocal, maladapted seed sources in the earlier studies may have predisposed those trees to thinning shock. Furthermore, we suspect that the much higher responses to fertilizer application reported in the earlier studies may be associated with intense natural fires prior to planting, and the reduced nutritional status of those sites may have been further exacerbated by the use of maladapted seed sources.

OSU Link
Non-OSU Link

40. Drever, C.R. and K.P. Lertzman. 2003. Effects of a wide gradient of retained tree structure on understory light in coastal Douglas-fir forests. Canadian-Journal-of-Forest-Research 33(1): 137-146.

Keywords: thinning
stand conditions

Abstract: We characterize understorey light of seven stands that varied along a gradient of tree retention. Using hemispherical canopy photographs and digital image, we estimated gap light or solar radiation reaching the understorey through the canopy. Using nonlinear regressions, we related gap light to several structural attributes in the examined silvicultural treatments. The silvicultural treatments affected both the median and range of gap light in the understorey. As overstorey removal increased from uncut second growth to green-tree retention, the median value of light increased from 8 to 68% full sun, while the range of light increased from 3-22% to 26-88% full sun. We found strong, significant, and negative nonlinear relationships between gap light at a particular microsite (0.04 ha) in the understorey and the height, diameter at breast height, density, and volume of surrounding retained trees (ra2=0.77-0.94). These relationships can aid planning of treatments that retain forest structure, such as variable retention, by allowing predictions of understorey light from commonly used field data. These predictions allow forest managers to understand some of the ecological consequences and tradeoffs associated with retaining structure during harvesting.

OSU Link
Non-OSU Link

41. Duke, K.M., G.M. Townsend and W.A. White. 1989. An economic analysis of fertilization and thinning effects on Douglas-fir stands at Shawnigan Lake. Canadian-Forest-Service, Pacific and Yukon Region Information-Report BC-X-312. v + 19 p.

Keywords: fertilization
thinning
economics
computer modeling

Abstract: A single-tree density-dependent growth model was used to project, from age 24 to age 120 yr, 9 combinations of thinning and fertilizer application (nitrogen as urea or ammonium nitrate) in Douglas fir (Pseudotsuga menziesii) near Shawnigan Lake, British Columbia. Costs and benefits were estimated as a function of stand diameter, and forestry investment criteria were used to evaluate each treatment on both an incremental and a regime basis. The effect of rising real prices, and the treatment of silvicultural costs as an initial investment or as a harvest cost were also studied.

OSU Link
Non-OSU Link

42. Edmonds, R.L. and T. Hsiang. 1987. Forest floor and soil influence on response of Douglas-fir to urea. Soil-Science-Society-of-America-Journal 51(5): 1332-1337.

Keywords: fertilization
thinning

growth
soil properties

Abstract: Data from the Regional Forest Nutrition Research Project (RFNRP) in Washington and Oregon were analyzed to improve stand-specific prediction of Douglas-fir [Pseudotsuga menziesii (Mirb.) Franco] response to urea fertilization. The response variable (relative difference in volume growth between fertilized and control plots 4 yr after fertilization with 448 kg N/ha) was regressed against 28 stand and site variables (e.g., age, elevation, forest floor C/N ratio, soil cation exchange capacity, etc.) using stepwise multiple regression analysis. Data from 120 installations were stratified by thinning level (thinned or unthinned), geographic location (provinces), and site quality (site index and class). Forest floor C/N ratio was the dominant variable related to response. In thinned installations of high site quality (site classes 1 and 2), 60% of variation in response was explained by the forest floor C/N, and 75% of the variation in response was explained with inclusion of surface soil exchangeable K. In thinned, low site quality stands, response was not as well related to forest floor C/N. Analysis of the data by province indicated that S may be limiting in southwest Oregon and P in coastal Washington.

OSU Link
Non-OSU Link

43. El Kassaby, Y.A. and A. Benowicz. 2000. Effects of commercial thinning on genetic, plant species and structural diversity in second growth Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) stands. Forest-Genetics 7(3): 193-203.

Keywords: thinning
commercial thinning
genetic relationships

Abstract: The impact of commercial thinning on biodiversity was studied in two Douglas-fir (Pseudotsuga menziesii) plantations, Weeks Lake (WL) and Fairservice Creek (FC) located on southern Vancouver Island, British Columbia, Canada. The age of the stands at thinning was 53 and 70 years for FC and WL, respectively. Other tree species were also present in both sites due to natural regeneration. Biodiversity was evaluated before and after commercial thinning with respect to tree species composition/abundance, tree species genetic diversity assessed by allozyme analysis and stand structural diversity represented by the diameter class (5-cm) distribution. In addition, understorey plant species diversity was monitored in WL and FC for 4 and 5 years following thinning, respectively. Tree species composition changed in both plantations in a similar fashion as the proportion of Douglas-fir increased at the expense of all other tree species. Stand structural diversity was simplified due to the decreased number of trees in small diameter classes. These results were expected since the commercial thinning was conducted to promote the growth of Douglas-fir. Genetic diversity parameters (average number of alleles per locus, percent polymorphic loci and expected heterozygosities) did not differ significantly before and after thinning; however, thinning resulted in a loss of 8 and 7 alleles across species for FC and WL, respectively. Most of the allelic loss occurred in the naturally regenerated species (93%). This allelic loss represents 7 and 6% of the total alleles present in FC and WL, respectively. Thus, only one allele was lost from the crop tree in the FC plantation. Understorey vegetation species richness decreased the year following commercial thinning and then consistently increased over time in both plantations. A total of 17 and 9 new species colonized FC and WL, respectively. One species was replaced in each plantation. In FC, diversity of the understorey plant community based on

the Shannon diversity index (H) changed in an increasing linear trend that corresponded to the increase in species richness. On the other hand, H in WL remained stable. Species evenness (H/Hmax) did not change in WL and FC over the course of study except for seasonal fluctuations. Rare species diversity increased over time in both plantations.

OSU Link

44. Emmingham, W.L., P. Oester, M. Bennett, F. Kukulka, K. Conrad and A. Michel. 2002. Comparing short-term financial aspects of four management options in Oregon: implications for uneven-aged management. Forestry-Oxford 75(4): 489-494.

Keywords: thinning
commercial thinning
economics
yield

Abstract: Private family forest owners are often more interested in comparing short-term financial outcomes of management options, as opposed to longer time horizons and classical economic analyses including net present value. Therefore, we compared projected 10-year value of timber and land for four theoretical management scenarios starting with stands ripe for thinning. The options were (1) hold for 10 years (i.e. no thinning), (2) thin for even-age, or (3) partial cut for uneven-age and (4) clearcut now. To simulate the outcomes of these scenarios, we marked and measured 2-ha plots in 10 stands typical of private forest ownerships across Oregon and projected timber yields and revenues. The financial analysis included current market values for logs, payment of taxes and typical reforestation costs and computation of net asset values (NAV) at a 7 per cent interest rate. The hold option consistently gave the highest NAV for timber and land after 10 years, and the thin option was within 2 per cent. For the eight western Oregon stands, the partial-cut option averaged about 3 per cent less, and the clearcut option ranged from 8 to 17 per cent less than holding. Pine stands of eastern Oregon showed similar trends; however, all options were within about 6 per cent of the hold option. Thus, using financial criteria typical of those used by private forestowners, we found that there was little short-term financial loss in choosing to thin toward even-age, partial cut toward uneven-age, or the hold approach in well-stocked stands.

OSU Link
Non-OSU Link

45. Entry, J.A., K. Cromack, Jr., R.G. Kelsey and N.E. Martin. 1991. Response of Douglas-fir to infection by Armillaria ostoyae after thinning or thinning plus fertilization. Phytopathology 81(6): 682-689.

Keywords: thinning
fertilization
tree/stand protection
growth
tree morphology
carbon allocation
tree/stand health
tree physiology

Abstract: Second-growth stands of Douglas-fir (Pseudotsuga menziesii) were thinned to a 5- x 5-m spacing (TT); additional plots were thinned and fertilized once with 360 kg of N (as urea)/ha (TF). An unthinned, unfertilized stand (UT) served as a control. Ten years after treatment, trees were inoculated with 2 isolates of A. ostoyae. Trees receiving the TF and TT treatments produced greater diameter growth, leaf area, and wood production/msuperscript 2 leaf area per year than did those under the UT treatment. Rates of infection by A. ostoyae were highest in trees that received the TF and lowest in trees that received the TT treatment. Concn of sugar, starch and cellulose in root bark tissue were highest in trees receiving the TF treatment and lowest in trees receiving TT treatment. Concn of lignin, phenolics and protein-precipitable tannins were highest in root bark from TT trees and lowest in root bark from TF trees. Biochemical parameters of root bark tissue were regressed with incidence of infection; coefficients of determination (rsuperscript 2) ranged from 0.07 (starch) to 0.57 (phenolic compounds). Ratios of the energetic costs of phenolic and of lignin degradation to the energy available from sugars (Epd:Eas and Eld:Eas) were correlated with incidence of infection (rsuperscript 2 = 0.77 and 0.70, respectively). It is concluded that thinning combined with fertilization may predispose P. menziesii trees to infection by A. ostoyae by lowering concn of defensive compounds in root bark and increasing the energy available to the fungus to degrade them.

OSU Link
Non-OSU Link

46. Feller, M.C., J.P. Kimmins and K.A. Scoullar. 1983. FORCYTE-10: calibration data and simulation of potential long-term effects of intensive forest management on site productivity, economic performance, and energy benefit/cost ratio. *In* I.U.F.R.B. Symposium on.Forest Site and Continuous Productivity; Seattle, Washington; August 22-28, 1982. *Eds.* R. Ballard and S.P. Gessel. Pacific-Northwest-Forest-and-Range-Experiment-Station, USDA-Forest-Service General-Technical-Report PNW-GTR-163 Part B. 179-200 pp.

Keywords: thinning
fertilization
soil properties
economics
computer modeling

Abstract: FORCYTE (FORest nutrient Cycling and Yield Trend Evaluator) is a computer simulation model of forest plant biomass production, litterfall, and decomposition, complete with nutrient cycling, nutrient limitation on growth, and a variety of management interventions. The model is a computerized approach to the estimation of the effects of varying thinning and fertilizer regimes, utilization level, and rotation length on site nutrient budgets, stand productivity, and the economic performance and energy efficiency of management. The model has evolved over 5 years to its present version FORCYTE-10, which is briefly described. Accompanying the development of FORCYTE, there has been a series of field research projects. Detailed biomass and biogeochemical descriptions of age sequences of Douglas-fir stands on both good and poor sites have been prepared for purposes of model calibration and testing. The present report summarizes some of the results of the FORCYTE-10 field studies on Vancouver Island, British Columbia, and presents some examples of the use of the model when calibrated with these data.

OSU Link
Non-OSU Link

47. Fight, R.D., J.M. Cahill, T.D. Fahey and T.A. Snellgrove. 1988. A new look at pruning coast Douglas-fir. Western-Journal-of-Applied-Forestry 3(2): 46-48.

Keywords: pruning
thinning
fertilization
economics

Abstract: A short account of an evaluation of the financial returns of pruning coast Douglas fir (Pseudotsuga menziesii), using new product-recovery information and computer software, and assuming that: the analysis is for lumber, interest rates are 4 and 8%, stands are fertilized 2 or 3 times and thinned periodically, and that trees were pruned at age 20 yr. Results showed that higher returns from pruning could be achieved by concentrating pruning in younger stands that have a higher site index and that will be fertilized.

OSU Link
Non-OSU Link

48. Filip, G.M. and L.M. Ganio. 2004. Early thinning in mixed-species plantations of Douglas-fir, hemlock, and true fir affected by Armillaria root disease in Westcentral Oregon and Washington: 20 year results. Western-Journal-of-Applied-Forestry 19(1): 25-33.

Keywords: thinning
precommercial thinning
tree/stand protection
growth
tree/stand health

Abstract: Four 10- to 20-year-old plantations were treated to determine the effects of precommercial thinning on tree growth and mortality caused by Armillaria root disease in the Cascade Range of western Oregon and Washington, USA. One plantation was Douglas-fir (Pseudotsuga menziesii) and noble fir (Abies procera), one Douglas-fir and western hemlock (Tsuga heterophylla), one Douglas-fir alone, and one Shasta red fir (Abies magnifica var. shastensis) and mountain hemlock (Tsuga mertensiana). After 20 years, differences in crop tree mortality between thinned and unthinned plots were not significant (P=0.9768). Quadratic mean diameter growth of crop trees, however, was significantly (P=0.0053) greater in thinned than in unthinned plots. Crop tree basal area/ac growth was significantly (P=0.0008) greater in thinned plots. There were no significant (P=0.6647) differences in basal area/ac growth of all trees between thinned and unthinned plots. Apparently, from a root-disease perspective, precommercial thinning does not affect incidence of crop-tree mortality after 20 years, but individual and per acre tree growth of crop trees increase significantly.

OSU Link
Non-OSU Link

49. Filip, G.M. and D.J. Goheen. 1995. Precommercial thinning in Pseudotsuga, Tsuga, and Abies stands affected by armillaria root disease: 10-year results. Canadian-Journal-of-Forest-Research 25(5): 817-823.

Keywords: thinning
precommercial thinning
tree/stand protection
growth
tree/stand health

Abstract: Four 10- to 20-year-old stands were pre-commercially thinned to determine the effects of thinning on tree growth and mortality caused by armillaria root disease (Armillaria ostoyae) in the Cascade Range of western Oregon and Washington, USA: one stand of Douglas fir (Pseudotsuga menziesii var. menziesii) and noble fir (Abies procera), one of Douglas fir and western hemlock (Tsuga heterophylla), one of Douglas fir alone, and one of Shasta red fir (Abies magnifica var. shastensis) and mountain hemlock (Tsuga mertensiana). After 10 years, differences in crop-tree mortality between thinned and unthinned plots were not significant in any of the four stands. Tree radial growth was significantly increased by thinning in 6 of 15 plots. Crop-tree basal area (per hectare) growth was significantly greater in thinned plots. Basal area (per hectare) growth of all trees was significantly greater in unthinned plots. Apparently, from a root-disease perspective, pre-commercial thinning does not affect the incidence of crop-tree mortality after 10 years, but tree growth increases significantly.

OSU Link
Non-OSU Link

50. Gardner, E.R. 1990. Fertilization and thinning effects on a Douglas-fir ecosystem at Shawnigan Lake: 15-year growth response. Canadian-Forest-Service, Pacific and Yukon Region Information-Report BC-X-319. ix + 42 p.

Keywords: fertilization
thinning
growth
yield
tree morphology
tree/stand health

Abstract: Responses after 15 yr to 3 rates of nitrogen (urea), applied at 0, 224 or 448 kg N/ha to a 24-yr-old Douglas fir (Pseudotsuga menziesii) stand in the very dry maritime region of British Columbia, were analysed on the basis of per hectare, individual tree, crop tree and tree size class. Thinned and unthinned plots were measured.

