Silvicultural and Financial Analysis of Three Case Studies in the Oregon Coast Range

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Three data sets were examined to determine the costs with and without constrained forest management practices. Two adjacent sites in the Coast Range of Oregon were studied. One of the units was broadcast burned while the adjacent site was left unburned. The stands were projected for growth and yield in the Douglas-Fir Simulator (DFSIM) and Oregon Growth and Yield Projection System (ORGANON). For the simulations a 70 year rotation at 4% interest was used. The total timber volume differed by (1-4%) with the higher volume on the burned unit. Soil expectation value was 4% ($400) higher on the burned unit.

Black Rock plot 31, a stand of conifers, was analyzed for retention of various amounts of overstory Douglas-fir trees with an understory of hemlock. Eight different rotations of varying amounts of retained green trees and rotation lengths were forecast with ORGANON. The lowest opportunity cost was realized on the shorter rotation when two trees were left in the overstory and understory hemlocks were pre-commercially thinned.

Forest weeding in the first two years of plantations was analyzed at four sites of increasing site index. DFSIM and the stand projection system (SPS) were used to project two different thinning regimes on weeded and non-weeded sites. Weeded sites produced consistently higher timber yields. Thinning to 100 trees per acre (TPA) produced higher yields on the weeded sites and thinning to 150 TPA produced higher yields on non-weeded sites. All weeded sites produced higher value stands ranging between (5-75%). The most pronounced weeding value difference was at the low productivity site and the least value difference was at the high productivity site.

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Silvicultural and Financial Analysis of Three Case Studies in the Oregon Coast Range

Introduction

In recent years, decisions about management of the Pacific Northwest forest resource have generated much debate among policy-makers. New policies may exclude some forest management techniques used in stand establishment. Traditional regeneration techniques, such as slash burning, applying herbicides, and clearcutting help to establish new forests after a harvest. Constraints on these established techniques may cause declines in wood production and profitability, a serious concern, especially to land managers whose primary objective is wood production.

The goal of this thesis is to gain an understanding of the economic impacts of constraints on site preparation techniques and harvesting methods. I have conducted stand level analysis on site preparation techniques, and various types of rotations. I compared adjacent units at Norton Hill for the economic impacts of constraints on broadcast burning. Norton Hill is an observational study that was not replicated for statistical certainty, but it demonstrates a real case study. At Black Rock I examined extended rotations of a two-story stand of Douglas-fir and hemlock and made a comparison to other green tree retention studies. In the third section of this thesis I compared weeded and non-weeded areas on four sites in the coast range.

Calculations

Most of the financial analyses in this study are traditional present net worth (PNW) comparisons. The present net worth calculation is the sum of the accountable financial benefits and costs of a management regime discounted to the same point in time (Davis and Johnson, 1987, and Cleaves and Brodie, 1991). The discount rate corresponds to the real rate of interest, usually 4% in forestry projects. Historically forestry projects have been evaluated at 4% since the rate of return on long term U. S. government securities, net of inflation, has fluctuated between 2.5 and 4%. Inflation is not included in the real rate of interest.

The Present Net Worth equation is:

$$PNW = \sum_{t=1}^{n} \frac{B_t}{(1+i)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+i)^t} \qquad \textit{Equation } (1)$$

where B_t = Benefits: Positive returns received in year t

C_t = Costs: Expenditures in year t

i = interest rate or discount rate

t = # of years (periods) until benefit or cost occurs

If two separate forest stands have the same rotation length, the PNW calculation is a useful comparison.

The soil expectation value (SEV) aids comparison of stands that have different length rotations. SEV includes the value of timber and the timber that the land can produce in all future rotations. Therefore, SEV is a more complete accounting of the total value of forest land and the timber it can produce (Davis and Johnson, 1986). Future rotations of land can produce 4 to 10% of the total SEV depending on the interest rate. In other words, 90 to 96% of the value is in the first rotation, for rotations of 60 to 90 years at moderate discount rates.

The Soil Expectation Value Equations:

Method I

$$SEV = \frac{N_R}{(1+i)^R - 1} \qquad \textit{Equation } (2)$$

$$N_R = \sum_{t=1}^{R} B_t \,(1+i)^{R-t} - \sum_{t=0}^{R} C_t \,(1+i)^{R-t} \qquad \textit{Equation } (3)$$

Method II

$$SEV = PNW \frac{(1+i)^R}{(1+I)^R - 1} \qquad \textit{Equation } (4)$$

where B_t = Benefits: Positive returns received in year t

C_t = Costs: Expenditures in year t

N_R = Net Return at the end of the rotation R

i = interest rate or discount rate

R = Rotation Length

t = number of years until benefit or cost occurs

If forest managers wish to evaluate an existing stand that is several years into the rotation, they would use a modification of the first three equations.

Net Present Amount of an existing stand:

$$NPA = \frac{\sum_{t=0}^{R}(R_t - C_t)}{(1+i)^{R-t}} + \frac{SEV}{(1+i)^{R-t}} \qquad \textit{Equation (5)}$$

A growth and yield model called DFSIM (Curtis, 1985) performs calculations for stumpage and average volumes of each commercial thin and final harvest, and the associated costs.

Net present amount (NPA) is computed by using a formula that determines a present value as in the present net worth formula, without accounting for sunk costs and revenues assessed before the period of analysis. If a a stand was thinned in 1958, the early harvest does not figure into the current rotation in the case of a resale in 1990. NPA is the amount a buyer would pay for a stand in the middle of the rotation, while PNW is the value of one rotation at its beginning.

The Net Present Amount Equation:

$$NPA = PNW_t + \frac{SEV}{(1+i)^{R-t}} \qquad \textit{Equation (6)}$$

The use of PNW and NPA interchangeably can be confusing. In this thesis PNW refers to a single rotation at the beginning of the rotation using equation (1). Net present amount refers to equation 6, meaning the value of the current stand and future rotations. Soil Expectation value refers to all rotations evaluated at the beginning of the first rotation.

Broadcast Burning

Prescribed fire has many advantages as a tool in site preparation. Site preparatory burning can improve regeneration effectiveness, improve planting efficiency, control competing vegetation, manipulate pest species habitat, and reduce the risk of wildfires in the future (Cleaves and Brodie, 1991). This study will emphasize productivity and value differences between management treatments.

In the coast range fire helps remove the slash remaining after a harvest, opening space and allowing light to reach the seedlings. Fire helps control vegetation that would compete with trees. Prescribed burning costs less than mechanical site preparation and does not compact clay soils (Gratkowski et. al., 1973). These advantages usually translate into lower costs of establishing a successful stand of trees than when fire is excluded.

The role of fire in forestry is discussed throughout forestry literature. Through additional yield, shorter rotations, and greater planting success, a prescribed burn can produce a $200-$240 higher SEV than unburned sites (Powell, 1992). Cleaves and Brodie found a $164 net gain in a simulated prescribed burn at a 4% discount rate (Cleaves and Brodie, 1991).

Specific gains in productivity that are attributable to prescribed burning (Powell, 1992). include the above mentioned increase in SEV, an additional 4000-5000 board feet of timber per acre, 50-75 more trees per acre, more uniform planting of about 15% greater area planted, and a 2-4 year reduction in rotation length.

Slash burning in the Willamette National Forest in 1987 costs between $270 and $450 per acre (Cleaves and Brodie, 1991). Powell (1992) has published average costs for management and prescribed burning on Starker Forest lands in the Coast Range (1992 prices). Any combination of pre-burn treatments might need to be performed, including: herbicide $65, scarification $142, slashing $52, and fire trailing $8 (all on a per acre basis). On the average, total costs for broadcast burned sites are $149 per acre, and total costs for slash pile burning are $161 per acre.