OSU Link
Non-OSU Link

51. Garman, S.L., J.H. Cissel and J.H. Mayo. 2003. Accelerating development of late-successional conditions in young managed Douglas-fir stands: a simulation study. Pacific-Northwest-Research-Station,-USDA-Forest-Service General-Technical-Report PNW-GTR-557. ii + 57 p.

Keywords: thinning
commercial thinning
yield

Abstract: The goal of this simulation study was to provide information for defining thinning regimes for young Douglas-fir (Pseudotsuga menziesii) stands in the Central Cascades Adaptive Management Area, located in west-central Oregon, USA. Specifically, this study used the ZELIG.PNW (3.0) gap model to evaluate effects of experimental thinning treatments on the development of late-successional attributes and on extracted merchantable volume. Sixty-four thinning treatments were simulated for four rotation intervals (260, 180, 100, and 80 years) starting with a 40-year-old managed Douglas-fir stand. The amount of time for five late successional attributes to reach defined threshold levels, long-term developmental trends of these attributes, and amount of extracted merchantable volume were recorded for each treatment. Stand conditions of selected treatments were used in a subsequent harvest rotation in which 64 additional experimental thinning treatments were applied and evaluated. A total of 1744 thinning treatments was evaluated in this study. Results of this study confirm previous recommendations for accelerating development of late-successional attributes in young managed stands. Additionally, results show the potential for a range of thinning treatments to attain late-successional conditions in about the same amount of time, but with different trade-offs in terms of merchantable volume and long-term stand conditions. In general, heavy thinning of existing stands at ages 40 and 60 years promoted rapid development of large boles, vertical diversity, and tree-species diversity, but provided the least amount of extracted volume and required artificial creation of dead wood. Treatments that retained more than 40% of the original overstorey and thinned to 99 trees per hectare at age 60 delayed attainment of late-successional conditions by 10 to 30 years but provided 12 to 20% more extracted volume, resulted in higher levels of most late-successional attributes at the end of a rotation, and required less artificial creation of dead wood. Treatments providing the fastest development of late-successional conditions in subsequent rotations varied with the amount of canopy cover retained at the end of the first rotation. For stands starting with <more or =>30% canopy cover, delaying the first commercial thin for 40 years promoted the most rapid development of vertical structure and shade-tolerant stems. Lower canopy-retention levels required heavy or light thins in subsequent entries, depending on the rotation interval, for rapid development of late-successional attributes.

OSU Link
Non-OSU Link

52. Gartner, B.L., J.J. Morrell, C.M. Freitag and R. Spicer. 1999. Heartwood decay resistance by vertical and radial position in Douglas-fir trees from a young stand. Canadian-Journal-of-Forest-Research 29(12): 1993-1996.

Keywords: fertilization
thinning
wood quality

Abstract: Heartwood durability of Douglas-fir (Pseudotsuga menziesii var. menziesii) was studied as a function of vertical and radial position in boles of trees with a wide range of leaf area/sapwood area ratios. Six 34-year-old trees were harvested from each of three plots: very dense, thinned, and thinned and fertilized with N, P, K, Ca, S and Fe (51, 11, 10, 7, 4 and 0.3 kg/ha, respectively), established 14 years before at a site in the central Cascades of Oregon. Heartwood samples from three radial positions and five heights were incubated with the decay fungus Postia placenta [Oligoporus placenta]. There were no significant differences in wood mass loss (decay resistance) by vertical or radial position. One could expect that trees with high leaf area/sapwood area could have the carbon to produce heartwood that is more resistant to decay than trees with lower leaf area/sapwood area. However, no relationship was

found between leaf area above node 20, sapwood area there, or their ratio, and the decay resistance of outer heartwood at that node. These results suggest that, for young Douglas-fir trees, heartwood durability does not vary with position in the bole or with environments that alter the balance of sapwood and leaf area in a tree. It is suggested that young stands may thus be robust with respect to the effect of silvicultural regimes on heartwood durability.

OSU Link
Non-OSU Link

53. Gartner, B.L., E.M. North, G.R. Johnson and R. Singleton. 2002. Effects of live crown on vertical patterns of wood density and growth in Douglas-fir. Canadian-Journal-of-Forest-Research 32(3): 439-447.

Keywords: thinning
pruning
wood quality

Abstract: It would be valuable economically to know what are the biological triggers for formation of mature wood (currently of high value) and (or) what maintains production of juvenile wood (currently of low value), to develop silvicultural regimes that control the relative production of the two types of wood. Foresters commonly assume the bole of softwoods produces juvenile wood within the crown and mature wood below. We tested that assumption by comparing growth ring areas and widths and wood density components of the outer three growth rings in disks sampled from different vertical positions of 34-year-old Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) trees. The 18 trees were sampled from one site and had a wide range of heights to live crown. Most of the variance (63-93%) in wood characteristics (growth ring area: total, earlywood, latewood; growth ring width: total, earlywood, latewood; latewood proportion: by area, width; and ring density: total, earlywood, latewood) was due to within-tree differences (related to age of the disk). Stepwise regression analysis gave us equations to estimate wood characteristics, after which we analysed the residuals with a linear model that included whether a disk was within or below the crown (defined as the lowest node on the stem with less than three live branches). After adjusting for tree and disk position, only 2-10% of the residual variation was associated with whether the disk was in or out of the live crown. There were no statistically significant differences at p=0.05 between a given disk (by node number) in versus out of the crown for any of the factors studied. Moreover, the wood density characteristics were not statistically significant at p=0.30. This research suggests that there was no effect of the crown position on the transition from juvenile to mature wood as judged by wood density. Therefore, we found no evidence to support the concept that tree spacing and live-branch pruning have a significant effect on the cambial age of transition from juvenile to mature wood in Douglas-fir trees of this age.

OSU Link
Non-OSU Link

54. Greene, S.E. and W.H. Emmingham. 1986. Early lessons from commercial thinning in a 30-year-old Sitka spruce-western hemlock forest. Pacific-Northwest-Research-Station,-USDA-Forest-Service Research-Note PNW-RN-448. 14 p.

Keywords: thinning

commercial thinning
growth
tree/stand health
tree morphology

Abstract: Three commercial thinning treatments were applied to a 30-yr-old stand of Picea sitchensis and Tsuga heterophylla with Pseudotsuga menziesii that had been precommercially thinned at 15 yr old on the Oregon coast. Data were collected to determine the effects of thinning on diam. and ht. growth, the amount of damage and subsequent decay in remaining trees and relations between leaf area and volume production.

OSU Link
Non-OSU Link

55. Haight, R.G. 1993a. The economics of Douglas-fir and red alder management with stochastic price trends. Canadian-Journal-of-Forest-Research 23(8): 1695-1703.

Keywords: planting operations
site preparation
prescribed fire
release treatments
chemical release
thinning
precommercial thinning
commercial thinning
tree/stand protection
economics

Abstract: A financial analysis of Douglas fir (Pseudotsuga menziesii) and red alder (Alnus rubra) management was conducted using yield projections from the Stand Projection Simulator for the Pacific Northwest region of the United Sates. The analysis included uncertainty in the price trends and stocking levels of both species following reforestation. Results from a case study in which Douglas fir price is likely to increase faster than red alder price show that (i) on more productive sites, greater regeneration investment is justified to increase the likelihood of Douglas fir establishment, (ii) on less productive sites, low-cost regeneration options that produce mixed-species stands have expected present values close to or greater than a high-cost Douglas fir regeneration effort, (iii) optimal precommercial removal of red alder depends on mid-rotation prices and regeneration success, and in many cases growing a mixed-species stand to maturity produces the highest economic return, and (iv) commercial thinning of Douglas fir increases the expected present value of the most intensive regeneration option by up to 10%. The low-cost regeneration options have relatively high expected returns because of low initial investments and the presence of two species that may have high values in the future. The sensitivity of these results to changes in the probability distributions of regeneration success and price trends is discussed.

OSU Link
Non-OSU Link

56. Haight, R.G. 1993b. Technology change and the economics of silvicultural investment. Rocky-Mountain-Forest-and-Range-Experiment-Station,-USDA-Forest-Service General-Technical-Report RM-GTR-232. ii + 18 p.

Keywords: planting operations
site preparation
prescribed fire
release treatments
chemical release
tree/stand protection
thinning
commercial thinning
precommercial thinning
yield
economics

Abstract: Financial analyses of intensive and low-cost reforestation options are conducted for loblolly pine (Pinus contorta) stands with broadleaved competition in the Southern USA, and Douglas fir with red alder (Pseudotsuga menziesii with Alnus rubra) in the Pacific Northwest. Results show that the expected present values (EPVs) of low-cost options that result in mixtures of conifers and broadleaves are superior in some situations to the EPVs of the intensive options.

OSU Link
Non-OSU Link

57. Hall, T.H., R.V. Quenet, C.R. Layton and R.J. Robertson. 1980. Fertilization and thinning effects on a Douglas-fir ecosystem at Shawnigan Lake: 6 year growth response. Pacific-Forest-Research-Centre, Canadian Forestry Service Information-Report BC-X-202. 31 p.

Keywords: fertilization
thinning
growth

Abstract: Further results are given for this stand in British Columbia at 30 yr old [see FA 43, 1945]. Gains in gross vol. increment (over control at 24 yr old) for the 200 initially largest trees/ha were 20% for heavy thinning alone, 51% for heavy fertilizer (urea) application alone and 139% for heavy thinning plus heavy fertilizer application. Adjustments by covariance analysis for differences in intitial stocking and tree size distributions gave values of 47, 76 and 139% respectively.

OSU Link
Non-OSU Link

58. Han, H., L.D. Kellogg, G.M. Filip and T.D. Brown. 2000. Scar closure and future timber value losses from thinning damage in western Oregon. Forest-Products-Journal 50(1): 36-42.

Keywords: thinning
tree/stand health

economics

Abstract: This study investigated bark growth and decay development after thinning damage at two western Oregon sites, and estimated value loss with a tree growth model. All scars that remained open in western hemlock (Tsuga heterophylla) and Sitka spruce (Picea sitchensis) had advanced decay 13 years after initial wounding. Scars less than 4 inches wide closed in 8 years. Douglas-fir (Pseudotsuga menziesii) was more resistant to decay; no rot was observed in scars less than 21 years old. Advanced decay and pitch rings, however, were observed in 29-year-old scars, both open and closed. Because of these defects, future value loss increased with time after wounding and with higher stand damage levels. Fifty years after thinning, about 2% of the total future log value, or $189/ac. (1997$), could be lost in Douglas-fir stands with 20% stand damage and a 2-inch diameter deduction. This loss could be reduced to $58/ac. if stand damage were minimized to 5% with more careful techniques. The increase in thinning costs ($61/ac. for tractor thinning; $79/ac. for cut-to-length; $124/ac. for skyline; with a 5% increase in production time) that is incurred while trying to minimize stand damage could be justified if it reduced future value losses to crop trees.

OSU Link
Non-OSU Link

59. Harper, P.A. and A.S. Harestad. 1986. Vole damage to coniferous trees on Texada Island. Forestry-Chronicle 62(5): 429-432.

Keywords: thinning
precommercial thinning
tree/stand protection
tree/stand health
growth

Abstract: Microtus townsendii injured trees by removal of bark and cambium from stems, branches and roots of Douglas fir, western hemlock and, rarely, Pinus monticola on Texada Island, British Columbia. Damage occurred more frequently in precommercially thinned stands <40 yr old than in unspaced stands. Trees with d.b.h. <less or =>19 cm were damaged by voles, but there was no selection by diam. or age class. No trees of ht. >16 m were damaged. For trees <16 m, damage increased as ht. decreased. There were n.s.d. in growth rates of trees damaged by voles when comparing the 2-yr av. before spacing and vole damage with the av. after these events. Stands should continue to be monitored to evaluate long-term effects of vole damage. On the basis of these results, control of voles is not recommended.

OSU Link
Non-OSU Link

60. Heath, L.S. and H.N. Chappell. 1989. Growth response to fertilization in young Douglas-fir stands. Western-Journal-of-Applied-Forestry 4(4): 116-119.

Keywords: fertilization
thinning
growth

Abstract: Response surface methodology was used to estimate 6-yr vol. growth response to 1 application of 200 lb N/acre in unthinned and thinned Douglas fir (Pseudotsuga menziesii) stands of b.h. age <less or =>25 yr in W. Washington and W. Oregon. Regional mean fertilizer response was 16% in unthinned stands and 20% in thinned stands. Site index had an increasingly inverse effect on response as b.a. increased in both unthinned and thinned stands. Response varied little over site index in regions of low b.a., decreased moderately as site index increased in the intermediate region, and decreased rapidly in the high b.a. region.

OSU Link
Non-OSU Link

61. Henry, C.L., D.W. Cole, T.M. Hinckley and R.B. Harrison. 1993. The use of municipal and pulp and paper sludges to increase production in forestry. Journal-of-Sustainable-Forestry 1(3): 41-55.

Keywords: nursery operations
nursery fertilization
fertilization
thinning
growth
tree/stand health
soil properties

Abstract: Because of their high nutritional content and soil conditioning properties, municipal and pulp and paper (P&P) sludges (biosolids) can serve as soil amendments for nutritionally deprived or organically poor soils on forest sites. Studies conducted over the past 20 years at an experimental forest site in Western Washington, USA, have largely confirmed the potential of biosolids to increase the productivity of many forest lands. These studies clearly demonstrated that application of biosolids at environmentally acceptable rates will result in growth responses for both young seedlings as well as established stands. Municipal biosolids have been applied to a number of Douglas fir (Pseudotsuga menziesii) stands. Young stands treated with 47 t/ha showed an average of 72, 14 and 2% height responses for Site Class IV, III and II, respectively, over a 10 year period. Thinned versus unthinned 55-year-old Douglas fir treated with 142 dry t/ha averaged 43 and 48%, respectively, for the 12 year period greater than controls. Average growth responses of 65 and 40% occurred in the 65-year-old stand for the Site Class IV and II, respectively, from a 47 dry t/ha application. Growth response resulting from application of P&P biosolids to a number of tree species (Douglas fir, Pinus monticola and Abies procera in nursery beds, and plots of Populus deltoides x P. trichocarpa rooted cuttings) has also been excellent. When properly applied, biosolids can provide an excellent alternative to chemical fertilizers as a means of enhancing forest production. Growth response is typically greater and lasts longer when compared with chemical fertilizers.

OSU Link
Non-OSU Link

62. Hermann, R.K. and D.P. Lavender. 1999. Douglas-fir planted forests. New-Forests 17(1/3): 53-70.

Keywords: genetic tree improvement
nursery operations

planting operations
site preparation
release treatments
fertilization
thinning
pruning
tree/stand protection
growth
yield

Abstract: A combination of superior wood quality and high productivity has made Douglas fir (Pseudotsuga menziesii) one of the premier timber trees in the world. As such, it is grown as a plantation species in several countries in Europe and South America, and in New Zealand and Australia, as well as throughout its extensive natural range in western North America. Decades of experience with the silviculture of young stands have demonstrated that practices such as planting, the use of genetically improved seedlings, precommercial and commercial thinning, and fertilizing may dramatically increase the yield of industrial products over that of natural forests. Further, such silviculture is compatible with the production of desired amenities. Vigorous implementation of such practices wherever Douglas fir is cultivated will increase the world's timber resources, and be an effective strategy for reducing the pressure, occasioned by the world's rapidly increasing population, to harvest the fragile tropical and boreal forests.

OSU Link
Non-OSU Link

63. Hessburg, P.F., D.J. Goheen and H. Koester. 2001. Association of black stain root disease with roads, skid trails, and precommercial thinning in Southwest Oregon. Western-Journal-of-Applied-Forestry 16(3): 127-135.

Keywords: thinning
precommercial thinning
tree/stand protection
tree/stand health

Abstract: The incidence and severity of black stain root disease (BSRD), caused by Leptographium wageneri, were evaluated in a two-stage sample of 500 precommercial-aged Douglas-fir (Pseudotsuga menziesii) plantations on 5 Resource Areas of the Medford District, Bureau of Land Management in Oregon, USA. Black stain was widely distributed throughout the western half of the District. Nearly 19% of the susceptible-aged (10- to 30-year-old) plantations were infected with black stain, but mortality losses were low. In both the extensive and intensive surveys, BSRD was more often distributed in precommercially thinned than unthinned plantations. Black stain occurred with significantly greater frequency adjacent to roads and major skid trails than in the main body of plantations. Roadside strips displayed significantly more injured trees and recent soil disturbance than the main body of plantations. BSRD incidence was high in comparison with other root diseases, but there was minimal impact to precommercial stand management. Low disease severity is somewhat unique among managed forests within this area of known high BSRD hazard. The lack of widespread damage from BSRD was associated with a lack of extensive tractor yarding and an apparent lack of precommercial thinning. Forest managers within high BSRD hazard areas can maintain low mortality levels by

minimizing site disturbance and tree injury associated with timber harvesting, road building, and road maintenance activities and by timing precommercial thinning to avoid vector insect emergence and flight periods. Increased disturbance and injury to precommercial-aged stands will likely result in increased disease.

OSU Link
Non-OSU Link

64. Hong, S. and J.J. Morrell. 1997. Treatability of Douglas-fir heartwood with ACZA or CCA: effect on site, silvicultural practice, and wood properties. Forest-Products-Journal 47(10): 51-55.

Keywords: planting operations
fertilization
thinning
wood quality

Abstract: The effects of site, silvicultural treatments, and wood properties on treatability of Douglas-fir (Pseudotsuga menziesii) heartwood, from Washington and Oregon, with chromated copper arsenate (CCA) or ammoniacal copper zinc arsenate (ACZA) were studied. Thinning appeared to be associated with slight improvements in treatability (penetration and retention of preservative), but combinations of thinning and fertilization had no significant effect on this property. Other factors such as site, height from which the sample was removed, and percentage of juvenile wood had inconsistent effects on treatability. Although the results indicate that silvicultural practices have minimal effects on treatability of Douglas-fir, further studies are required to clarify these effects.

OSU Link
Non-OSU Link

65. Huffman, D.W. and J.C. Tappeiner, II. 1997. Clonal expansion and seedling recruitment of Oregon grape (Berberis nervosa) in Douglas-fir (Pseudotsuga menziesii) forests: comparisons with salal (Gaultheria shallon). Canadian-Journal-of-Forest-Research 27(11): 1788-1793.

Keywords: thinning
stand conditions

Abstract: Seedling regeneration and morphology of Oregon grape (Berberis nervosa) and salal (Gaultheria shallon) were studied in thinned and unthinned Douglas fir (Pseudotsuga menziesii) stands in the central Coast Range, Oregon. Above- and below-ground growth of both species were significantly and negatively correlated with stand density. Oregon grape appears to have less potential for vegetative spread than does salal. It produced two to three times fewer rhizome extensions, and rhizome extensions were only half as long as those of salal. Oregon grape seedlings were common in areas of moss ground cover among patches of the two species. Salal seedlings were restricted to decaying logs. Seedling densities of Oregon grape in thinned stands were more than six times those in unthinned stands. For Oregon grape, understorey establishment is accomplished by seedling establishment and recruitment of new genets. In contrast, salal maintains itself in forest understories primarily through vegetative growth, since its seedling establishment is restricted mainly to decayed wood. Continual

recruitment of new aerial stems or ramets enables Oregon grape to maintain a dense cover once it is established in the understorey.

OSU Link
Non-OSU Link

66. Huffman, D.W., J.C. Tappeiner, II and J.C. Zasada. 1994. Regeneration of salal (Gaultheria shallon) in the central Coast Range forests of Oregon. Canadian-Journal-of-Botany 72(1): 39-51.

Keywords: thinning
stand conditions

Abstract: Regeneration of salal (Gaultheria shallon) by seedling establishment and vegetative expansion was examined in Douglas fir (Pseudotsuga menziesii) stands that had been thinned, clear felled or undisturbed in the central Coast Range of Oregon. Size and expansion rate of individual clonal fragments were negatively correlated with overstorey stand density (p <less or =>0.039). As overstorey basal area increased from 25 to 75 msuperscript 2/ha, mean annual growth percentage of clone rhizome systems decreased from 23.7 to 0% and mean total rhizome length decreased from 102 to 0.89 m. Interclonal competition in dense clumps of salal apparently caused rhizomes to die and clones to fragment. In these patches, rhizome biomass and density, aerial stem biomass and density, and total biomass of G. shallon were negatively correlated with overstorey density (p <less or =>0.01). In clear fellings, salal clumps had up to 177.7 m rhizome/msuperscript 2 and 346 stems/msuperscript 2, whereas patches under dense overstories had as few as 10.6 m rhizome/msuperscript 2 and 19 stems/msuperscript 2. Aerial stem populations had uneven-age distributions in all overstorey densities. This structure is apparently maintained through annual production of new ramets. Salal seedling establishment rates were significantly affected by study site location, overstorey density, and substrate (p <less or =>0.05). Two-year survival was highest on rotten logs and stumps in thinned stands.

OSU Link
Non-OSU Link

67. Hummel, S. and R. Hummel. 2004. Five-year thinning response of an overgrown Douglas-fir Christmas tree plantation. Western-Journal-of-Applied-Forestry 19(3): 171-174.

Keywords: planting operations
thinning
growth
yield
economics

Abstract: A 15-year-old Douglas-fir Christmas tree plantation in western Oregon was thinned in 1996 according to regional sawtimber conversion guidelines. The plantation comprised two strata, distinguished by initial planting density (Area 1=5x5 ft and Area 2=10x10 ft). Unthinned control plots were established in both Area 1 and Area 2 at the time of the thinning treatment. Five years later, the quadratic mean diameter (QMD) in Area 1 (thinned) was 6.4 in. versus 5.2 in. in Area 1 (unthinned), while in Area 2 (thinned) the QMD was 11.4 in. compared to 9.3 in. in Area 2 (unthinned). Over the same period, the volume/ac in Area 1 (thinned) (1,080 ft3/ac) was nearly twice that of Area 1

(unthinned) (576 ft3/ac). In contrast, the volume/ac in Area 2 (thinned) (2,318 ft3/acre) was almost half that of Area 2 (unthinned) (4,264 ft3/ac). These results suggest that while thinning was timely for Area 1, the thinning treatment could have been delayed for Area 2. By plantation age 30, the treated units in Area 1 and Area 2 have estimated yields of 9.6 and 11.6 thousand bd ft (mbf), respectively, with no additional thinning. Given 2002 average prices for #3 sawmill grade logs, gross return at age 30 would range between $5,000 and $6,000/ac.

OSU Link
Non-OSU Link

68. Hunt, J.A. 1995. Commercial thinning a coastal second-growth forest with a Timberjack cut-to-length system. Forest-Engineering-Research-Institute-of-Canada FERIC TN-235. 14.

Keywords: thinning
commercial thinning
economics
tree/stand health

Abstract: In the summer of 1994, after 2 years operation, FERIC monitored a thinning operation of second-growth forest dominated by Douglas fir [Pseudotsuga menziesii] near Cowichan Lake, Vancouver Island, to determine productivities, costs and impacts to sites and residual stands. The thinning treatment was carried out with a Timberjack 1270 harvester and a Timberjack 910 forwarder.

Non-OSU Link

69. Jozsa, L.A. and H. Brix. 1989. The effects of fertilization and thinning on wood quality of a 24-year-old Douglas fir stand. Canadian-Journal-of-Forest-Research 19(9): 1137-1145.

Keywords: fertilization
thinning
wood quality
growth

Abstract: The effect of thinning and N fertilization on growth and wood density of coastal Douglas fir (Pseudotsuga menziesii) on a poor site on Vancouver Island (British Columbia) is described for plots established at approx. 24 yr old in 1971-72. Stem cores were taken using an increment borer in Mar.-Apr. 1984. Ring-width and ring-density data were obtained from pith to bark for all trees using computerized X-ray densitometry. Fertilization reduced ring density at b.h. and 25% stem ht. by an av. of 6% for a 3- to 4-yr period after treatment, but not thereafter. Reductions in ring density resulted from decreases in the density of earlywood and latewood, as well as from decreases in latewood percentages. Effects were only pronounced in the lower half of the stem. Thinning resulted in a slight increase in ring-density in the lower bole and a reduction in the top. The combined treatments had an intermediate effect on ring density. Ring density showed an increasing trend from pith to bark at all ht. except at 75% stem ht., and a decrease with increasing ht. in the bole. Fertilization and thinning both increased diam. growth, and the beneficial effects were still evident 13 yr after treatments.

OSU Link
Non-OSU Link

70. Kellogg, L.D., G.V. Milota and M. Miller, Jr. 1996. A comparison of skyline harvesting costs for alternative commercial thinning prescriptions. Journal-of-Forest-Engineering 7(3): 7-23.

Keywords: thinning
commercial thinning
economics

Abstract: Harvesting production and costs were examined for three alternative silvicultural prescriptions at two sites in the Coast Range of Oregon, USA. Thirty-three-year-old Douglas fir (Pseudotsuga menziesii) stands were commercially thinned to residual densities of 247, 148, and 74 trees per hectare (tph). Detailed time studies were conducted on manual felling and uphill skyline yarding with small yarders. Separate regression equations were developed to predict delay-free felling cycle time and delay-free yarding cycle time. The 74 tph treatment had the highest production rate and was the least costly to harvest. Total harvesting costs of the other two treatments averaged from 6.0% (148 tph) to 12.3% (247 tph) more than the 74 tph treatment.

OSU Link
Non-OSU Link

71. Kellogg, L.D., G.V. Milota and B. Stringham. 1998. Logging planning and layout costs for thinning: experience from the Willamette young stand project. Forest-Research-Laboratory Research Contribution 20, Oregon-State-University, Corvaliis, OR.

Keywords: thinning
commercial thinning
economics

Abstract: Logging planning and layout costs were examined for commercial thinning of 40- to 50-yr-old stands of Douglas-fir (Pseudotsuga menziesii) on the Willamette National Forest in the Cascade Mountains of Oregon. The study consisted of four replications of three silvicultural treatments. Thinning involved three types of logging systems: mechanized cut-to-length (a combination of single-grip harvester and forwarder), tractor, and skyline. Data for the study came from two sources: activities completed by the Forest Service in preparing sales for bid, and the layout completed by the logging contractor after a contract was awarded. Planning and layout costs showed no consistent relationship to type of silvicultural treatment. Logging contractor layout costs showed a relationship to type of logging system: the mechanized system had the lowest layout cost, followed by the tractor systems, with the skyline systems having the highest costs.

OSU Link
Non-OSU Link

72. Kimball, B.A., E.C. Turnblom, D.L. Nolte, D.L. Griffin and R.M. Engeman. 1998b. Effects of thinning and nitrogen fertilization on sugars and terpenes in Douglas-fir vascular tissues: implications for black bear foraging. Forest-Science 44(4): 599-602.

Keywords: fertilization
thinning
tree/stand protection
tree physiology
tree/stand health

Abstract: Analyses of vascular tissue samples from Douglas fir (Pseudotsuga menziesii) trees collected in test plots in W. Washington and NW Oregon, USA, showed that both thinning and N fertilizer application caused the sugar concentration of vascular tissues in the lower bole to increase. However, these treatments had no effect on the concentrations of hydrocarbon monoterpenes, oxygenated monoterpenes or sesquiterpenes. These results may explain the observations that black bears (Ursus americanus) prefer to forage in thinned and fertilized stands, as the bears maximize sugar intake and minimize terpene intake while foraging.

OSU Link
Non-OSU Link

73. King, J.E., D.D. Marshall and J.F. Bell. 2002. Levels-of-growing-stock cooperative study in Douglas-fir: report no. 17 - the Skykomish study, 1961-93; the Clemons study, 1963-94. Pacific-Northwest-Research-Station, USDA-Forest-Service Research-Paper PNW-RP-548. vii + 120 p.

Keywords: thinning
commercial thinning
growth
yield
tree/stand health

Abstract: A study was conducted at the Skykomish Tree Farm, and at the Clemons Tree Farm, Washington, USA, to determine how the amount of growing stock in repeatedly thinned stands of Douglas Fir (Pseudotsuga menziesii) affects cumulative wood production, tree size and growth-growing stock ratios. Initial stands were thinned to the same level of growing stock so that all plots would have virtually the same growth potential except the unthinned controls. The Skykomish and Clemons stands were 24 and 19 years old, respectively, when the studies were started. Stand treatments were completed at ages 42 and 36, and measurements were continued to ages 56 and 50. After 32 years at Skykomish and 31 years at Clemons, the basal area per acre in the eight regimes ranged from 119-244 ft2 at Skykomish and 101-195 at Clemons. The corresponding gross yields in cubic feet per acre were 8709-13 579 at Skykomish and 6329-9072 at Clemons. Volume in thinnings were 18-53% of the gross yield. Stand treatments included four regimes with different combinations of heavy and light thinning and four regimes with constant intensities of thinning. Variable regimes were found to have consistent advantage over constant regimes. Within a given level of growing stock, the constant regimes are recommended for applications where wood production is the primary objective. A substantial increase in the yield was produced in all regimes during the post thinning holding period. Based on standing volume after the last thinning, the holding period of 4 years produced approximately 30% more volume in all regimes. Extending the period to 9 years produced approximately 70% more volume, and at 14 years, the standing volume was more than double the volume remaining after the last thinning. This extra yield enhanced by the high quality of the stands makes the length of the holding period an important factor in the scheduling of final harvest.