Prescribed burning has its disadvantages that translate into higher costs in some cases compared to other methods. For example, a large crew is necessary to build fire lines and attend fire equipment to help prevent fire from escaping the established boundaries. An escaped fire can destroy valuable timber. The costs of a prescribed burn increase considerably if fire escapes to neighboring stands of timber. Risk analysis is an integral part of planning a prescribed burn to assess whether the risk of an escape is worth taking (Cleaves and Brodie, 1991).

Many of the social costs associated with burning are unclear or not easily quantifiable. Long-term decreases in productivity associated with nutrient loss are an example. Smoke pollution and loss of soil are two examples of costs that are not quantified in benefit-cost analysis. Presently society has determined that social costs are acceptable on "burn days" when atmospheric conditions reduce the social costs of air pollution. This is complicated by the fact that burn days are also set for times when the risk of wild-fire is low, making ignition difficult.

Site Description Norton Hill

Norton Hill North and Central units are adjacent sites in the Oregon Coast Range located about 20 miles north west of Corvallis and about 4 miles north east of Eddyville (Township 10 South, Range 9 West). Norton Hill is owned and managed by Starker Forests, Inc. of Corvallis.

The sites are in the middle of the Coast Range, a highly productive Douglas-fir region. Both units are site I, site index 140 at age 50 (King, 1966). The temperate rain forest ecosystem here encourages fast growth rates for trees, and intense competition from vegetation for growing space and for light. The vegetation types at Norton Hill are typical of the coastal Douglas-fir region with salmonberry and salal understory vegetation. The principal tree species are Douglas-fir (Pseusotsuga menziesii Mirb., Franco), red alder (*Alnus rubra*), bigleaf maple (Acer macrophyllum Pursh), vine maple (Acer circinatum Pursh), California Hazel (Corylus cornutta var. californica Sharp), and elderberry (Sambucus spp.). The principal brush species are, salmonberry (Rubus spectabilis), salal (Gaultheria shallon Pursh), and Himalaya blackberry (Rubus discolor Pursh).

Both units have slopes ranging from (less than 15% to 90%). The majority of the unburned *North unit* is flat enough for tractor skidding during commercial thinning and final harvest, while the rest will require cable logging. Approximately half of the burned *Central unit* is loggable by tractor while the other half will require cable logging. The two units have slightly different topography. The unburned north unit faces entirely northward but contains two drainages that disrupt the strictly northerly aspect. Forty percent of the burned Central unit lies on the same north aspect, while the remaining area faces south easterly down the opposite side of a ridge. The difference in aspect may affect the growth of the stand because the southerly aspect of the burned unit exposes young seedlings to slightly harsher conditions.

A comparison of the two units with 1993 aerial photographs shows more uniform stocking success of Douglas-fir in the burned unit. The unburned unit contains more openings of salmonberry and grass, as well as a greater mix of hardwoods.

Management

Norton Hill is a tract of Starker Forest land that was partially broadcast burned, on unit 1305, while the adjacent unit 1301 was left unburned. An initial attempt to burn the unit partially failed, and weather conditions were too wet to permit a second attempt to burn.

Both sites received the same plantation establishment treatments with the exception of mountain beaver trapping on the *burned* unit in 1979, 1980, and 1981. Trees in the *unburned* unit were covered with flexible mylar tubing in 1979, and the unit was trapped in 1980. The excess slash prevented effective mountain beaver trapping on the unburned unit. As a preventive measure, Starker used flexible mylar tubing to protect the seedlings. This is the reason for higher costs of regeneration on the unburned unit. The inability to control mountain beaver populations may also have contributed to lower stocking at year 18.

Both units received the same herbicide treatments for competing vegetation. Herbaceous weeds were treated with Roundup in 1981, and woody vegetation was treated with 2-4-D in 1983 and 1984. Both units were planted with 2-1 seedlings in the winter of 1979 / 1980 and have grown for 15 seasons to the present. Both units have received virtually the same management with the exception of burning for site preparation. These conditions will allow a comparison of a burned and unburned site.

Methods

Norton Hill was measured on November 3, 1994 by sampling 100th acre fixed plots (11.78 ft. radius) tree species, height, and diameter. The plots were taken every two chains in a grid pattern. Diameters were measured with a diameter tape to 1 inch size classes and heights were measured with a clinometer and loggers tape.

Plot data from the stand exams were projected with two different growth and yield models: the Oregon Growth and Yield Projection System *ORGANON* (Hann, 1992) and the Douglas-Fir Simulator *DFSIM* (Curtis, 1985). DFSIM and ORGANON projected growth of the stands to a commercial thinning and final harvest. The growth projections were then evaluated for present net worth and soil expectation value.

DFSIM Projections

The Douglas-Fir Simulator is a whole-stand / diameter-free growth and yield model. Individual tree heights and diameters are not required as input to the model (diameter-free). Diameters for various stand components are generated in the model. DFSIM requires average stand attribute values as input (whole stand). The program requires trees per acre, quadratic mean diameter and / or basal area per acre for the stand. Height distribution of the stand is calculated from the total stand age and site index.

More accurate projections are made if care is taken to stay within the limitations of the growth model. The models are limited to a geographic area and limited by the data used to derive them. DFSIM is applicable to even-age stands of Douglas-fir in the northern part of Oregon, western Washington, and British Columbia. DFSIM is better suited to British Columbia and Washington as 75% of the data set is from those regions and 25% is from Oregon. DFSIM is designed for no more then 20% hardwoods mixed in the Douglas-fir stand. DFSIM is derived from a data set that contains no plantations that were planted with less than 300 TPA. Projections with multiple thinnings and fertilizations should be made with the understanding that few of these stands were measured in the DFSIM data set (David Hann, personal communication).

In order to begin the DFSIM program, the stand must be entered into the computer to compare the burned and unburned units. The units are entered as two similar stands that have different diameter, height, and trees per acre, as a result of the better growth conditions provided by fire. For the growth all other program defaults are held equal. The site conditions are: Kings (1966) site index 140, and the total age is 18 or 12 years at breast height. In the simulations both units were thinned at year 38 and harvested at year 68 total stand age. There are no pre-commercial thinnings or fertilizations. See table 1 for the set up of the simulations.

Table 1. Summary of variables used to simulate no broadcast burning and broadcast burning on the Norton Hill Units.

	Stand 1301	**Stand 1305**
	Unburned Site Preparation	Broadcast Burned
Total Age	18	18
Breast Height Age	12	12
Planted	1979 to 360 TPA with 2-1's 12 X 12 spacing	same
Total Acres	112	74
Trees per Acre	393 includes hardwoods 323 Douglas-fir	305 with hardwoods 292 Douglas fir
Basal Area per Acre	114 square feet	101
Quadratic Mean Diameter	7.3 inches DBH	7.8

A thinning was simulated at 38 years total age with a d/D (diameter thinned to diameter before thinning) ratio of (.9). The residual basal area (BA) was set at 120 square feet per acre (See Table 2). Year 38 was chosen to allow the trees time to grow to a sufficient size to support a commercial thinning from below, resulting in larger more valuable trees as growing stock. The late thinning will pay for logging costs[1] and still retain sufficient growing stock. The reason for choosing the thinning and final harvest was to present a workable regime, not to optimize the timing of the thin and final harvest. This study presents the difference in soil expectation value attributable to fire, not the rotation that maximizes SEV. However, the thinning is similar to those performed in the Hoskins study (Tappeiner, Bell, and Brodie, 1982) where SEV was maximized.

Table 2. Summary of commercial thin conditions at age 38, Norton Hill.

Table 2.	**Commercial Thin 1301 and 1305**
Total Age	38
Breast Height Age	32
DFSIM	d/D = .9
ORGANON	Below
Residual Basal Area	120 square feet (both models)

The final harvest for these projections was at 68 years total stand age and 62 years breast height age. The longer rotation length was chosen to allow additional diameter and volume growth after the thinning. By treating both stands with the same thinning and final harvest, the differences in volume and value due to prescribed burning were determined.