OSU Link
Non-OSU Link

74. Kramer, H. and J.H.G. Smith. 1985. Establishment of Douglas fir stands in British Columbia. Forstarchiv 56(1): 9-13.

Keywords: planting operations
thinning
pruning
growth
yield
economics
wood quality

Abstract: Square spacing trials were established NW of Haney (180 m alt.) at 0.91, 1.83, 2.74, 3.66 and 4.57 m. Growth to age 25 yr, and simulation estimates up to 100 yr are reported. Results indicated that extra costs (incurred by thinning) of stands closer than 4 m spacing are difficult to justify in economic terms, because the market for Douglas fir timber grown in British Columbia is such that only production of large timber is economically viable. The quality of timber from trees grown at wide spacing without thinning is acceptable in relation to Canadian requirements, and could be improved if wide spacing were combined with pruning. It is recommended that close spacings be used only if availability of land is limited or demand for biomass is very strong.

OSU Link
Non-OSU Link

75. Latham, P. and J. Tappeiner. 2002. Response of old-growth conifers to reduction in stand density in western Oregon forests. Tree-Physiology 22(2/3): 137-146.

Keywords: thinning
commercial thinning
growth

Abstract: The positive growth response of healthy young trees to density reduction is well known. In contrast, large old trees are usually thought to be intrinsically limited in their ability to respond to increased growing space; therefore, density reduction is seldom used in stands of old-growth trees. We tested the null hypothesis that old-growth trees are incapable of responding with increased growth following density reduction. The diameter growth response of 271 Douglas-fir (Pseudotsuga menziesii), ponderosa pine (Pinus ponderosa) and sugar pine (Pinus lambertiana) trees in Oregon, USA, ranging in age from 158 to 650 years was examined 20 to 50 years after density reduction. Density reduction involved either light thinning with removal of less vigorous trees, or shelterwood treatments in which overstorey trees were not removed. Ratios of basal area growth after treatment to basal area growth before treatment, and several other measures of growth, all indicated that the old trees sometimes benefited and were not harmed by density reduction. Growth increased by 10% or more for 68% of the trees in treated stands, and nearly 30% of trees increased growth by over 50%. This growth response persisted for at least 20 years. During this 20-year period, only three trees in treated stands (1.5%) exhibited a rapid decrease in growth, whereas growth decreased in 64% of trees in untreated stands.

The length of time before a growth response to density reduction occurred varied from 5 to 25 years, with the greatest growth response often occurring 20 to 25 years after treatment. These results have important implications both for the basic biology of aging in woody plants as well as for silvicultural practices in forests with old-growth trees.

OSU Link
Non-OSU Link

76. LeDoux, C.B., R.D. Fight and T.L. Ortman. 1986. Stump-to-truck cable logging cost equations for young-growth Douglas-fir. Western-Journal-of-Applied-Forestry 1(1): 19-22.

Keywords: thinning
commercial thinning
economics

Abstract: Data on log sizes were generated to simulate young (age 40-120 yr) Douglas fir site III and IV in the Pacific Northwest. The data were used to develop equations for estimating the delay-free costs of: (1) felling, limbing and cross-cutting; (2) yarding; (3) loading; (4) road changing; and (5) moving in and out and initial rigging up and down. An additional equation estimates the number of logs per 1000 ftsuperscript 3 for logs of d.b.h. 6-24 inch. The equations were developed for 2 small and 1 medium sized yarders and are applicable on slopes of 10-50%. The equations can be used to provide detailed estimates for thinning, partial or shelterwood felling and clearfelling. A BASIC computer program is available from the authors.

OSU Link
Non-OSU Link

77. Lee, Y.J. and H.J. Barclay. 1985. Ten-year growth response of a 25-year-old and a 55-year-old Douglas-fir stand to thinning and urea fertilization. Pacific-Forestry-Centre, Canadian-Forest-Service Information-Report BC-X-260. 14 p.

Keywords: fertilization
thinning
growth
tree/stand health

Abstract: In stands of medium site quality in British Columbia, 4 rates of nitrogen (0, 112, 224, and 336 k/ha of N), in the form of urea (46% N), were tested at two thinning intensities. Fertilizer was applied in spring or fall, but the season of application had little effect on growth. Thinning almost doubled diam. growth by 10 yr but affected only net vol. growth; gross vol. was only minimally affected by thinning. Fertilization in the 25-yr-old stand increased mean d.b.h. growth significantly in the second and third yr and increased vol. growth significantly in the first 3 yr, but the effect diminished thereafter. Different rates of fertilizer application on the 55-yr-old stand gave inconsistent results. Combined thinning and fertilizer treatment had the greatest growth response. In both stands the overall effect of 336 kg/ha N was to increase vol. growth by about 20%. Thinning significantly decreased mortality, but the effect of fertilizer was negligible. Combined treatment had the greatest effect on the advancement of trees by

the number of d.b.h. classes. The effect of thinning and fertilizing on the cumulative growth will probably continue after 10 yr until crowding sets in.

OSU Link
Non-OSU Link

78. Maguire, D.A. 1994. Branch mortality and potential litterfall from Douglas-fir trees in stands of varying density. Forest-Ecology-and-Management 70(1/3): 41-53.

Keywords: thinning
wood quality
soil properties

Abstract: Differential crown recession and crown development among stands of differing density suggest that an opportunity may exist to control the input of fine woody litter into the system by manipulating stand density. The objective of this study was to measure the rate of branch mortality among stands of differing density and to estimate the range in total per hectare necromass inputs. Although litter traps are reliable for estimating per hectare rates of litterfall, branch mortality dating on sectioned stems uniquely allows assessment of several other litterfall components: (1) individual tree contributions to total litterfall; (2) the amount of branch material released by mortality, regardless of whether the branches are shed to the forest floor; (3) the distribution of basal diameters characterizing the litterfall from a given tree and stand. Twenty-four trees were felled and sectioned on permanent plots that were part of a silvicultural study of Douglas fir (Pseudotsuga menziesii) stand density regimes, in Umpqua National Forest, near Tiller, Oregon. Whorl branches were dissected out of bole sections to determine the dates of mortality, and a branch biomass equation was applied to estimate potential rate of litterfall. Periodic annual rates were expressed in four ways: (1) number of branches per tree; (2) mass of branches per tree; (3) mass of branches per unit of crown projection area; (4) mass of branches per hectare. For the growth periods investigated, larger trees and trees growing on denser plots tended to release a greater necromass through branch mortality. Average branch basal diameter generally decreased with increasing stand density. Annual branch mortality ranged from 33 to 430 g m-2 crown projection area for individual trees, and from 236 to 1035 kg ha-1 for individual plots. These rates approached the low end of the range of previously published fine litterfall rates for Douglas fir. Rates on these plots were relatively low owing to the temporary delay in crown recession imposed by artificial thinning. A conceptual model of branch litter dynamics is presented to depict consistencies with crown development among stands managed under different density regimes.

OSU Link
Non-OSU Link

79. Maguire, D.A. and W.S. Bennett. 1996. Patterns in vertical distribution of foliage in young coastal Douglas-fir. Canadian-Journal-of-Forest-Research 26(11): 1991-2005.

Keywords: thinning
precommercial thinning
tree morphology

Abstract: Variation in foliage distribution was analysed on trees and plots in a series of even-aged Douglas fir (Pseudotsuga menziesii) stands scheduled for management under a wide range of silvicultural regimes in British Columbia, Washington and Oregon. Branch-level foliage mass and foliage area equations were developed from a sample of 138 branches. These equations were applied to 27 trees on which the diameter and height of all live primary branches were measured, allowing estimation of both the total amount of foliage and its vertical distribution. A beta -distribution was fitted to data describing the vertical distribution of foliage on each tree, and the resulting parameter estimates were modelled as functions of tree height, diameter at breast height, crown length, and relative height in the stand. Foliage area distribution tended to be shifted downward relative to foliage mass because of the expected increase in specific leaf area with depth into the crown. Similarly, the relative foliage distribution in terms of both mass and area was shifted downward as the tree became more dominant, or as relative height in the stand increased. In contrast, foliage on trees of similar relative height was shifted upward in response to the lower stand densities imposed by precommercial thinning. On the stand level, relative vertical distribution of foliage in the canopy was more peaked than would be implied by assuming a constant leaf area/sapwood area ratio throughout the composite tree crowns. Between-stand variation in vertical foliage distribution was dictated by differences in stand top height, height to crown base, and number of trees per hectare.

OSU Link
Non-OSU Link

80. Maguire, D.A., J.A. Kershaw, Jr. and D.W. Hann. 1991. Predicting the effects of silvicultural regime on branch size and crown wood core in Douglas-fir. Forest-Science 37(5): 1409-1428.

Keywords: thinning
precommercial thinning
commercial thinning
wood quality

Abstract: Three major determinants of wood quality (whorl frequency, branch size and crown wood core) in Douglas fir (Pseudotsuga menziesii) were estimated from the dynamics of crown structure in ORGANON, an individual-tree, distance-independent growth model. Data for the model were collected from Douglas fir plots in SW Oregon. Branch whorl locations were estimated directly from the height growth predictions assuming formation of one whorl per year. Mean maximum branch diameter was predicted as crown base receded past each whorl; branch diameter estimates were based on current depth of the whorl into crown, tree diameter, stand relative density, and site index. Diameter of crown wood core was established as diameter inside bark, also as crown base receded past each branch whorl. This approach facilitated description of harvested log distribution (40-ft butt logs) by various branch size, whorl frequency and crown wood core indices. Based on projections of a 9-yr-old Douglas fir stand to final harvest at 65 years, thinning precommercially to 121 trees/acre at 9 yr old resulted in a BD4 (mean of four largest branch diameters per log) of 2.5 inches, vs. 1.5 inches for the unthinned stand (484 trees/acre). When thinned to 121 trees/acre, approximately 55% of the volume/acre in 40-ft butt logs consisted of crown wood, as opposed to 30% at 484 trees/acre. Responses to subsequent thinnings were less pronounced, but included larger branches in the largest 80 trees/acre, and larger total crown wood percentages for a given initial stand density. Thinning from below resulted in larger average BD4 values and slightly greater crown wood percentages than proportional thinning. Individual-tree growth models that contain a crown recession component can easily be modified to predict crown wood core and indices of branch size.

OSU Link
Non-OSU Link

81. Marshall, D.D. and R.O. Curtis. 2002. Levels-of-growing-stock cooperative study in Douglas-fir: report no. 15 - Hoskins: 1963-1998. Pacific-Northwest-Research-Station,-USDA-Forest-Service Research-Paper PNW-RP-537. 80 p.

Keywords: thinning
commercial thinning
growth
yield
tree/stand health
tree morphology

Abstract: The cooperative levels-of-growing-stock (LOGS) study in Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) was begun to study the relations between growing stock, growth, cumulative wood production, and tree size in repeatedly thinned stands. This report summarizes results from the Hoskins installation through age 55. Growing stock has been allowed to accumulate for 19 years since the last treatment thinning was applied in this high site class II natural stand. Volume and diameter growth were strongly related to growing stock. Basal area growth-growing stock relations were considerably weaker. Differences in tree size and volume distribution were considerable. Culmination of mean annual increment has not occurred for any of the treatments, although the control has culminated for total stem cubic volume and is near culmination for merchantable cubic volume. Only small differences are seen in growth percentages between thinning treatments. Results demonstrate potential flexibility in managing Douglas-fir to reach a range of objectives.

OSU Link
Non-OSU Link

82. Marshall, P.L. 1988. A decision analytic approach to silvicultural investment decisions. Forest-Economics-and-Policy-Analysis-Research-Unit, University-of-British-Columbia Working-Paper 110. 28 p.

Keywords: planting operations
thinning
precommercial thinning
economics
growth

Abstract: A brief review of the literature is presented on methods for achieving optimal silvicultural decisions. The methods are generally computationally cumbersome and difficult to convert to simpler approximations required for most silvicultural decisions. An alternative method is presented and illustrated with two examples. The method involves a simple decision analytic structure. Projections were made for pure coastal Douglas fir Pseudotsuga menziesii for several treatments using three previously published growth models. Present NetWorth (PNW) was used as the criterion for choosing the treatment option and rotation age. The first example involved an initial planting density decision. Three planting densities were considered, viz. (1) 2500, (2) 1100 or (3) 750 seedlings/ha. The second example involved the decision to thin a 15-yr-old stand to a spacing similar to that produced by (1). The

options were: (a) no treatment; (b) thin to 1100 stems/ha; and (c) thin to 500 stems/ha. The best strategy depended on which growth model was used. The study showed that a simplified decision analytic approach is a useful method to evaluate a decision, when aided by several growth models.

OSU Link
Non-OSU Link

83. Marshall, P.L. 1989. The economic value of additional information about treatment-response information for coastal Douglas-fir. Forest-Economics-and-Policy-Analysis-Research-Unit, University-of-British-Columbia Working-Paper 121. 39 p.

Keywords: planting operations
thinning
precommercial thinning
economics
growth

Abstract: A simple decision analytic approach was applied to initial planting density and precommercial spacing decisions for coastal Douglas fir (Pseudotsuga menziesii) across a range of sites in British Columbia. The range of biological response was represented by the output from 3 growth and yield models. Recent production costs and product values were applied to obtain value per hectare after delivery of logs to the mill. Future costs and revenues were discounted at 4, 6 and 8%. The best decisions from each growth model are presented by scenario. Limitations of the analysis and managerial implications are discussed.

OSU Link
Non-OSU Link

84. Messier, C. and A.K. Mitchell. 1994. Effects of thinning in a 43-year-old Douglas-fir stand on above- and below-ground biomass allocation and leaf structure of understory Gaultheria shallon. Forest-Ecology-and-Management 68(2/3): 263-271.

Keywords: thinning
stand conditions

Abstract: Salal (Gaultheria shallon) was studied in an unthinned and a heavily thinned (two-thirds of basal area removed) 43-yr-old Douglas fir (Pseudotsuga menziesii) plot 6 yr after thinning at Shawnigan Lake on southern Vancouver Island, British Columbia. The increase in both above- and below-ground resources caused by thinning resulted in a smaller fine-root/leaf biomass ratio in the thinned (1.2) than the unthinned (2.0) plot. The balance between the production of fine-roots to acquire limited water and of foliage to acquire limited light is suggested as an explanation for this shift in carbon allocation from fine-root to leaf biomass between the two plots. The responses of G. shallon to thinning are discussed in relation to its role as a competitor for below-ground resources.

OSU Link
Non-OSU Link

85. Miller, M. and B. Emmingham. 2001. Can selection thinning convert even-age Douglas-fir stands to uneven-age structures? Western-Journal-of-Applied-Forestry 16(1): 35-43.

Keywords: thinning
commercial thinning
growth
yield
tree/stand health
regeneration

Abstract: Uneven-age management of Douglas-fir (Pseudotsuga menziesii) stands can be used to address aesthetic, wildlife habitat, biodiversity and sustainability concerns, but there has been little long-term experience with this type of management. To develop timely information on converting even-age stands to uneven-age forests, we used retrospective stand reconstruction methods to document harvest frequency, intensity and stand structural development at four sites in western Oregon, USA. We studied stands managed by selection thinning and identified strategies for creating and managing uneven-age forests. Selection thinning benefited mid- and understorey trees and stimulated natural regeneration. Although stand growth was less than expected from low thinning, growth per unit of growing stock was similar to that in unmanaged stands. Douglas-fir often dominated natural regeneration and had satisfactory vigour at stocking levels about half that considered full stocking for even-age management, but good growth of regeneration may require even lower overstorey stocking. Shade-tolerant grand fir (Abies grandis) and western hemlock (Tsuga heterophylla), however, were more abundant at higher stocking levels. Selection thinning of young Douglas-fir (Pseudotsuga menziesii) stands can sometimes be effective in promoting viable regeneration while providing regular income and biodiversity. Because this was a retrospective study only, further, long-term testing is necessary.

OSU Link
Non-OSU Link

86. Miller, R.E., G.W. Clendenen and D. Bruce. 1988. Volume growth and response to thinning and fertilizing of Douglas-fir stands in southwestern Oregon. Pacific-Northwest-Research-Station,-USDA-Forest-Service General-Technical-Report PNW-GTR-221. ii + 38 p.

Keywords: fertilization
thinning
growth

Abstract: Data were collected from 114 thinning (felling 15-80% of initial basal area) and/or fertilizer application (usually urea at 200 or 400 lb N/acre) trials in naturally regenerated Douglas fir (Pseudotsuga menziesii) stands in SW Oregon (111 stands) and N. California (3 stands). The data were used to develop regression equations to estimate volume growth for a 10-yr period of treated and untreated stands, aged 10-70 yr. The predictions for SW Oregon (SWOR) were compared with other growth predictions including DFSIM, a simulation model based on a broader, regional database. SWOR consistently showed greater gross and net growth of untreated Douglas fir and showed greater benefits of nitrogen fertilization, especially on poor quality sites and in young stands in the subregion than did DFSIM. SWOR predicted reduced gross volume growth during the 10 yr after thinning, faster recovery from early thinning on good than on poor sites, and increased wood production after nitrogen treatment in 70% of thinned and unthinned Douglas fir stands.

OSU Link
Non-OSU Link

87. Miller, R.E., E.L. Obermeyer and H.W. Anderson. 1999. Comparative effects of precommercial thinning, urea fertilizer, and red alder in a site II, coast Douglas-fir plantation. Pacific-Northwest-Research-Station,-USDA-Forest-Service Research-Paper PNW-RP-513.ii + 25 p.

Keywords: fertilization
thinning
precommercial thinning
growth
yield
tree/stand health
soil properties

Abstract: The number of red alder (Alnus rubra) trees retained with 300 Douglas-fir (Pseudotsuga menziesii) per acre was varied on a high-quality site in coastal Oregon. Alder densities of 0, 20, 40, and 80 per acre were tested. A fifth treatment eliminated nitrogen-fixing alder, but substituted nitrogen fertilizer. Treatment 6 had neither thinning nor alder control. Treatments were randomly assigned within each of three blocks in a 9-year-old plantation. Stand density was reduced within 15 of these 18 experimental units. Surplus conifers were cut, but surplus red alder were controlled by the "hack-and-squirt" method. Because numerous trees of other species regenerated naturally, combined density of all species before thinning ranged from 1400 to 5700 trees per acre. Subsequent 17-year change in number, average height, basal area, and volume of Douglas-fir were compared. Retaining 20, 40, or 80 alder per acre reduced numbers of associated Douglas-fir by about 10, 17, and 23 percent, respectively. In pure Douglas-fir plots, gross volume growth was similar for non-fertilized and fertilized plots, indicating no measurable benefits of additional nitrogen. In mixed stands, red alder reduced yield of associated Douglas-fir, but not yield of combined species. Similar comparisons are needed at other locations, especially those with known nitrogen deficiency.

OSU Link
Non-OSU Link

88. Miller, R.E., J. Smith and H. Anderson. 2001. Detecting response of Douglas-fir plantations to urea fertilizer at three locations in the Oregon Coast Range. Pacific-Northwest-Research-Station,-USDA-Forest-Service Research-Paper PNW-RP-533. 20 p.

Keywords: fertilization
thinning
growth
tree/stand health

Abstract: Fertilizer trials in coast Douglas-fir (Pseudotsuga menziesii var. menziesii) in the Oregon Coast Range (USA) usually indicate small and statistically non-significant response to nitrogen (N) fertilizers. Inherently weak experimental designs of past trials could make them too insensitive to detect growth differences that actually exist. Ability to detect real differences among treatments should be improved by having more than two replications per treatment and by using covariance analysis to adjust observed

treatment means for unequal starting conditions among experimental treatments. To demonstrate these assumptions, we used size at fertilizer application and a pre-fertilizer application (calibration) period of growth as covariates when analysing data from five coastal plantations at three locations: Toledo North, Toledo South and Bone Mountain. The trials had three to six replications per treatment and calibration periods of 6 or 7 years. Nitrogen fertilizer (urea at 200 lb N/acre) was assigned randomly to half the plots at each location when trees were 16 or 17 years old from seed. Our objectives were to quantify 4- or 7-year response to N fertilizer and to demonstrate practical means for detecting response. Effects of fertilizer application on tree diameter and height, and on basal area and volume growth per acre were estimated. Among the five non-thinned plantations, observed gross basal area growth was changed by -2 to 13% in the 4 or 7 years after fertilizer application. In the thinned portion of one plantation, there were few differences in response to fertilizer between thinned and unthinned plots. Observed responses were increased substantially by covariance analyses at some plantations but decreased at others. Random assignment of three to six plots per treatment did not ensure balanced or comparable plots for fertilized and non-fertilized treatments.

OSU Link
Non-OSU Link

89. Mitchell, A.K., H.J. Barclay, H. Brix, D.F.W. Pollard, R. Benton and R. DeJong. 1996. Biomass and nutrient element dynamics in Douglas-fir: effects of thinning and nitrogen fertilization over 18 years. Canadian-Journal-of-Forest-Research 26(3): 376-388.

Keywords: fertilization
thinning
precommercial thinning
carbon allocation
tree physiology
growth
soil properties

Abstract: The effects of thinning (two-thirds of basal area removed) and N fertilizer (448 kg N/ha as urea) on biomass and nutrition of a 24-year-old Douglas fir (Pseudotsuga menziesii) stand at Shawnigan Lake, British Columbia, were studied over 18 years. At years 0, 9, and 18 after treatments, the aboveground biomass and N, P, K, Ca, and Mg contents of stemwood, stem bark, foliage, and dead and live branches were determined (kg/ha), and increments in these properties (kg/ha per year) were calculated for the 0-9 and 9-18 year periods. Foliar biomass was increased by both treatments during the first period and also by thinning in the second period. Aboveground net primary production (ANPP) per unit of foliage biomass (foliage efficiency) was increased by treatments in the 0-9 year period. The combined effects of increased foliage mass and foliage efficiency resulted in increased total biomass production. Thinning and fertilizer application increased the uptake of all elements except for P with fertilizer. This increase may have contributed to the long-term increase in stem growth. Retranslocation of elements before foliage shedding was important for tree nutrition, but was not improved by fertilizer during the 9-18 year measurement period. The efficiency of N use in dry matter production (ANPP/unit of N uptake) was decreased by fertilizer. This implied that poor sites would respond to fertilizer better than rich sites.

OSU Link
Non-OSU Link

90. Mitchell, K.J. and J.R. Cameron. 1985. Managed stand yield tables for coastal Douglas-fir: initial density and precommercial thinning. Ministry-of-Forests, British-Columbia

Keywords: planting operations
thinning
precommercial thinning
growth
yield

Abstract: Yield tables are presented for second growth stands of Pseudotsuga menziesii, established naturally (4440 trees/ha) or planted with 300, 500, 750, 1110 or 2500 trees/ha in British Columbia. Separate tables describe the development of stands thinned to 500 or 1100 stems/ha when 6 m tall. The yield tables were produced by a biologically oriented tree and stand simulation model (TASS) calibrated to conform with the yield of remeasured plots.

OSU Link
Non-OSU Link

91. Mitchell, S.J. 2000. Stem growth responses in Douglas-fir and Sitka spruce following thinning: implications for assessing wind-firmness. Forest-Ecology-and-Management 135(1/3): 105-114.

Keywords: thinning
tree morphology
carbon allocation
growth

Abstract: Diagnosing the stand hazard component of windthrow risk requires evaluation of the 'acclimation' of trees to wind loads. Height-diameter ratio is a commonly used indicator of relative wind-firmness. A sample of coastal Sitka spruce (Picea sitchensis) and interior Douglas fir (Pseudotsuga menziesii) trees, representing a range of initial slenderness, were sampled from stands in British Columbia, Canada, which had very high densities (about 6000 and 23,000 stems/ha, respectively) prior to thinning. Annual height increment, radial increment, allocation of radial increment along the bole, and height-diameter ratio were reconstructed using stem analysis. Thinning treatments affected growth responses compared to trees in control (unthinned) stands: temporary reduced height increment, increased radial increment and increased basal allocation contributed to a reduction in height-diameter ratio. This reduction was most pronounced in trees which were initially more slender. The reverse-S pattern of height-diameter ratio adjustment and the patterns of growth allocation suggest a period of acclimative growth during which the trees re-equilibrate with post-thinning wind loads. Observing the rate of stem form adjustment could be useful in diagnosing wind-firmness when scheduling multiple thinning entries in high-density stands.

OSU Link
Non-OSU Link

92. Morrison, D.J. and A.L.S. Johnson. 1999a. Annosus root disease in pre-commercially thinned stands in coastal British Columbia. Canadian-Forest-Service Technology Transfer Note 20, Pacific-Forestry-Centre, Victoria, BC.

Keywords: thinning
precommercial thinning
tree/stand protection
tree/stand health

Abstract: An outline is given of the strategic importance of Heterobasidion annosum, detection and recognition, damage to roots, factors affecting infection and colonization of stumps and management implications for spacing in juvenile stands. The relative susceptibilities of different species were: Abies amabilis>Picea sitchensis>Tsuga heterophylla>Pseudotsuga menziesii.

OSU Link
Non-OSU Link

93. Morrison, D.J. and A.L.S. Johnson. 1999b. Incidence of Heterobasidion annosum in precommercial thinning stumps in coastal British Columbia. European-Journal-of-Forest-Pathology 29(1): 1-16.

Keywords: thinning
precommercial thinning
tree/stand protection
tree/stand health

Abstract: Coniferous stumps in 83 stands in coastal British Columbia, Canada, were sampled 3-5 years after precommercial thinning between 1981 and 1986. The percentage of stumps and surface area colonized by H. annosum were determined for 25 stumps of each species, in each 5-cm diameter class present in each stand. There were significant differences among species in the percentages of stumps and surface area colonized, with Douglas-fir (Pseudotsuga menziesii) having the lowest values, amabilis fir (Abies amabilis) and Sitkaspruce (Picea sitchensis) the highest and western hemlock (Tsuga heterophylla) being intermediate. For each species, both the percentage of stumps and surface area colonized increased with increasing diameter. In stumps that were grafted to an adjacent tree, there was decreased incidence of H. annosum for Douglas-fir and Sitka spruce and increased incidence for western hemlock and amabilis fir. There were trends in the percentage of stumps and area colonized for season of thinning and biogeoclimatic subzones, with the values for most species decreasing as the amount of precipitation increased. It is suggested that the increase in inoculum can be minimized by thinning trees when less than 15 years old, by cutting only trees less than 10 cm in diameter and by thinning during low risk seasons.

Non-OSU Link

94. Morrison, D.J., M.D. Larock and A.J. Waters. 1986. Stump infection by Fomes annosus in spaced stands in the Prince Rupert Forest Region of British Columbia. Pacific-Forestry-Centre, Canadian-Forest-Service Information-Report BC-X-285. 12 p.

Keywords: thinning
tree/stand protection
tree/stand health

Abstract: Discs 3-5 cm thick were collected after removal of the top 5-10 cm from stumps left by thinning 1-8 yr previously of 12- to 37-yr-old stands of 5 coniferous species, and the occurrence and area of surface colonization with F. annosus [Heterobasidion annosum] were measured. Based on the % of stumps with more than 10% of their area colonized, susceptibility decreased in the sequence Abies amabilis, Picea sitchensis, Tsuga heterophylla, Pseudotsuga menziesii; Pinus contorta was unaffected. Fewer stumps were colonized in a T. heterophylla/A. amabilis stand thinned in winter than in an adjacent stand thinned in late spring: the difference was attributed to effects on spore populations of low temp. and heavy precipitation. There was a significant correlation between % stump area colonized and % root vol. colonized by H. annosum for A. amabilis and T. heterophylla. H. annosum had spread from colonized roots on some excavated stumps to or into adjacent roots of reserved trees.

OSU Link
Non-OSU Link

95. O'-Hara, K.L. 1988. Stand structure and growing space efficiency following thinning in an even-aged Douglas-fir stand. Canadian-Journal-of-Forest-Research 18(7): 859-866.

Keywords: thinning
commercial thinning
growth
tree morphology
carbon allocation

Abstract: The growth of individual trees from four thinning treatments in a 64-yr-old Pseudotsuga menziesii stand in western Washington was analysed to determine desirable residual stand structures after thinning. Dominant and codominant trees had the highest individual tree stem vol. growth rates over the previous 5 yr and accounted for most stand vol. growth in thinned and unthinned stands. Two measures of growing space, crown projection area and sapwood b.a. (a surrogate for leaf area), were used to measure how efficiently individual trees used their growing space. Crown classes were useful in characterizing growing space efficiency (vol. growth per unit of growing space) only in the unthinned treatment. In thinned treatments, tall trees with medium-sized crowns were most efficient, while in the unthinned treatment tall trees with relatively large crowns were most efficient. A large crown in an unthinned stand was comparable in size to a medium-sized crown in a thinned stand. Results suggest growing space is not limiting individual tree growth in thinned stands and that thinning to a particular stand structure is more appropriate than thinning to a particular stand density.

OSU Link
Non-OSU Link

96. O'-Hara, K.L. 1989. Stand growth efficiency in a Douglas fir thinning trial. Forestry-Oxford 62(4): 409-418.

Keywords: thinning
commercial thinning
growth
carbon allocation
tree morphology

Abstract: Stand growth efficiency (ratio of periodic stand volume growth to sapwood basal area) was measured over 5 yr (1980-84) in a long term Douglas fir (Pseudotsuga menziesii) thinning trial (established in 1957 at 36-yr-old, with 5 thinnings over 23 yr) in coastalWashington, USA. Sapwood basal area - as a surrogate for leaf area - and volume growth were estimated in two fifth-hectare plots from each of three thinning treatments, and from a single fifth-hectare control plot. Stand growth increased with increasing sapwood basal area. No distinct pattern of stand growth efficiency with sapwood basal area was evident. Large differences in efficiency between plots of the same treatment were found and were attributed to differences in stand structure, or the arrangement of tree sizes.