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[1]Whether the commercial thin generates a positive cash flow depends on if the logging and hauling costs exceed about $400/MBF, the mill value for a #4 saw log.

DFSIM with Economics

DFSIM calculates the present net worth (PNW)[2] of an existing stand to its current age, and in this analysis the stand is assessed at year 18. The stand is actually in its 15th growing season since planting but it is not necessary to account for the three years that the seedlings were in the nursery. This analysis is based on the time that the trees are grown in the forest. The seedlings start growing at the nursery while the previous rotation of trees are still in the forest. Therefore no time is lost while seedlings grow in the nursery.

The present net worth of the current stand will be adjusted to reflect future harvests by calculating the soil expectation value (SEV). The SEV will also account for planting and site preparation costs that were foregone in the calculation of PNW at year 18 (1994).

Site preparation and planting costs varied between the two sites. Total site preparation and planting costs were $414 for the burned unit and $454 for the unburned unit. These costs are not factored into the DFSIM present net worth calculations because they are foregone, or sunk into the 1979 expenditures. The SEV was calculated by hand from the DFSIM output to account for the stand establishment costs.

DFSIM allows eight stumpage or pond values for input to the model. The per thousand board foot dollar values are based on the mix of logs from stands of the indicated average DBH (See Table 3).

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[2] The calculation of PNW at year 18 does not include the SEV of all future rotations as the NPA calculation would.

Table 3. Stumpage values ($/MBF) of logs by average tip diameter.

Diameter[3]	**6"**	**10"**	**14"**	**22"**	**28"**
Stumpage	$350	$500	$600	$700	$800

For this analysis it is assumed that logging costs and hauling costs are the same on both units. They may not be, but the objective is to test the affects of the burn and not logging costs due to differences in terrain.

ORGANON Projections

The Oregon Growth and Yield Projection System (ORGANON) is an individual-tree distance-independent growth and yield model. As an individual-tree or single-tree model it is capable of handling inventory data directly. The final growth projections are more accurate than whole stand models (David Hann, Class notes). Individual-tree models make projections based on the actual trees in the stand and whole-stand models make projections based on an estimate of the average stand diameter and height distribution. ORGANON has more options for management and more flexibility than DFSIM. Options in ORGANON include uneven-aged and even-aged management and the capability to project mixed species stands, as well as extensive output options allowing thorough analysis.

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[3] Diameter of the harvested trees.

The Western Willamette Valley version of ORGANON was used for the prescribed burning section of the analysis. This version was derived exclusively from a large data set of trees from the McDonald and Dunn research forests. WWV ORGANON is applicable to stands west of the Cascade Range of Oregon.

Results

DFSIM predicted 1081 BF per acre greater volume for the commercial thinning and a 1013 BF per acre greater volume at final harvest on the burned unit compared to the unburned unit. The 2094 BF per acre volume difference between the burned and unburned sites amounted to a $613 per acre greater PNW in 1994 at 18 years total stand age. The SEV is $426 per acre greater on the burned unit according to the DFSIM model (Appendix A, See Tables 3 and 4 for volume predictions and tables 5 and 6 for financial values).

The ORGANON growth projections are lower in total volume produced compared to DFSIM. The ORGANON total volume predictions for thinning and final harvest average 97,842 BF per acre while the DFSIM volume predictions average 115,135 BF per acre, a difference of 17,293 BF on the average.

The commercial thinning of the *unburned* stand produced 737 BF per acre more volume than the burned unit but final harvest was 648 BF per acre greater on the *burned* unit based on ORGANON predictions. The total for the thinning and final harvest was 89 BF higher on the unburned unit (Table 4, Appendix A). This is a reversal for the trend that DFSIM predicted.

Whether using ORGANON or DFSIM, the burned unit had higher present net worth and higher soil expectation value. The difference between SEV in the burned and unburned unit was \$426 with DFSIM and \$378 with ORGANON. The difference in present net worth in 1994 at age 18 is \$613 for DFSIM and \$538 dollars for ORGANON. The present net worth difference in 1978 before planting would have been \$383 for DFSIM and \$336 for ORGANON. These values represent less than 4% of the total economic value (See tables 5 and 6 for the financial values, Appendix A).

Discussion of Burned Versus Unburned Units

In this analysis, burned and unburned units at Norton Hill were compared. Since trees on both units have grown under the same management, climate, and edaphic conditions, the size differences between the trees on the two units is attributable to either broadcast burning or some other variable that was not controlled. In the growth simulations, all program defaults remained the same except diameter, height , and trees per acre, which quantified the difference between the burned and unburned harvest units.

This is an observational study, and no attempt has been made to control for extraneous variables that might also account for differences in size and value between the units (for example, deer browsing, seedling vigor, slope, or aspect). This study is a simplified stand-level economic analysis of two sites in the Coast Range. Therefore, differences in volumes or growth cannot be directly attributed to the burn with statistical certainty, and the same results cannot be predicted for other sites. For this site and in similar conditions one might find similar results if they were to repeat the experiment.

In this analysis the difference between the SEV of the burned unit and the unburned unit averaged about $400 per acre or 4.2% of the total SEV (426/10,460). It has been observed by Powell (1992) that the expected difference in SEV associated with burning for site preparation is about $250 per acre.

Growth Models

DFSIM should be used for stands with no more than 20% hardwood stems. The unburned unit contained 18% hardwoods while the burned unit contained 4% hardwoods. ORGANON has better capability to project hardwoods although each species is not represented in the model.

The growth models do not project completely all of the changes in structure that may be caused by fire (Dave Marshall, personal communication). There may be different amounts of course woody debris on each site, and variable habitats for different plant and animal populations. Different woody debris structure, may affect the different animal populations that utilize the stand. Perhaps one structure will support a higher population of porcupines which might impact the survival of pole size trees. These differences may be reflected indirectly by manipulating different features within the growth models such as site index for productivity differences, and commercial thinning to represent mortality due to bear or porcupine.

Green Tree Retention

Green tree retention refers to the practice of retaining standing live trees in the unit after the harvest. A number of types of harvest cuts may fall into the category of green tree retention. A shelterwood with 10 to 20 overstory trees remaining after harvest is considered a practice of retaining green trees. A forest manager may wish to retain trees on a site to meet forest practice requirements. By retaining these trees the forest has greater structural diversity for birds and wildlife (Franklin, 1989) and aesthetic advantages. Retaining trees with merchantable value has an opportunity cost when compared to the alternative of harvesting them. If society values the benefits of retaining the trees higher than their net commercial value, green tree retention becomes a viable option.

In this section of my thesis I quantify the opportunity costs associated with green tree retention and extended rotations in a two-species and two-story stand at Black Rock. Black Rock Plot 31 has an overstory of Douglas-fir and an understory of hemlock that has grown as a two-storied stand since 1958. In previous studies the understory was simulated with ingrowth files into the growth projection.

Literature Review

Long and Roberts (1992) simulated a multi-storied stand or irregular shelterwood with 20 leave-trees managed as continuous rotations to maintain both canopies. Using PROGNOSIS (Stage, 19) they simulated a regime of a pre-commercial thinning, and commercial thinnig that reduced the stand to 20 trees per acre (TPA), and compared it to even-aged management.

Birch and Johnson (1991) simulated a stand retaining between 2 and 20 green trees per acre in either a scattered or a clumped pattern by using ORGANON and ORGECON. They also created snags for standing dead wood. Volume reductions associated with green tree retention and snags reduced total merchantable wood volume by 6 to 25%. The value reduction in PNW was 2.7 to 17.7% of the total. Each residual tree represented about 1% of the total harvest volume.