OSU Link
Non-OSU Link

97. O'-Hara, K.L. 1990. Twenty-eight years of thinning at several intensities in a high-site Douglas-fir stand in western Washington. Western-Journal-of-Applied-Forestry 5(2): 37-40.

Keywords: thinning
commercial thinning
growth
yield

Abstract: Results are presented of a 28-year thinning study of a dense (182-452 tree/acre) natural, second growth Douglas fir (Pseudotsuga menziesii) stand at Delezenne, which compared 3 thinning treatments with an unthinned control. Treatments were: an increasing basal area treatment; a constant basal area treatment (of approximately 140 ftsuperscript 2/acre); a decreasing/increasing reserve basal area treatment; and control plots, which were 35 to 37-years-old with basal area 80-203 ftsuperscript 2/acre in 1957 when the tests were started. Gross, net, and total recoverable periodic cubic volume increments of the control treatment (10 396, 9108 and 16 092 ftsuperscript 3/acre, respectively) were not significantly different from the highest yielding treatment, which was the increasing reserve basal area thinning treatment (8896, 8594 and 16 636 ftsuperscript 3/acre, respectively). These results, and options for thinning schedules, are discussed; it is suggested that commercial thinnings of dense or fully stocked plantations of Douglas fir may produce similar results, that is, vigorous stands with rapid growth potential.

OSU Link
Non-OSU Link

98. O'-Hara, K.L. and C.D. Oliver. 1988. Three-dimensional representation of Douglas-fir volume growth: comparison of growth and yield models with stand data. Forest-Science 34(3): 724-743.

Keywords: planting operations
thinning
growth
yield
computer modeling

Abstract: Growth and yield estimates for unthinned stands from the Douglas fir Stand Simulator (DFSIM) and the Tree and Stand Simulator (TASS) were used to construct graphical three-dimensional

representations of Douglas fir (Pseudotsuga menziesii) stand growth on site index 44 m (50 yr). The three-dimensional models used three variables: trees per hectare, b.h. age, and either mean tree vol. or stand vol. The TASS and DFSIM models were in agreement over most of their common range of age and number of trees. At wider spacings and older ages, however, the volumes predicted by the DFSIM model exceeded those predicted by the TASS model by as much as 25%. Comparisons of these three-dimensional models to unthinned and thinned stand data from a site of similar quality in the Delezenne thinning trial, Washington, found the models to be reasonably accurate representations of unthinned stand growth. The thinned stands, however, had greater mean tree and stand volumes than those indicated by the TASS model for unthinned stands at similar spacings. Complete comparisons were not possible with the DFSIM model because of its limited range of number of trees. These results suggest that the TASS model, and to a lesser extent, the DFSIM model may be underestimating the growth of widely spaced stands, or thinning may actually increase the growth of thinned trees over that of trees which had always grown at the post-thinning spacing.

OSU Link
Non-OSU Link

99. Oliver, C.D. and M.D. Murray. 1984. Stand structure, thinning prescriptions, and density indexes in a Douglas-fir thinning study, Western Washington, U.S.A. Canadian-Journal-of-Forest-Research 13(1): 126-136.

Keywords: thinning
commercial thinning
growth
stand conditions

Abstract: In a stand regenerated after logging in 1930, thinnings to set b.a. values were carried out in 1959, 1962, 1966, and 1970. On each plot both large and small trees were removed since av. b.a. per tree was kept constant before and after thinning. Volume growth varied greatly between plots of the same age, initial b.a., and site because of differences in stand structure. Large trees on a plot grew more per tree and per b.a. than small trees. Stand b.a., stand vol., number of stems, or number of dominant and codominant trees were not closely related to vol. growth/ha, although density indexes giving weight to larger trees showed the closest relationship. The lack of a close relationship between stand desnsity indexes and growth probably means the indexes do not uniquely define structures; it does not necessarily mean that thinning will not increase volume growth/ha. Volume growth/ha after thinning to a given b.a. will be greater and probably more consistent if larger trees are left and enough time is allowed for the stand to recover following thinning.

OSU Link
Non-OSU Link

100. Omule, S.A.Y. 1984. Results from a correlated curve trend experiment on spacing and thinning of coastal Douglas fir. B.C. Ministry-of-Forests Research-Note 93. ix + 22 p.

Keywords: thinning
precommercial thinning
growth

yield
tree/stand health

Abstract: Plots were established in 1952 in 13-yr-old plantations and given a variety of thinning treatments to produce post-thinning densities of 125-3000 stems/ha. Trees were measured at intervals up to 1980. Analysis showed that diam., ht. and their growth increased with decrease in density. Mortality, b.a., total vol. and b.a. growth decreased as density decreased. Stand merchantable vol. was not affected by density except at extremes. Prolonged early suppression appeared to reduce the ability of a stand to respond to subsequent thinning in terms of b.a. and total vol.

OSU Link
Non-OSU Link

101. Omule, S.A.Y. 1988. Growth and yield 35 years after commercially thinning 50-year-old Douglas-fir. B.C. Ministry of Forests FRDA-Report 021. vi + 15 p.

Keywords: thinning
commercial thinning
growth
yield
tree/stand health

Abstract: Remeasurement data over a period of 35 years from fourteen 0.2023-ha permanent plots were analysed to determine the growth and yield effects of commercially thinning 50-year-old Douglas fir (Pseudotsuga menziesii) stands on a good site on Vancouver Island, British Columbia. Compared to unthinned stands, the commercially thinned stands had: virtually the same total volume gross annual increment, top height and top height increment; 12% more potentially usable total volume yield (including thinnings); 18% less total volume at final harvest age 86 yr; virtually the same crop tree (193 largest diameter trees per hectare) average diameter, but 24% larger entire stand quadratic mean diameter; and 11% less total volume production lost to mortality. These results show that commercial thinning slightly increased total stand yield (including thinnings) and produced larger stand diameter at rotation age 86 yr, but that it also reduced usable total volume at final harvest and had virtually no effect on size of the crop trees. Data from this study are useful for validating growth models, and for constructing and comparing managed stand yield tables for various commercial thinning regimes.

OSU Link
Non-OSU Link

102. Omule, S.A.Y. 1990. Net basal area response 9 years after fertilizing thinned and unthinned Douglas-fir. B.C. Ministry of Forests FRDA-Report 097. vi + 20 p.

Keywords: fertilization
thinning
growth

Abstract: Equations were developed to estimate net basal area response of Douglas fir (Pseudotsuga menziesii) to nitrogen (urea) fertilizer in terms of initial stand attributes, based on remeasurement data over a 9-yr period from 176 plots on Vancouver Island, British Columbia.

OSU Link
Non-OSU Link

103. Peterson, C.E. 1984. Fertilization of Douglas-fir plantations in the Pacific Northwest RFNRP Cooperative. *In* Proceedings IUFRO Symposium on Site and Productivity of Fast Growing Plantations Volume 2, South African Forest Research Institute, Pretoria, South Africa. Eds. D.C. Grey, A.P.G. Schonau and C.J. Schutz. pp. 637-645.

Keywords: planting operations
fertilization
thinning
precommercial thinning
growth

Abstract: Since 1975, the RFNRP cooperative has established 26 installations in young widely spaced plantations of Douglas-fir for testing response to 224 kg-N/ha. These plantations ranged in breast-height age from 3 to 23 years, and although response to fertilization was favorable in all Douglas-fir plantations, those which were spaced to 1000 trees/ha responded significantly better than plantations of 725 trees/ha, in both absolute and relative 2-year basal area increment (msuperscript 2 ha-1 year-1). Response also appears to be greater when fertilizer was applied 2 years after precommercial thinning, as opposed to fertilizing and thinning at the same time. The relationship of growth response with stocking level is discussed, as well as the timing of fertilization relative to spacing, in young Douglas-fir plantations.

OSU Link
Non-OSU Link

104. Peterson, C.E. and J.W. Hazard. 1990. Regional variation in growth response of coastal Douglas-fir to nitrogen fertilizer in the Pacific Northwest. Forest-Science 36(3): 625-640.

Keywords: fertilization
thinning
growth

Abstract: Hypothesis-testing for differences in growth responses among physiographic strata, thinning levels, and fertilizer dosage levels resulted in a set of empirical models for predicting the volume increment response of even-aged coastal Douglas fir (Pseudotsuga menziesii) in W. Washington and Oregon to N fertilizer treatment. Absolute and percentage responses are estimated for both thinned and unthinned stands as a function of dosage levels and physiographic provinces. Although not 'highly' significant, the physiographic factor was retained in the models for purposes of refinement.

OSU Link
Non-OSU Link

105. Peterson, C.E., P.J. Ryan and S.P. Gessel. 1984. Response of northwest Douglas-fir stands to urea: correlations with forest soil properties. Soil-Science-Society-of-America-Journal 48(1): 162-169.

Keywords: fertilization
thinning
growth
soil properties

Abstract: Replicated forest floor and surface soil (0-15 cm) samples were obtained from control plots at 160 field installations in western Washington and Oregon. Six-year growth responses of thinned and unthinned Douglas-fir [Pseudotsuga menziesii] treated with 0, 224, and 448 of urea-N ha-1 were correlated with 18 forest floor and surface soil properties of the control plots. Forest floor nitrogen properties were the most highly correlated with various estimates of response in both thinned and unthinned stands; these correlations were generally independent of methods used to estimate response. For unthinned stands, C/N ratios of both forest floor and surface soil were well correlated with growth response to fertilizer, whereas for thinned stands, N content (kilograms per hectare) of the forest floor was consistently correlated with response.

OSU Link
Non-OSU Link

106. Pilkerton, S.J., H. Han and L.D. Kellogg. 1996. Quantifying residual stand damage in partial harvest operations. *In* Planning and implementing forest operations to achieve sustainable forests: Proceedings of papers presented at the joint meeting of the Council on Forest Engineering and International Union of Forest Research Organizations. North-Central-Forest-Experiment-Station, USDA-Forest-Service General-Technical-Report NC-GTR-186. *Eds.* C.R. Blinn and M.A. Thompson. 62-72 pp.

Keywords: thinning
tree/stand health

Abstract: Stand damage studies were conducted on 2 cable thinning operations in 33-year-old Douglas fir (Pseudotsuga menziesii) stands having residual stockings of 74, 148 and 247 trees/ha in the Oregon Coast Range. The percent of residual stems damaged increased with decreasing residual density. Average scar sizes were significant, but at levels lower than cited as major. Observed thinning damage from helicopter logging was smaller and higher on the stem, characteristics associated with a lower incidence of decay. Line plots, random plots, strip transects and blocks on corridors are compared for sampling damage.

OSU Link
Non-OSU Link

107. Preston, C.M. and R.H. Newman. 1995. A long-term effect of N fertilization on the 13C CPMAS NMR of de-ashed soil humin in second-growth Douglas-fir stand of coastal British Columbia. Geoderma 68(4): 229-241.

Keywords: fertilization
thinning

soil properties

Abstract: Carbon-13 CPMAS NMR spectroscopy was used to examine long-term effects of thinning and N fertilization on the humin fraction of soil organic matter in a second-growth Douglas-fir (Pseudotsuga menziesii) stand in coastal British Columbia, Canada. De-ashed OM-enriched humin fractions were prepared from three mineral soil horizons of four silvicultural treatments using 1.0M HF accompanied by removal of ferromagnetic iron particles, and a density separation. With some exceptions a higher proportion of mass was recovered in the denser, light-coloured fraction, and a higher proportion of C and N in the less-dense, dark fraction. In all cases, the less-dense fraction was enriched in total C compared to the original crude humin, and had a more favourable C:Fe ratio for NMR spectroscopy. The fraction of observable C was 33-37% for 8 of the samples, but as low as 7.6% for the remaining four. Carbon-13 CPMAS NMR spectra had typical features for humins (alkyl C, O-alkyl C, di-O-alkyl C, aromatic C, and carboxyl, ester and amide C). With fertilization, there was a small but consistent decrease in the ratio of alkyl to O-alkyl C, regardless of horizon or thinning, indicating a lower extent of decomposition. Carbon-13 subspectra based on proton spin relaxation time (T1(1H)) were obtained for one fertilized and one unfertilized sample. Subspectra of the slowly-relaxing (long T1(1H)) domain were dominated by long-chain alkyl C. For the fertilized sample, the subspectrum of the fast-relaxing (short T1(1H)) domain had a higher proportion of O- and di-O-alkyl C, consistent with results from the normal CPMAS NMR spectra. Despite the uncertainties introduced by the de-ashing treatment and the low fraction of observable C, 13C CPMAS NMR showed that fertilization has a long-term effect which is reflected in this humin fraction.

OSU Link
Non-OSU Link

108. Ralston, R., J. Buongiorno and J.S. Fried. 2004. Potential yield, return, and tree diversity of managed, uneven-aged Douglas-fir stands. Silva-Fennica 38(1): 55-70.

Keywords: thinning
commercial thinning
economics
yield

Abstract: The effects of different management regimes on uneven-aged Douglas-fir stands in the Pacific Northwest of the United States were predicted with a simulation model. Management alternatives were defined by residual stand structure and cutting cycle. The residual stand structure was set by basal area-diameter-q-ratio (BDq) distributions, diameter-limit cuts (assuming concurrent stand improvement), or the current diameter distribution. Cutting cycles of 10 or 20 years were applied for 200 years. The current diameter distribution was defined as the average of the uneven-aged Douglas-fir stands sampled in the most recent Forest Inventory and Analysis conducted in Oregon and Washington. Simulation results were compared in terms of financial returns, timber productivity, species group diversity (hardwoods vs softwoods), size class diversity, and stand structure. Other things being equal, there was little difference between 10- and 20-year cutting cycles. The highest financial returns were obtained with either a 58.4 cm diameter-limit cut, or a BDq distribution with 8.4 m2 of residual basal area, a 71.1 cm maximum diameter, and a q-ratio of 1.2. Using the current stand state as the residual distribution was the best way to obtain high tree size diversity, and high species group diversity. Several uneven-aged regimes gave net present values comparable to that obtained by converting the initial, uneven-aged stand to an even-aged, commercially thinned, plantation.

OSU Link
Non-OSU Link

109. Riitters, K. and J.D. Brodie. 1984. Implementing optimal thinning strategies. Forest-Science 30(1): 82-85.

Keywords: thinning
economics
growth
yield

Abstract: [See FA 41, 3436; 44, 201] A method is described for comparing the results of optimal thinning analyses based on different management or economic criteria (such as soil expectation value, forest rent or m.a.i.). Optimal thinning regimes for Douglas fir and ponderosa pine were calculated using dynamic programming algorithms based on 2 stand growth simulators. Residual mean tree volumes were then plotted against stand density at varying time intervals. On a graph of this kind, the time trajectory of optimal thinning regimes for even-aged stands is approximately parallel to the line of maximum size/density.