Birch and Johnson used the SPS (Arney, 1985) growth model to simulate young (15 year) Douglas-fir stands that were input to ORGANON as "ingrowth" files ORGANON users can choose an "ingrowth" management option to simulate young stand growing underneath the dominant canopy. Birch and Johnson elevated logging costs five to ten percent in their leave-tree scenarios to reflect differences in management costs as compared to clearcut harvesting.

Bishaw and Johnson (1994) demonstrated an analysis of green tree retention with two TPA scattered over the landscape which included a riparian zone with 38 TPA. The scattered pattern yielded 1.3% less wood volume and the riparian yielded 19% less volume. The first commercial thinning yielded 28% more volume on the scattered pattern than on the clearcut used as a control for comparison. This at first seems counterintuitive, but when you consider that the scattered pattern was thinned from below and the clearcut was proportionally thinned, the scattered pattern would have many small trees that were thinned and the clearcut would have some small trees, just a few large trees, and less volume. The entire unit, with the scattered residual trees and the riparian zone, yielded 10.8% less value for one rotation in present net worth.

A masters thesis by David Bartlett (1993) found volume reductions of 3 to 29% and value reductions of 6 to 15% when green trees were retained over continuous rotations. Bartlett compared 1 acre patch cuts managed in a regulated series of rotations, and retention of 5, 10, 15, and 20 overstory trees per acre in a two-storied stand. Bartlett (1993) and Bishaw and Johnson (1994) used ingrowth files to simulate the understory. They created the ingrowth files by sampling actual stands and manipulating the tree sizes to simulate shade effects.

Green Tree Arrangements

There will be advantages and trade-offs when forest managers decide to leave green trees in a scattered or in clumped pattern,. Their decision to clump or scatter trees depends on the objectives. Scattered residual trees have biological advantages such as retention of biomass and habitat (Franklin, 1989). Clumping trees may protect a riparian zone or protect the stand from blow-down.

Clumping trees has its advantages in lower logging costs and may have lower opportunity costs associated with retaining merchantable trees. One practice is to clump non-merchantable trees in a group that can grow for harvesting later. With this method the trees are out of the way of logging operations and meet the requirement for leaving trees.

Clumping trees into smaller areas in relation to the size of the clearcut seems to lower the cost of leaving trees after a harvest. This can be demonstrated based on Bartlett's (1993) work. The highest cost for leaving trees is associated with leaving more trees in a scattered pattern or in a multiple story canopy. As the number of trees per acre in a scattered pattern decreases, so does the cost of leaving them. If a multi-storied clump is left in the midst of a clearcut, the cost of leaving the trees decreases as the clump size decreases and the clearcut size becomes relatively larger (Table 4).

Growing a multiple-story stand on 60 acres with 5 TPA in the main canopy, the SEV per acre is $26,060; this is $1,563,600 for the stand. A 60 acre clearcut is worth $1,668,900. Therefore the opportunity cost of leaving 5 TPA compared to clearcutting is $105,300. With 10 TPA in the canopy, the total SEV for the stand is $1,520,980, or $147,960 less than a 60 acre clearcut. With 20 TPA in the overstory the stand is worth $232,800 less than a 60 acre clearcut. The previous calculations show that scattering fewer leave trees after a harvest has a smaller opportunity cost.

Here is a demonstration of leaving 5 TPA (or 300 total trees for 60 acres) in an increasingly tighter bunch. The opportunity cost of leaving 5 TPA is $105,300 compared to a 60 acre clearcut. Scattering 10 leave trees per acre over 30 acres and clearcutting the remaining 30 acres gives a total SEV of $1,594,941, or $73,959 less than a 60 acre clearcut. Twenty leave trees per acre on 15 acres plus a 45 acre clearcut yields $1,610,710 or $58,190 less than a 60 acre clearcut. If all the leave trees are put on 2 acres and never harvested, one would give up $55,630 to harvest 58 acres. This demonstrates lower costs for clumping leave trees.

Table 4. Scattered leave trees versus clumping and the associated opportunity costs based on a clearcut[4].

Scattered	Leave	Trees		
Management	*Total Number of Leave Trees*	*SEV Per Acre*	*Total SEV on 60 acres*	*Opportunity Cost Based on clear-cut*
Clearcut 60 ac.	0	$27,815	$1,668,900	0
Leave 5 TPA over 60 acres	300	$26,060	$1,563,600	$105,300
Leave 10 TPA over 60 acres	600	$25,349	$1,520,940	$147,960
Leave 20 TPA over 60 acres	1200	$23,935	$1,436,100	$232,800
Clumping	Leave	Trees		
10 TPA on 30 ac. Clearcut 30 ac.	300	$25,349 $27,815	$1,594,941	$73,959
20 TPA on 15 ac. Clearcut 45 ac.	300	$23,935 $27,815	$1,610,7108	$58,190
1850 TPA on 2 ac. Clearcut 58 ac.	300	$27,815	$1,613,270	$55,630

Site Description Black Rock

Black Rock is an Oregon State University research area owned and managed by the Oregon Department of Forestry and located in the coastal Douglas-fir and hemlock ecosystem. After wild fire in 1910 Black Rock was logged and naturally regenerated. Today there are several research plots maintained in the area, but the plot of interest is number 31, a one acre plot buffered by forest that was thinned to 51 Douglas-fir TPA in 1958 and underplanted with hemlock. The original objective was to cut the hemlock at the time of final harvest along with the Douglas-fir. In 1993 the Douglas-fir had not yet reached maximum culmination of mean annual increment of cubic foot volume, the best

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[4]The SEV numbers in table 4 are based on Bartlett, 1993

biological rotation age for maximizing wood production (Curtis and Marshall, 1993). Best economic rotations are usually shorter due to the time value of money, and product markets.

Black Rock is unique because it demonstrates a long term study of a two-storied stand with two species. Previous studies of two-storied stands of Douglas-fir use data from thinned stands with simulated understory trees. Black Rock is an example of an understory of hemlock that has grown under a thinned canopy since 1958.

Methods: ORGANON

The Southwestern Oregon (SWO) version of ORGANON is applicable to stands of even-aged and uneven-aged Douglas-fir, grand fir, white fir, ponderosa pine, incense cedar, and sugar pine. It has the capability to grow stands composed of western hemlock mixed with hardwoods (Hann, 1992b).

SWO ORGANON was the preferred growth model for the Black Rock simulations for its capability to project the growth of hemlock trees in the understory. In many cases, including this one, there is no available growth model to fit the area of analysis perfectly. Black Rock is more suited to the Western Willamette Valley Version (WWV) of ORGANON, but the WWV does not have the capability of projecting hemlock. The results of a projection with a large component of hemlock must be viewed cautiously. Although SW ORGANON accepts hemlock, the projections will be based on a relatively small data set used to build the model, and may not be completely accurate. The projections are extrapolations of stands with lesser site index possibly resulting in a lower volume growth projection for Douglas-fir and hemlocks than the actual stand growth.

Simulations: Input

The growth projections were run starting with Black Rock measurements from 1990 when the overstory was 72 years breast height age. For the calculation of SEV it was important to understand that plot 31 underwent a thinning in 1958 of 241 trees at a QMD of 10.8 inches and a total volume of 24,169 BF based on 32 foot logs and a six inch top (David Marshall personal communication). (See Table 5).

Table 5. Plot 31 harvested timber and standing timber.

Plot 31	**year**	**TPA**	**Basal Area**	**QMD**	**Volume**
Doug.-fir	1958	241	153	10.8	24,169 BF harvested
Doug.-fir	1990	51	225.5	28.47	66,343 BF remaining
hemlock	1990	699	680.5	3.98	448 ft^3

A PNW analysis was done on eight different possible harvest regimes. In general, each simulation was meant to extend the rotation closer to culmination of MAI of cubic foot volume and calculate its associated opportunity cost.

The volume projections were set-up at King's 50 year site index 130, which is outside the range of SW ORGANON. Again, the results must be treated with caution as they are an extrapolation. The volume defaults were set at 16 foot logs, and board foot calculations were based on a 1.0 foot stump height and a minimum log tip diameter of six inches. There were no hardwoods in the stand. It was assumed that the trees grew for six years before reaching breast height, meaning the total stand age in 1990 was 78 and a breast height age of 72. In 1990 the stand is actually about 80 years total age, but for the purposes of this analysis it was assumed that the trees became established in 1912, making them 78 years total age.

From the eight rotations, there is one 78 year rotation that represented the control (*stand 1)*. Stand 1 was harvested in the present time (year 78 of the analysis or 1990). There were two 98 year rotations: stand 5 with a pre-commercial thinning (PCT) of the hemlock at age 78 and stand 6 with an overstory thinning and PCT of the hemlock at age 78. Three regimes had final harvests in year 113 of the analysis: stand 2 had no thinning; stand 3 had a Douglas-fir overstory thinning to two TPA at age 78; and stand 4 had a PCT of understory hemlock, and an overstory thin to eight TPA at age 78. Stand 7 was harvested at culmination in year 133 without any thinning, and stand 8 was overstory thinned in year 78, and 113, and final harvested in year 148. See table 6 for a more descriptive display of the simulations.

Table 6. Management, yields, and financial results from the simulations of Black Rock Plot 31.

	Year	Management [5]	Species	Harvest Vol BF/Acre	NPA $/Acre	SEV $/Acre
	78	Harvest 51 Df TPA	Df	78,490		
Stand 1		and hemlock immediately	hemlock	448 ft^3	53,051	3,317
	113	After 113 yr harvest	Df	138,732		
Stand 2		51 Df and all hemlock	hemlock	5052	28,550	1,995
	78	Thin to 2	Df	77,514		
	113	Df TPA harvest all	Df	3195		
Stand 3		hemlock	hemlock	18,956	51,970	3,076
	78	Remove 43 overstory trees	Df	76,560		
	78	PCT to 270 hemlock TPA	hemlock			
	113	Harvest 8 Df TPA	Df	2,116		
Stand 4	113	Harvest 240 TPA	hemlock	17,388	52,775	3,048
	78	PCT hemlock to 150 TPA	hemlock			
	98	Hvst Df overstory 51 TPA	Df	120,965		
	98	Harvest hemlock 146	hemlock	3,014	44,612	2,754
Stand 5		TPA				
	78	Thin Df to 10 TPA	Df	35,274		
	78	PCT hemlock to 150 TPA	hemlock	63,671		
	98	Harvest Df leave 10 TPA	Df	14,608		
Stand 6	98	Harvest hem to 144 TPA	hemlock	5,271	49,673	2,916
	133	Final Harvest of 43 Df	Df	165,197		
Stand 7	133	and 167 Hemlock	hemlock	9,068	25,200	1,886
	78	Thin 41 Df TPA to 10 Df	Df	70,535		
	113	Thin 8 more Df per acre	Df	17,753		
	113	Thinned 423 hemlock	hemlock	13,264		
	148	Harvest 2 Df and	Df	1,183		
Stand 8	148	hemlock thin to 99 TPA	hemlock	4,342	53,332	3,071

These eight projections simulated growth of a multi-storied stand for extended rotations. Large trees are retained on the site longer with these options than standard practices, which is the idea of the previous studies of green tree retention.

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[5] All of the simulations had a thinning in 1958 (analysis year 46) of 24,169 BF included in the SEV calculations.

Stumpage Valuation

Stumpage prices represent the value of a tree standing in the woods before it has been logged, shipped, and processed. Financial analysis of bare land value or soil expectation value (SEV) is carried out in terms of stumpage. For this analysis stumpage prices were determined by subtracting logging costs and hauling costs from mill prices. The mill prices for Douglas-fir were based on Log Lines (January 1995) a survey of mills in the region. Hemlock prices are based on the Pacific Rim Wood Market Report (September 1994, page 4). The average mill prices by log grade are listed in Table 7 of the appendix. As an example, the QMD of timber for stand four is 29 inches. It was assumed that the average log in this stand is a number 2 saw log worth $754 at the mill. In *stand 4* it cost $100 per MBF to stage log and $25 per MBF to truck it to the mill, for a residual stumpage value of $629.

Logging Costs

Logging costs reflect variable costs that increase as smaller trees are removed. As the average log increases in size, greater volumes can be removed in fewer loads, and subsequent logging costs decrease. The relative costs are based on example files in ORGECON and relative logging prices from Kellogg in (Bartlett, 1993). See Table 8 of the appendix for the logging costs. In this analysis stump to truck costs cover all logging costs including: falling, limbing, bucking, skidding, and loading.

For the Black Rock runs logging of hemlocks at a size of eight to fourteen inches could be done with a feller buncher. The large Douglas-fir overstory would require equipment similar to a grapple skidder and front end loader. Slopes are relatively flat at Black Rock, eliminating the need for cable logging. Commercial thinning the overstory in stands 3, 4, 6, and 8 would require stage logging to protect the understory hemlocks. Stage logging is a method of felling the trees into corridors in successive stages to minimize damage to the understory. In discussions with Douglas Brodie, costs of stage logging were estimated at 50% higher than conventional falling for two stages. In stand 2, it was assumed that stage logging costs would be twice as much as conventional harvesting.

Results and Discussion: Simulation Output

The output from stand 1 represents harvesting Black Rock now. Stand 1 acts as a control to demonstrate the opportunity cost of the extended rotations. The highest SEV ($3,317/acre) and second highest NPA ($53,051) was achieved from stand 1. This outcome was to be expected as the time horizon was too long for the other options to surpass the control with the exception of stand 8. In all the other examples the unit value increase (MBF) or internal rate of return is less than the 4% interest rate used in the analysis, despite tremendous volume growth of the overstory trees.

The next option (stand 2) was to grow the present stand for 35 more years until final harvest of the whole stand. By year 113, five of the overstory trees had died before they were harvested. In stand 2 there was a significant amount of mortality that might have been avoided with commercial thinning. Stand 2 ranked seventh in SEV and seventh in NPA. Most of the value in this stand is reduced by interest over time, and the young hemlocks do not increase in value as fast as the interest rate.

Stand 3 is the second best of the extended rotations. Stand 3 retains 2 overstory Douglas-fir while allowing the understory hemlock to grow for 35 more years under an effectively open canopy. A large amount of volume was removed early, raising the NPA ($51,970) and the SEV ($3,076) to the fourth and second highest, respectively.

Stand 4 represented an attempt to open the overstory as in Stand 3, but in addition, the hemlock were pre-commercially thinned to release them from intraspecific competition (hemlocks to hemlocks). As in stand 3 an early harvest of 47 trees was removed from the overstory to collect an early return. In Stand 4 there are four Douglas-fir TPA left in the overstory canopy and 250 hemlock TPA in the lower canopy.

Stands 5 and 6 are on 98 year rotations, the shortest of the extended rotations. *Stand 6* was the best of the two 98 year rotations ranking fifth in both NPA ($49,673)and SEV ($2,916). In *stand 6* the overstory was thinned to ten TPA for an early return and was pre-commercially thinned to 150 hemlock TPA in the simulation. At the time of harvest in year 98 the hemlocks were nine inches QMD or an inch larger than *stand 5*. *Stand 5* and 6 have the same PCT, therefore, the difference in QMD can be attributed to opening the canopy in the commercial thin. There would have been an even greater response if the overstory was thinned to two TPA rather than ten, and the greater early harvest would have made this one of the most valuable stands.

The rationale behind *stand 7* was to allow the present stand to grow to culmination of cubic foot volume and place a value premium on the larger and better quality logs to evaluate the longer rotation. The extended rotation of 133 years with no other management resulted in the lowest NPA and SEV of all the rotations. The quality premium on larger logs is just not high enough to justify the longer rotation. Each year value is lost compared to the 4% interest rate, even though individual trees gain significant volume.