OSU Link
Non-OSU Link

110. Rosso, P. and E. Hansen. 1998. Tree vigour and the susceptibility of Douglas fir to Armillaria root disease. European-Journal-of-Forest-Pathology 28(1): 43-52.

Keywords: fertilization
thinning
pruning
tree/stand protection
growth
tree/stand health
carbon allocation

Abstract: The effects of thinning, fertilization and pruning on the vigour of Douglas fir (Pseudotsuga menziesii) and its susceptibility to Armillaria root disease were investigated in Oregon, USA. Tree vigour was defined as the relative capacity for tree growth, expressed as the above-ground biomass increment per unit of photosynthetic tissue, or growth efficiency (GE). It has been hypothesized that trees with higher GE can better resist pathogen attack, and that GE can be used as a predictor of tree susceptibility to disease. In a previous study, four P. menziesii plantations were thinned, fertilized and pruned in all combinations, and the effects of these treatments on tree vigour were measured after 10 years. Root disease was not a factor in the initial study design, and mortality was ignored until 8 years after the treatments were applied. The results of an earlier study were utilized and the correlation between Armillaria root disease incidence and the effects of earlier stand treatments on tree growth was investigated. A. ostoyae [A. obscura] was the primary cause of mortality in the study area. The disease incidence of infected subplots ranged from 2 to 20%. A. obscura incidence was the highest at medium tree density (6.1%), slightly lower on the low density (5.6%) and lowest on the unthinned plots (3.8%). There were no significant correlations between disease incidence and previous tree growth. The vigour

of trees that became symptomatic or died by 1993 was not significantly different from the vigour of trees that remained asymptomatic in 1983-85. On these sites, in areas of infection, A. obscura was causing mortality of the largest, fastest growing trees, as well as less vigorous trees. It is concluded that Armillaria continues to cause mortality, regardless of the growth efficiency or growth rate of the host.

OSU Link
Non-OSU Link

111. Sachs, D. and P. Sollins. 1986. Potential effects of management practices on nitrogen nutrition and long-term productivity of western hemlock stands. Forest-Ecology-and-Management 17(1): 25-36.

Keywords: thinning
commercial thinning
yield
soil properties
computer modeling

Abstract: The FORCYTE-10 computer model, developed by J.P. Kimmins and K. Scoullar for Douglas-fir forests in British Columbia, was modified to simulate growth and nutrient cycling of coastal western hemlock stands in Oregon. Initial calibration indicated that predicted yield was extremely sensitive to the rate of mineralization of soil organic matter (SOM), variation in SOM C/N ratio with site quality, the soil extractable NO3-/NH4+ ratio, and the decomposition rate and N mineralization pattern of large and medium-size roots and woody debris. The predictions suggested that yield and SOM remain stable under a management system consisting of six successive 90-yr rotations. More intensive utilization (e.g., shorter rotations, whole-tree harvesting and commercial thinning) causes depletion of soil and forest floor nitrogen and a small decline in site productivity in later rotations.

OSU Link
Non-OSU Link

112. Sachs, D. and J.A. Trofymow. 1991. Testing the performance of FORCYTE-11 against results from the Shawnigan Lake thinning and fertilization trials on Douglas-fir. Canadian-Forest-Service, Pacific and Yukon Region Information-Report BC-X-324. viii + 58 p.

Keywords: fertilization
thinning
precommercial thinning
growth
yield
tree physiology
carbon allocation
tree/stand health
computer modeling

Abstract: FORCYTE-11 is an ecosystem-based forest growth simulation model. Its performance was evaluated with data on stand and tree biomass, height, stocking (mortality) and foliar assimilation and loss rates for Douglas fir (Pseudotsuga menziesii) in thinning/fertilizer trials in British Columbia.

OSU Link
Non-OSU Link

113. Shumway, J.S. and H.N. Chappell. 1995. Preliminary DRIS norms for coastal Douglas-fir soils in Washington and Oregon. Canadian-Journal-of-Forest-Research 25(2): 208-214.

Keywords: fertilization
thinning
growth
soil properties

Abstract: The Diagnosis and Recommendation Integrated System (DRIS) has been used successfully to evaluate interactions between nutrients and fertilizer response and for diagnosing nutrient deficiency in agricultural crops. This study used soil tests to develop DRIS norms and evaluate their effectiveness in coastal Douglas fir (Pseudotsuga menziesii) forests. DRIS norms for nitrogen, phosphorus, potassium, and calcium were developed using soil test and site index data from 72 soil series that commonly support Douglas fir in westernWashington. The norms were tested using soil test and stand basal area growth response data from 20 thinned and 30 unthinned N fertilizer test sites in coastal Washington and Oregon. Response to urea fertilizer in thinned stands averaged 34% and 43% for 224 and 448 kg N.ha-1, respectively, when N was identified as the most limiting nutrient. When N was not the most limiting nutrient, N response averaged 8% and 10% for 224 and 448 kg N.ha-1, respectively. Results were similar in unthinned stands and thinned stands, although response to fertilizer appeared to be slightly less in unthinned stands when N was the most limiting nutrient. DRIS correctly classified 25 of the 33 sites (76%) where N fertilizer increased growth by more than 15%. More importantly, 13 of the 17 (76%) sites that responded by less than 15% were correctly identified by DRIS. The results clearly indicate that N fertilizer response is dependent on the interactions (balance) between soil nutrients at a given site. Future soil diagnostic work needs to focus on techniques, like DRIS, that provide an assessment of these interactions.

OSU Link
Non-OSU Link

114. Smith, S.H. and J.F. Bell. 1983. Using competitive stress index to estimate diameter growth for thinned Douglas-fir stands. Forest-Science 29(3): 491-499.

Keywords: thinning
growth

Abstract: A set of linear growth equations was developed using initial diam. (d.b.h.), initial competitive stress index (CSI, based on area of overlap of growing space), and change in CSI due to thinning as independent variables to predict periodic diam. growth response for 3- and 4-yr growth periods. CSI values were calculated from data collected in a naturally developed, pure, even-aged stand in Oregon [see FA 34, 2219]. Study plots were established in 1963, when the stand was 20 yr old, and thinned at varying intensities in 1963, 1966, 1970 and 1973. The data was divided into 2 periods: 1966-70 and 1970-73. Functions including all 3 independent variables accounted for the greatest variation in periodic diam. increment for both growth periods. Including transformations of initial CSI and change in

CSI in the model provided significant improvements over a model based only on functions of initial d.b.h.

OSU Link
Non-OSU Link

115. Sonne, E., E. Turnblom, D. Briggs and G. Becker. 2004. Log and lumber grades and value from a Douglas-fir stand 20 years after thinning and biosolids fertilization. Western-Journal-of-Applied-Forestry 19(1): 34-41.

Keywords: fertilization
thinning
economics
yield
wood quality

Abstract: Three replications of four treatments: biosolids fertilizer application, thinning, thinning plus biosolids fertilizer application, and untreated control were established in 1977 in a dense, low site, 55-year-old Douglas-fir (Pseudotsuga menziesii) stand in western Washington, USA. In 1998, 12 trees from each treatment were harvested, bucked into logs, and sawn into visually graded lumber. Taking into account effects of treatments on stand yield and log grades, biosolid fertilizer application only, thinning only, and thinning combined with biosolids increased log value/ac by $1142 (19%), $3642 (62%), and $9969 (155%), respectively, over the untreated control. When treatment effects were viewed in terms of changes in lumber yield and quality, per acre gains over the control were $2107 (26%), $5683 (70%), and $10 708 (132%), respectively. Willingness to pay analysis indicates that if the landowner intends to manage the stand to a rotation of approximately 75 years, each of the treatments, and especially the combination of thinning and applying biosolids, appears to be financially attractive at both 5 and 9% interest rates. However, if the rotation had been set at 55 years, only the thinning/biosolids combination at 5% interest rate would entice management to delay immediate harvest.

OSU Link
Non-OSU Link

116. Stegemoeller, K.A. and H.N. Chappell. 1990. Growth response of unthinned and thinned Douglas-fir stands to single and multiple applications of nitrogen. Canadian-Journal-of-Forest-Research 20(3): 343-349.

Keywords: fertilization
thinning
growth

Abstract: Basal area and volume growth response of unthinned and thinned Douglas fir (Pseudotsuga menziesii) stands to single and multiple applications of N fertilizer (as urea) were estimated for eight 2-yr periods in second-growth stands in Washington and Oregon. Response estimates, as differences between growth rates on fertilized and control plots after adjusting for initial volume (or basal area), and trends, were analysed on a regional scale. Average responses to the initial fertilization and to both the second and third fertilizer applications, 8 and 12 yr later, were statistically significant ($P < 0.05$). In

thinned stands, average duration of response to the initial treatment was approximately 8 yr; unthinned stands continued to show significant volume growth response through 14 yr although basal area growth response decreased to nonsignificant levels between years 10 and 12. In both cases, the response to refertilization, while significant, was smaller than the response to the initial fertilization. N applied after the 8th yr and a refertilization after the 12th, on one initially untreated plot at each site, also produced significant average growth responses.

OSU Link
Non-OSU Link

117. Stegemoeller, K.A. and H.N. Chappell. 1991. Effects of fertilization and thinning on 8-year growth responses of second-growth Douglas fir stands. Canadian-Journal-of-Forest-Research 21(4): 516-521.

Keywords: fertilization
thinning
growth

Abstract: An evaluation is presented of a regional research project on basal area and volume increment responses to fertilizer (N) and fertilizer with thinning treatments of Pseudotsuga menziesii in W. Washington and Oregon for four 2-year measurement periods. Fertilization generally increased both basal area and volume growth for at least 8 years. Thinning tended to have an even greater effect than fertilization on basal area and volume growth on an individual-tree basis. Overall, however, the removal of growing stock by thinning caused volume growth to be less than that of the control. The magnitude and duration of this negative response was dependent on the level of thinning and on site quality. A significant positive interaction between fertilization and thinning exists. The combined treatment resulted in the greatest absolute basal area and volume increments, and the response became greater than that to fertilizer alone in the 3rd and 4th years, and remained so for at least 8 years.

OSU Link
Non-OSU Link

118. Stinson, S.D. 1999. 50 years of low thinning in second growth Douglas-fir. Forestry-Chronicle 75(3): 401-405.

Keywords: thinning
growth
yield
wood quality

Abstract: Results are presented from four of the Port Blakely XT series of thinning trials, established during 1948-58 in naturally regenerated Douglas fir [Pseudotsuga menziesii] stands in western Washington. Three trials were designed to evaluate the effects of repeated low thinning and extended rotations, while the fourth compared the effects of different levels of removal on standing volume and wood quality. Periodic and mean annual increment trends were examined in all trials. Results indicated the extension of culmination of mean annual increment in response to low thinning, combined with extended rotations. Thinned plots in 2 trials had increased stem size and total harvested

volume. Extended rotations and low thinning increased the quantity of structural log grades when compared with stands harvested on shorter rotations.

OSU Link
Non-OSU Link

119. Stone, M. 1993. An economic evaluation of commercial thinning Douglas-fir in the coastal region of British Columbia. BC Ministry of Forests FRDA-Working-Paper WP-6-002. x + 146 p.

Keywords: thinning
commercial thinning
economics
growth
yield

Abstract: The economic evaluation of commercial thinning of Douglas fir [Pseudotsuga menziesii] in the coastal region of British Columbia, includes an estimation of the economic effects of the thinning on the final harvest. This was done by simulating the growth and yield impacts of a commercial thinning, estimating the potential costs and revenues derived from the thinning and the final harvest, and determining the net present value of the full impacts of commercial thinning.

Non-OSU Link

120. Strand, R.F. and D.S. DeBell. 1981. Growth response to fertilization in relation to stocking levels of Douglas-fir. In Proceedings: Forest Fertilization
Conference, University of Washington, Seattle, Washington, USA. Eds. S.P. Gessel, R.M. Kenady and W.A. Atkinson.pp. 102-106.

Keywords: planting operations
fertilization
thinning
growth

Abstract: Growing stock levels affect the response of Douglas-fir stands to applications of nitrogen fertilizer. Response is maximum at intermediate stocking levels, and is less at higher or lower levels of stand density. Nitrogen fertilization accelerates growth and therefore increases the rate of buildup of stand density. Thinnings will be required to reduce stocking to appropriate levels if good responses to repeated nitrogen applications throughout a rotation are to be obtained.

OSU Link
Non-OSU Link

121. Tait, D.E. 1988. The dynamics of stand development: a general stand model applied to Douglas-fir. Canadian-Journal-of-Forest-Research 18(6): 696-702.

Keywords: planting operations
thinning

growth
tree/stand health

Abstract: A linked pair of hypotheses are developed that represent causal explanations for plant growth and stand mortality for an even-aged stand. The pair of dynamic equations lead to a four-parameter Douglas fir simulation model that relates the development of stand volume and density to site quality, initial stocking density and alternative thinning regimes. The mortality hypothesis, a dynamic hypothesis related to stand density and stand growth, generates the -superscript 3/2 power law as an equilibrium solution.

OSU Link
Non-OSU Link

122. Tappeiner, J.C., J.F. Bell and J.D. Brodie. 1982. Response of young Douglas-fir to 16 years of intensive thinning. Forest-Research-Laboratory,-Oregon-State-University

Keywords: thinning
growth
yield
tree/stand health
economics

Abstract: The report of the thinning study in the Oregon Coast Range includes a financial analysis of representative thinning regimes.

OSU Link
Non-OSU Link

123. Taylor, A.M., B.L. Gartner and J.J. Morrell. 2003. Co-incident variations in growth rate and heartwood extractive concentration in Douglas-fir. Forest-Ecology-and-Management 186(1/3): 257-260.

Keywords: thinning
growth
wood quality

Abstract: Extractives can have a major impact on the properties of heartwood; however, our understanding of the process of heartwood formation and extractives production is limited and there are few data on how environment affects heartwood extractive content. This study assessed the relationship between growth ring width and extractive content of heartwood in Douglas-fir (Pseudotsuga menziesii [Mirbel] Franco) trees. The radial growth rates of the sampled trees were variable over their 53-61 years, in part, because of recent stand thinning treatment. The year that each heartwood increment was formed was estimated by assuming that the trees maintained the same number of growth rings of sapwood in the past as they had at the time of sampling. Growth ring width increased after the recent thinning and there was an associated increase in the extractive content of the heartwood estimated to have been formed at the same time. In addition, there appeared to be a rough correlation between growth ring width and extractive content in the time before the thinning. These

results suggest that silvicultural treatments that affect growth rate may affect wood durability in Douglas-fir.

OSU Link
Non-OSU Link

124. Tesch, S.D., G.M. Filip, S.A. Fitzgerald and D.D. Marshall. 1994. Silvicultural treatments for enhancing tree value, vigor, and growth in 70- to 120-year-old stands dominated by noble fir on the Warm Springs Indian Reservation: a synthesis of the literature. ForestResearch Laboratory, College of Forestry, Oregon State University. iii + 21 p.