In *stand 8* the rotation is extended to 148 years with a return in year 78 on 40 TPA. A second thin occurs in year 113 of eight TPA and 423 hemlock. Final harvest occurs in year 148 of two large Douglas-fir and 99 hemlock. Of the extended rotations *stand 8* has the third highest SEV ($3,071) and the highest NPA ($53,332). (See Appendix Tables 13 - 18 for financial data on Black Rock.)

Table 7. The opportunity cost for each option.

	Value	$/Acre	Rank	Difference	% Reduction
Stand 1	NPA	53,051	2	0	0
	SEV	3,317	1	0	0
Stand 2	NPA	28,550	7	24,501	46
	SEV	1,995	7	1,322	40
Stand 3	NPA	51,970	4	1,081	2
	SEV	3,076	2	241	7
Stand 4	NPA	52,775	3	276	0.5
	SEV	3,048	4	269	8
Stand 5	NPA	44,612	6	8,439	16
	SEV	2,754	6	592	18
Stand 6	NPA	49,673	5	3,378	6
	SEV	2,916	5	401	12
Stand 7	NPA	25,200	8	27,851	52
	SEV	1,886	8	1,431	43
Stand 8	NPA	53,332	1	+281[6]	+0.5
	SEV	3,071	3	246	7

From an economic perspective, the best management for Black Rock plot 31 is to harvest the entire stand of trees and to replant with Douglas-fir. As in the first alternative this would yield around $53,052 NPA per acre. Each stand has an opportunity cost compared to the best economic alternative. The cost is associated with the opportunity to retain trees in the overstory or understory for aesthetics and habitat. The opportunity costs listed in table 7 above are the cost for the aesthetic value of the other options compared to the first one. In choosing *stand 4*, as an example, the manager is valuing all other benefits realized in *stand 4* at or above $276/acre in the present. This paper does not evaluate individual benefits to wildlife, hunting or aesthetics. Rather, the <u>opportunity</u>

[6]Stand 8 had a higher NPA than stand 1 due to an early heavy thinning and high quality premiums on later harvests.

costs represent the value of all benefits except timber associated with choosing that alternative, while the NPA represents the value of timber.

If it is desirable to retain trees on plot 31 or a similar but larger stand, the preferred alternative would be stand 4 or stand 8, if NPA is the deciding criterion. If it is desirable to retain some of the large Douglas-fir, the preferred alternative would resemble stand 3, 4, or 8, where a heavy thinning from two to ten TPA in the present would capture a large early return. This would be accompanied by a reduction of the hemlock to about 150 TPA by logging and a PCT. The time before the next harvest should be minimized unless the hemlock grow vigorously, at a value rate greater than 4%.

The fact that Black Rock has an understory of hemlock is unique from a species diversity stand point, but does not appear to be as productive in financial returns compared to a even-aged or a two storied stand of Douglas-fir. Based on previous studies of green tree retention and two storied stands, leaving two TPA reduces SEV by about 2% and leaving ten TPA reduces SEV by about 10% (see Literature Review). It appears that hemlock are inferior to Douglas-fir in two story stands due to low growth response from thinning the overstory and to its lower value compared to Douglas-fir. This may be due in part to limitations of the growth model.

Weeding Study

The fact that site preparatory burning is becoming harder to administer has increased interest in weeding on forest lands as a method of controlling brush competition. There are also concerns that burning increases competitors such as red alder and salmonberry (Steve Knowe, personal communication). Herbicide spraying or hand weeding controls brushy competitors in plantations but does not prepare the planting bed by removing slash as in a prescribed burn. Mechanical site preparation on accessible sites or broadcast burning on steep sites (slope > 35%) in conjunction with hand weeding or spraying is an effective combination of site preparation in the coast range.

Studies show that weeding out herbaceous and woody competitors in the first few years of a plantation increases survival and productivity (Newton and Preest, 1988 in Gourley, et. al. 1990). Whether applying herbicides by backpack sprayer, helicopter, or by hand weeding, preventing over-topping by brush is important to give seedlings the best chance of survival and growth while in their first few years.

Weeding by hand is significantly more expensive than spraying, but may be the only operational means of brush control on Federal lands where herbicides are excluded. Spraying herbicides costs about $60 per acre and hand grubbing costs about $400 per acre (Discussions with Mark Gourley). Scarification by bulldozer with a raked blade costs about $143 per acre depending on terrain, size of slash, and obstructions such as stumps and snags (Powell, 1993).

This analysis will show the difference in yield associated with weeding in the first two years of four sites in the Oregon Coast Range. The difference in soil expectation value and net present amount on sprayed sites versus non-sprayed sites represents the break-even point of the total regeneration costs including spraying for the chosen regime.

In this thesis I use data from a study of animal damage protection that found a greater growth response on weeded sites compared to non-weeded sites. The study by Gourley et. al. (1990) found a positive growth response associated with weeding herbs, grasses, and shrubs in the first two years of a plantation. In the fifth year of growth, seedlings on weeded sites had greater diameter growth and total volume than seedlings on non-weeded sites. By the twelfth year, or 15 years total age, seedlings on the weeded area were significantly taller than seedlings on the non-weeded area (Mary O'Dea, 12th year progress report unpublished data). The greatest absolute and relative weeding effect was found on the lowest site index areas.

Site Description

Four sites of varying site index in the coast range were chosen for this study. The lowest site (112 feet) is just west of Corvallis. This droughty site on the fringe of the Willamette Valley is characterized by Douglas-fir (Pseudotsuga menziesii), bigleaf maple (Acer macrophyllum), Oregon white oak (Quercus garryana), poison oak (Rhus diversiloba) (T and G.), Thistle (Circinatum spp.), and common groundsel (Scenesio vulgaris L.) The other sites of 121, 128, and 138 feet, are located in the coast range characterized by Douglas-fir, bitter cherry (Prunus emarginata), elderberry (Sambucus spp)., and an understory of salmonberry (*Rubus spectabilis*), and grasses. Precipitation ranges from 43 to 93 inches annually at the sites (Gourley, 1990).

Methods

Results from the 12 year data from the animal damage study (*Forest weeding helps to Reduce the effect of deer-browsing on Douglas-fir*, Gourley et. al., 1990) were compiled on a per acre basis for input to the Douglas-Fir Simulator DFSIM and Stand Projection System (SPS) (Arney, 1985) growth models. A stand level-analysis was done to compare weeded versus non-weeded areas on four sites of varying site index (Kings 50 year site index 112, 121, 128, 138). The animal damage treatments were not compared as the greatest response in growth was found on weeded sites.

Each site was planted with 2-1 bare root seedlings in January of 1981 to a spacing of 3.3 meters by 3.3 meters (10.824 feet) or 371.8 TPA. The experiment was set-up in a randomized complete-block split-plot design. In other words weeding treatments were applied to plots and animal damage treatments were applied to rows within each plot. Only the weeding interaction was studied in this analysis.

The original data set contained 120 treated seedlings on each of eight Plots[7]. My data set did not include the seedlings treated with deer repellent causing defoliation. For this thesis I analyzed 120 seedlings on eight areas.

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[7]There are four sites with a weeded and non-weeded plot at each site.

Growth Models

I used the Douglas-Fir Simulator (DFSIM)[8] and Stand Projection System (SPS) (Arney, 1985) growth and Yield Models for this section of my thesis. SPS is a single-tree, distance-independent growth and yield model with the capability of generating a height and diameter distribution as if it were a whole-stand model. I used SPS as a whole stand model for this analysis. SPS is based on the same data set as DFSIM where 25% of the data deriving the model were from Oregon. SPS has two "levels" of stand parameters for data entry. The user can enter average values for stand parameters (level 1) or enter individual trees or diameter classes (level 2). Under level 1 the stand parameters are species, DBH, top height, TPA, breast height age, standard deviation, and stand origin. The user's manual does not give a thorough explanation of the input variables, but it is important to understand the exact definition of these parameters to insure the best possible volume forecast. DBH represents arithmetic mean diameter at breast height, not QMD. SPS calculates the QMD by an algorithm. Top height is the average height of the 40 largest basal area trees in the stand, not the 40 tallest. The standard deviation refers to mean diameter expressed as a percentage (SD / AVG. DBH * 100). Under "Thinning" the thinning method is by cut to residual (C/R), a slightly different ratio than the diameter cut to diameter before (d/D) ratio.

The average stand parameters are calculated by SPS to create a stand distribution of trees by diameter class that approximates the actual stand. This process utilizes a

[8]See a description of DFSIM under DFSIM Projections in the **Prescribed Burning** chapter.

Weibull function to generate a continuous distribution used in SPS. Figure 1 of the Appendix shows the Weibull stand diameter distribution plotted against the actual stand distribution. When the actual stand is divided into the same number of diameter classes the Weibull curve approximates the actual stand distribution. This process saves computation time with minimal sacrifice in accuracy.

Calculating Stand Parameters

DFSIM is a whole-stand model that requires averages of diameter (QMD) or basal area per acre as input. Since each area covers about a third of an acre it was necessary to expand the area to calculate the average diameter and basal area. Each area was expanded to a per acre basis by a factor of 3.0983 found by taking $(\frac{371.8\ T/A}{120T})$. To find the total basal per acre the factor was multiplied by the total basal area of the trees $(6.1 FT^2 * 3.0983 / A = 49.89 FT^2 / A)$. Seedlings in all locations experienced mortality. The trees per acre after mortality are a factor of the spacing and missing trees:

$$371.8\ T/A * \left(\frac{120\ T - 15\, dead\ T}{120\ T}\right) = 325.3\ T/A$$

The quadratic mean diameter (QMD), or diameter of the tree of mean basal area, was determined by the following equation:

$$QMD = \sqrt{\frac{BA/A}{TPA * (0.005454154)}}$$

For the above equations,

A = Acre.

BA = Basal Area.

T/A or TPA = Trees per acre.

T = Trees.

The determination of quadratic mean diameter and trees per acre is actually an extrapolation, as seen in the previous calculations, since the site tree data are over an area less than an acre. Table 8 shows the individual area statistics for each site. One following denotes weeded and the zero following denotes non-weeded. Top height$_{40}$ stands for the height of the 40 largest basal area trees.

Table 8. Area Statistics.

Site	Total Trees	TPA	Mortality %	QMD	True Diameter	St. Dev of True Dia. %	BA/A	Top HT_{40}
112-1	105	325	22.5	5.3	5.49	11	49.9	30
112-0	65	204	46	3.8	2.30	33	16.3	13
121-1	111	344	7.5	5.74	5.58	19	61.8	33
121-0	96	297	20	4.92	4.76	32	39.3	34
128-1	118	344	1.7	6.56	6.10	16	80.7	34
128-0	111	366	7.5	4.67	4.77	27	43.4	29
138-1	115	356	4.2	7.06	6.96	17	96.8	36
138-0	116	359	3.3	6.66	6.55	18	86.8	36

Simulations

Once the QMD, TPA, and BA/A were found, the simulations were performed. A regime with a 70 year rotation was used with a commercial thin at year 40 specified as a d/D ratio[9] of (.9) and a residual of 150 and 100 TPA. DFSIM uses the Scribner log rule with 16 foot logs to a 6 inch top.

At each site seedlings were grown on weed-free or non-weeded areas. The quadratic mean diameter (QMD), trees per acre (TPA), and basal area (BA), were variable on each weeded or non-weeded area of each site dependent on site productivity and other factors. There were a total of eight different plots on four sites. In addition, each site was evaluated at two thinning regimes that left 100 or 150 TPA. At one site a variety of thinnings was performed to determine if yield would increase or decrease with different thinning regimes. Site 128 and 138 had less than 150 trees at 40 years and did not support a thinning until a thinning of 100 TPA was specified. The yields dropped off with the heavier thinning.

Stumpage Valuation

The output from SPS and DFSIM was entered in a spreadsheet for the financial analysis. The 40 year thinning was evaluated for average diameter and Scribner volume to a six inch top and 16 foot logs. The average diameter for the stand was evaluated

[9]Recall that the d/D ratio stands for diameter thinned to diameter before thinning.

according to the log prices used in the green tree retention section, with a slight variation, minus costs and multiplied by the total volume.

There are two complications with the way I assigned log prices to the average diameter tree in section two of this thesis, even though the results will not be significantly affected. First, the log prices are based on tip diameter while the yield table output is listed in QMD or average diameter. A 16 foot log may have four inches difference between the tip diameter and diameter at the base of the log. A tree with an average diameter of 20 inches has five to seven 16 foot logs of varying diameter and grade. The taper differs depending on where on the tree the log is located. For example, the bottom log has a swollen base and much taper while the middle logs have variable taper. Programs like ORGECON account for these problems by breaking down the stand into stand tables to calculate stand values for the total of each individual log in the stand. The way I dealt with the two problems described above for the weeding study was to take a 20 inch average DBH tree and determine the tip diameters of each log of the tree by Girard form class theory (Bell and Dillworth, 1990). There are six merchantable 16 foot logs in a 20 inch tree. The tip diameters are (14, 13.3, 11.8, 9.7, 7.18, and 4.52) inches. The seventh log at the tip is culled. The six logs include three #2 saw logs, two #3 saw logs and one chip and saw log for an average price of $683/MBF of 20 inch trees (not $683 for the single tree) or approximately $679 which is the price of a #3 saw log. The price schedule was adjusted from a minimum tip diameter of 6 inches and a price of $679 to a DBH of 20 inches and a price of $679. See figure 2 of the Appendix.

The second problem was to change the price schedule from increments of diameter, reflecting quality premiums for larger logs, to a constant price increase. For example, all logs from 8 to 12 inches DBH were being assigned a price of $479 under "Green Tree Retention," logs from 12.1 to 24 inches DBH were being assigned a cost of $679, and logs from 24.1 to 32 inches were being assigned a price of $754. I converted the price schedule to a constant price increase from an 8 inch tree at $479 to a 20 inch tree at $679. (See Figure 2 of the Appendix).

Therefore, the adjusted price of a log is as follows:

Pond Value = 18.18*(True DBH - 8) + 479. See the "Adjusted Price for Average DBH" in Table 9.

Table 9. Log Prices.

Log Grade	Minimum Tip Diameter	Mill Price $/MBF	Adjusted Price[10] for Aver. DBH $/MBF
Chip and Saw	4	479	297 Chip and Saw
#3 Saw	6	679	442 Chip and Saw
#2 Saw	12	754	552 Chip and Saw
Special Mill	18	856	661 #3 Saw
#3 Peeler	24	1,358	770 #2 Saw
#2 Peeler	30	1,717	879 Special Mill

The stumpage value was then the net value once logging and hauling costs were subtracted. A logging cost of $100/MBF was used for all 40 year thins and $75/MBF was used for all final harvests at year 70. Hauling costs were assessed at $50/MBF for the

[10]The adjusted price follows: Price = 18.18(DBH-8) + 479 to adjust tip diameter to DBH.

weeding study. There were no per acre costs assessed for regeneration or first road building costs.

Per acre regeneration costs may be subtracted from the total present net worth if they are to be included. Weeding costs are a portion of the per acre regeneration costs. The PNW in this analysis is a value that represents the most that could be spent on first year costs including spraying to establish the stand at 4% interest and the given regime. The value represents a spending limit or break-even point. This is termed "backing out" the maximum feasible spraying costs rather than assessing the spraying costs directly in the analysis.