Keywords: fertilization
thinning
pruning
tree/stand protection
growth
yield
tree/stand health

Abstract: The Warm Springs Indian Reservation, Oregon, apparently contains some 30 000 acres of naturally regenerated, largely unmanaged stands of 70- to 120-year-old mixed conifer forest dominated by noble fir (Abies procera), with Douglas-fir [Pseudotsuga menziesii], and some Pacific silver fir [Abies amabilis] and western hemlock [Tsuga heterophylla]. The synthesis focuses on growth and yield, thinning, pruning, fertilizer treatment, disease, minimizing stand damage during thinning, and insect pests.

Non-OSU Link

125. Thies, W.G. and R.N. Sturrock. 1995. Laminated root rot in Western North America. Pacific Northwest Research Station, USDA Forest Service General Technical Report GTR-PNW-349. iv + 32 pp. p.

Keywords: planting operations
site preparation
mechanical preparation
fertilization
thinning
tree/stand protection
tree/stand health

Abstract: Laminated root rot, caused by Phellinus weirii, is a serious root disease affecting Douglas fir (Pseudotsuga menziesii) and other commercially important species of conifers in northwestern North America. This report gives an overview of the disease as it occurs in the Pacific Northwest in Canada and the USA. Information on recognizing crown symptoms and signs of the disease is presented. The disease cycle of laminated root rot, from initiation to intensification and distribution within infected stands, is described. Finally, disease management strategies during stand development and at stand regeneration are discussed. Features on the nomenclature of the fungus and on its management by silvicultural and mechanical approaches also are included.

OSU Link
Non-OSU Link

126. Thomson, A.J. and H.J. Barclay. 1984. Effects of thinning and urea fertilization on the distribution of area increment along the boles of Douglas-fir at Shawnigan Lake, British Columbia. Canadian-Journal-of-Forest-Research 14(6): 879-884.

Keywords: fertilization
thinning
tree morphology
growth

Abstract: Assessments were made using radial growth measurements made 6 and 9 yr after treatment. Within treatments, av. area increment per tree was linearly related to d.b.h. and this relation was used to evaluate the effects of treatment on growth rate. Fertilizing had the greatest effect on av. area increment, and for a particular fertilization regime, thinning increased the response. Thinning modified the distribution of growth over the bole of all trees and increased butt flare, especially in smaller trees. The effect declined from the 4- to 6-yr measurement period to the 7- to 9-yr measurement period. Fertilizing had no consistent effect on growth distribution. The regression methods used in this study provided a more sensitive measure of form changes than previous methods, were independent of size distribution, and facilitated extrapolations and evaluation of temporal trends.

OSU Link
Non-OSU Link

127. Trofymow, J.A., H.J. Barclay and K.M. McCullough. 1991. Annual rates and elemental concentrations of litter fall in thinned and fertilized Douglas-fir. Canadian-Journal-of-Forest-Research 21(11): 1601-1615.

Keywords: fertilization
thinning
soil properties

Abstract: Overstorey litterfall (primarily needles) was collected for 15 years (1972-86) within control and treated plots in a Douglas fir (Pseudotsuga menziesii) stand near Shawnigan Lake, British Columbia. Treated plots were thinned or fertilized, or both. Thinned plots had two-thirds of their basal area removed; fertilized plots were treated with 448 kg N/ha of either urea or ammonium nitrate, and the fertilized plots were refertilized at the same rate 9 years later. The annual rate of litterfall in control plots averaged 1890 kg/ha. In control plots, significant yearly variations were observed in litterfall mass and concentrations of K, Mg, and Ca but not N or P. Thinning decreased rates of litterfall by 80%, but rates returned to control-plot levels after 13-15 years in unfertilized plots and after 8-10 years in fertilized plots. Fertilizer treatment without thinning depressed litterfall in the year of treatment but increased the rate by 20-80% in subsequent years. Litterfall N concentrations increased by 40-80% the year of fertilizer treatment and then began decreasing 3-6 years later. Nitrogen fertilization reduced litterfall P, K and Mg concentrations for 8, 4 and 1 year(s), respectively, following fertilizer treatment. The effects were greater in ammonium nitrate plots than in urea plots. Rates of litterfall correlated

poorly with stand density but well with basal area and stemwood increment. Correlations with the latter two variables varied with time and treatment.

OSU Link
Non-OSU Link

128. Velazquez-Martinez, A. and D.A. Perry. 1997. Factors influencing the availability of nitrogen in thinned and unthinned Douglas-fir stands in the central Oregon Cascades. Forest-Ecology-and-Management 93(3): 195-203.

Keywords: fertilization
thinning
soil properties

Abstract: Soil N mineralized during 7-day anaerobic incubation at 40 degrees C (available N) was compared at 2 soil depths and correlated with soil and site factors in Douglas fir [Pseudotsuga menziesii] stands with different combinations of thinning and multinutrient fertilizing. Available N expressed either on an area basis (kg ha-1) or on a concentration basis (mg kg-1) at the 2 depths did not vary significantly by stocking density, treatment, or density-treatment interaction. There was a significant difference between the soil depths, averaging 39 mg kg-1 at 0-20 cm depth, and 20 mg kg-1 at 20-40 cm depth. Available N was positively correlated with total soil N, exchangeable Ca, and adjusted aspect (the former 2 factors accounting for 46% of the total variation), and negatively with rock content and slope steepness. Stand density had no effect.

OSU Link
Non-OSU Link

129. Velazquez-Martinez, A., D.A. Perry and T.E. Bell. 1992. Response of aboveground biomass increment, growth efficiency, and foliar nutrients to thinning, fertilization, and pruning in young Douglas-fir plantations in the central Oregon Cascades. Canadian-Journal-of-Forest-Research 22(9): 1278-1289.

Keywords: fertilization
thinning
pruning
growth
carbon allocation
tree physiology
tree morphology

Abstract: The effect of thinning and silvicultural practices (multinutrient fertilization and/or pruning) on total aboveground biomass increment and growth efficiency was studied over three consecutive 2-year periods (1981-1987) in young Douglas fir (Pseudotsuga menziesii) plantations in the central Oregon Cascades. Plantations were 21-27 yr old in 1987. Plots were heavily thinned (leaving 300 trees/ha), moderately thinned (leaving 604 trees/ha) or left unthinned (leaving 3459 trees/ha) in 1981. Fertilizer (N, P, K, Ca, S and Fe) was applied with slow-release tabs. Net above-ground biomass annual increment over the 6-year period averaged 14.5, 7.8, and 5.5 t/ha for the high-, medium-, and low-density plots,

respectively. Growth efficiency, after dropping sharply between leaf area indexes (LAI) of 1 and 6 msuperscript 2/msuperscript 2, remained relatively constant up to the highest measured LAI of 17. Consequently, above-ground biomass increment continued to increase at LAIs well above that at which the Beer-Lambert law predicts maximum light should be absorbed. Foliage analyses indicated that thinning improved N, K and Mg nutrition and increased the translocation of K from 1-yr-old foliage to support new growth. However, fertilizer application increased foliar N and P contents only when coupled with pruning, suggesting that trees favour total leaf area over individual needle nutrition. Indications of K and Mg limitations in this study are supported by other recent studies of Douglas fir.

OSU Link
Non-OSU Link

130. Williamson, R.L. 1982a. Applicability of four regional volume tables for estimating growth response to thinning in Douglas-fir. Pacific-Northwest-Forest-and-Range-Experiment-Station, USDA-Forest-Service Research-Paper PNW-RP-295. 10 p.

Keywords: thinning
commercial thinning
growth

Abstract: A 110-yr-old stand in Washington was given light or heavy thinning or left unthinned in 1952 and 1971. Stem sections were taken from trees removed in 1971 and analysed to show volume growth for the 19 yr before and 19 yr after the 1952 thinning. Estimates of volume growth for the same stand were also made from 4 volume tables and the results compared. The agreement between volume table estimates and the stem analysis results was within 10%, and was unaffected by thinning severity.

OSU Link
Non-OSU Link

131. Williamson, R.L. 1982b. Response to commercial thinning in a 110-yr-old Douglas-fir stand. Pacific-Northwest-Forest-and-Range-Experiment-Station, USDA-Forest-Service Research-Paper PNW-RP-296. i + 16 p.

Keywords: thinning
commercial thinning
growth
tree/stand health

Abstract: [See FA 28, 584] A stand in Washington was thinned in 1952 to 75 or 50% of normal b.a. After 19 yr the plots were remeasured and thinned again and stem analyses made for felled trees. Overall growth was similar in thinned and control plots, although mortality was 3-5x higher on control plots. The growth response relative to control trees was significantly greater for suppressed trees in the heavily thinned plots.

OSU Link
Non-OSU Link

132. Williamson, R.L. and R.O. Curtis. 1984. Levels-of-growing-stock cooperative study in Douglas-fir. Report No. 7 - Preliminary results, Stampede Creek, and some comparisons with Iron Creek and Hoskins. Pacific-Northwest-Forest-and-Range-Experiment-Station,-USDA-Forest-Service Research-Paper PNW-RP-323. v + 42 p.

Keywords: thinning
commercial thinning
growth

Abstract: [See FA 43, 3890, 6692] A further report in a series on 9 study areas in Canada and the USA. Results are summarized for a 43-yr-old stand in SW Oregon, which was 'calibration thinned' in 1968 (aged 33 yr) and thinned again to retain 10-70% of the b.a. increment of the untreated control plot at age 38 yr. Recommendations for desirable density are given.

OSU Link
Non-OSU Link

133. Wilson, J. 2004. Vulnerability to wind damage in managed landscapes of the coastal Pacific Northwest. Forest-Ecology-and-Management 191(1/3): 341-351.

Keywords: planting operations
thinning
tree/stand protection
computer modeling
tree/stand health

Abstract: Managed forested landscapes in the coastal Pacific Northwest follow a pattern of transition from dominance by naturally regenerated second growth to dominance by planted stands. This transition should have dramatic influence on many characteristics of these landscapes and the larger region, including susceptibility to wind damage. In this paper, inventory and spatial information from an example landscape are integrated using the Landscape Management System to produce alternative management scenarios and evaluate the projections using a wind damage vulnerability rating system. Planted Douglas-fir stands tend to develop higher height to diameter ratios in the dominant trees, are thinned more often, and tend to have more exposed windward edges; characteristics which increase susceptibility to wind damage. In this analysis, the increasing vulnerability factors are mostly compensated for by the reduced rotation lengths expected in the plantations. The pattern of transition in managed landscapes generates an associated pattern of vulnerability to wind damage. Homogeneously and heterogeneously aged landscapes have distinct patterns of vulnerability. These differences could be harnessed to enhance the particular goals associated with managing individual ownerships.

OSU Link
Non-OSU Link

134. Wilson, J.S. and P.J. Baker. 2001. Flexibility in forest management: managing uncertainty in Douglas-fir forests of the Pacific Northwest. Forest-Ecology-and-Management 145(3): 219-227.

Keywords: planting operations
thinning
yield
tree morphology
economics
tree/stand health

Abstract: Long planning horizons generate substantial uncertainty in forest management, making management flexibility, the ability to choose between multiple options or opportunities, a desirable attribute of managed forests. Flexibility in forest management reflects both the relative rigidity of intervention requirements and the potential range of development pathways for a stand. The wind stability of Pacific Northwest Douglas-fir (Pseudotsuga menziesii) plantations is used to demonstrate the concept of management flexibility. Dense Douglas-fir plantations develop high height to diameter ratios in the dominant trees making them unstable and prone to wind damage. The management of these plantations is inflexible, because without early and timely thinning, the stands do not contain stable trees that could be expected to survive long rotations or late thinnings. A combination of reduced planting densities and site-specific management reduces both the necessity and rigidity of intervention requirements (e.g., thinning) and expands the number of potential developmental pathways for these stands. The cost of greater management flexibility is reduced efficiency of wood volume production; however, greater adaptability to changing markets, labour conditions, and management objectives may be more important for many forest owners. While this approach to management is complex, it frees owners and managers from rigid management requirements and allows for a wider range of future stand conditions.

OSU Link
Non-OSU Link

135. Wilson, J.S. and C.D. Oliver. 2000. Stability and density management in Douglas-fir plantations. Canadian-Journal-of-Forest-Research 30(6): 910-920.

Keywords: planting operations
thinning
tree/stand protection
tree morphology
tree/stand health

Abstract: Limited tree size variation in Douglas fir (Pseudotsuga menziesii) plantations in coastal Oregon, Washington, and British Columbia makes them susceptible to developing high height to diameter ratios (H/D) in the dominant trees. The H/D of a tree is a relative measure of stability under wind and snow loads. Experimental plot data from three large studies were used to evaluate the impact of initial planting densities and thinning on plantation H/D values. The H/D predictions from the experimental plot data match spacing trial results closely but are substantially different from distance-independent growth model predictions. The results suggest that plantation H/D values can be lowered and stability promoted through reduced planting densities or early thinning; however, later thinnings may not be effective in promoting stability, since they do not appear to lower H/D values. Higher initial planting densities shorten the time period during which thinning can be expected to effectively lower future H/D values. Time-sensitive thinning requirements in dense plantations make their management

inflexible. The flexibility with which a stand can be managed describes the rigidity of intervention requirements and/or potential range of stand development pathways.

OSU Link
Non-OSU Link

136. Wimberly, M.C. and B.B. Bare. 1996. Distance-dependent and distance-independent models of Douglas-fir and western hemlock basal area growth following silvicultural treatment. Forest-Ecology-and-Management 89(1/3): 1-11.

Keywords: fertilization
thinning
growth

Abstract: Distance-independent and distance-dependent individual-tree basal area growth equations for Douglas fir (Pseudotsuga menziesii) and western hemlock (Tsuga heterophylla) growth following thinning and fertilizer treatments were developed using regression analysis. Data came from an even-aged, naturally regenerated, mixed species stand near Jordan River, SW Vancouver Island, Canada. Distance-independent models included only non-spatial competition and thinning indices, while distance-dependent models included both spatial and non-spatial indices. The distance-independent models with the highest adjusted multiple coefficient of determination (adjusted Rsuperscript 2) for both species included diameter at breast height, crown class, percent basal area removed in thinning, plot basal area greater than the subject tree and stand age as independent variables. The distance-dependent models with the highest adjusted Rsuperscript 2 included all of these variables in addition to a variant of the area potentially available index, which is based on the spatial tessellation of the point pattern of trees in the stand. Addition of this spatial index produced only a small (<.01) increase in adjusted Rsuperscript 2 for models of both species. The relatively small amount of increase was due to three factors: thinning resulted in an even distribution of growing space among residual trees; tree size explained much of the variation in local competitive stress; and the competitive neighbourhood of individual trees was large relative to sample plot size. The results suggest that the additional effort and expense required to obtain spatially referenced stand data for developing empirical forest growth models in similar stands is not justified.

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