Results and Discussion

The Douglas-fir Simulator (DFSIM) and Stand Projection System (SPS) made consistent yield projections in this analysis. I made 16 projections with each model for a total of 32 stand simulations of the eight areas. There were two thinning regimes to 100 and 150 TPA and two growth models. The two models differed by (0 - 7%) for thinning to 100 TPA and (2-14%) for thinning to 150 TPA with the exception of stand 112-0, which differed by 51% and 45% respectively. The difference in stand 112-0 is most likely due to the fact that the DFSIM projection was based on a stand quadratic mean diameter of 3.8 inches. The SPS model bases its projections on average diameter, in this case stand 112-0 was 2.3 inches. The difference is only 1.7 inches, but this is 43 % of the QMD of the small diameter trees. A difference of 1.7 in larger diameter trees will not have as much of an impact in the growth projection as it did with this run.

Site productivity (by Kings 50 year site index) is the biggest factor associated with differences in yield between sites at year twelve (O'Dea[11]). However, the site preparation differences between sites were not controlled. Two sites were broadcast burned; one was piled and burned, and one was left unprepared. These factors may have an influence between sites, but not when comparing areas of weeding to non-weeding on the same site. At site 112 the trees in the weeded area are larger than in the non-weeded area. At site 121 the weeded area again has larger trees. In addition the trees are larger on site 121 than on site 112 regardless of weeding, due to site productivity and other factors such as site preparation.

Thinning Results

Thinning to 100 TPA produces higher yields than thinning to 150 TPA on all weeded sites with the exception of SPS-128. The two thinning regimes produce similar yields at the high site (138) for both models. Table 10 displays total yield by thinning regime and weeding treatment for both growth models. Numbers in bold are the higher yield for each thinning regime. A noticeable pattern is that Thin-100 stands have higher yields on weeded sites (1) and Thin-150 stands have higher yields on non-weeded sites (0). In table 10 the "Difference" is between weeding and no weeding (Also see Appendix Table 23).

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[11]O'Dea, M. Animal Damage Protection and Weeding Effects on Douglas-fir; Progress Report for Year twelve. Unpublished data. Oregon State University, Corvallis.

Table 10. Total Yields in Scribner to a six inch top and 16 foot logs.

Stand	DFSIM-100	DFSIM-150	SPS-100	SPS-150
112-1	**103,845**	65,365	**110,380**	97,660
112-0	76,951	**81,295**	37,330	**44,980**
Difference	26,894	14,070	73,050	52,680
	26%	15%	66%	54%
121-1	**114,793**	106,828	106,240	**121,670**
121-0	98,414	**101,486**	98,640	**115,360**
Difference	16,379	5,342	7,600	6,310
	14%	5%	7%	5%
128-1	**128,462**	114,957	120,450	**129,930**
128-0	97,207	**103,583**	98,050	**113,920**
Difference	31,255	11,374	22,400	16,010
	24%	10%	19%	12%
138-1	**143,266**	127,261	141,640	**142,120**
138-0	**140,894**	128,218	**141,890**	139,310
Difference	2,372	-957	-250	2,810
	2%	-1%	< -1%	2%

Weeding site 112 raised the yield 26% with DFSIM and 66% with SPS when thinning to 100 TPA. The low site showed considerably more improvement in yield than the high site from weeding. Weeding site 138 changed the yields by -1 to 2%. This may suggest that competition from brush species is affecting seedlings on the low site more substantially than the high site. Since the higher site is more productive it may support brush and trees with less competition between them. Conversely, the low site may induce more competition since resources are limited.

The soil expectation value and net present amount calculated from timber yields predicted by both models suggest that thinning to 100 TPA was superior to thinning to 150 TPA. The range of SEV and NPA differences between the two thinning regimes was between (0- 20%) for the Douglas-fir Simulator (DFSIM) and (-6 to 20%) for the Stand Projection System (SPS). The two exceptions were non-weeded areas (112-0 and 121-0)[12] but the percentage difference (0-2%) was such that the stands could be thinned to either 100 TPA or 150 TPA. Table 11 shows the difference between the two thinning densities for SEV and NPA in both growth models. In six out of eight cases the thinning to 100 TPA outperformed the thinning to 150 TPA (Appendix Tables19 - 22 list financial values by growth model and thinning regime).

Table 11. Difference between thinning to 100 TPA and thinning to 150 TPA.

Stand	**112-1**	**112-0**	**121-1**	**121-0**	**128-1**	**128-0**	**138-1**	**138-0**
Thin Diff. SEV (DFSIM)	$1182 18%	$332 8%	$1,253 17%	$521 9%	$1456 16%	$290 5%	$1987 20%	$1,824 20%
Thin Diff. NPA (DFSIM)	$1,892 18%	$531 8%	$2,006 17%	$835 9%	$2,332 16%	$464 5%	$3,181 20%	$2,919 20%
Thin Diff. SEV (SPS)	$1,444 20%	-$110 -6%	$168 2%	-$119 -2%	$612 8%	$55 1%	$2,017 19%	$1,596 16%
Thin Diff. NPA (SPS)	$2,311 20%	-$176 -6%	$269 2%	-$190 -2%	$980 8%	$88 1%	$3,230 19%	$2,555 16%

The heavier thinning at age 40 to 100 TPA provides a greater harvest and is more likely to pay for the logging costs, but the remaining growing stock will be lower. Profitability is higher. The present net worth assessed in 1994 for the thinning to 100 TPA is about double the thinning to 150 TPA. For example, the PNW at age 15 of stand (SPS-121-1-100) is $4,782 and (SPS-121-1-150) is $2,904. Stand 121-1 was weeded and

[12]Sites are represented by site idex (112) iether weeded (1) or non-weeded (0).

had nearly the same SEV for both thinnings. Stand 138-1 had a greater SEV ($10,798 versus $8,781) when thinned to 100 TPA. Again, the first thinning was twice as profitable when thinned to 100 TPA with SPS ($6,988 versus $3,053). See table 12 for a demonstration of the greater profitability of the first thinning to 100 TPA.

Table 12. PNW at age 15 (1994) of the commercial thinning.

SPS Stand	112-1	112-0	121-1	121-0	128-1	128-0	138-1	138-0
Thin 100	$4,153	$580	$4,782	$4,244	$4,987	$4,527	$6,988	$5,262
Thin 150	$2,385	$271	$2,904	$2,874	$2,743	$2,920	$3,053	$2,159

The DFSIM projections for stands 128-1 and 138-1 did not have 150 TPA at the time of the thinning. These two DFSIM runs did not have a thin at age 40 for the specified thinning to 150 TPA.

Weeding Results

All weeded stands were superior to non-weeded stands in total timber yield and in value. Both DFSIM and SPS predicted a smaller weeding effect for site 138 of 5-10% more value. The most pronounced weeding difference was at the low site. The weeded area at site 112 produced 36% more value (Thin-100) and 29% more value (Thin-150) according to DFSIM, and 75% more value (Thin-100) and 67% more value (Thin-150) for SPS. Total value increases ranged from 5 - 35% for the two medium sites. See table 12 for results (Appendix Table 24 summarizes NPA and SEV for all projections).

Table 12. Comparison of weeding versus no weeding.

	Stand Thinning	112 100	112 150	121 100	121 150	128 100	128 150	138 100	138 150
DFSIM	SEV diff.	$2,452	$1,602	$1,385	$654	$3,085	$1,892	$585	$422
	% diff.	36%	29%	19%	11%	35%	26%	6%	5%
	SEV diff.	$3,926	$2,565	$2,218	$1,047	$4,897	$3,029	$937	$675
	% diff.	36%	29%	19%	11%	35%	26%	6%	5%
SPS	SEV diff.	$5,342	$3,789	$663	$376	$1,608	$1,051	$1,110	$689
	% diff.	75%	67%	9%	5%	20%	14%	10%	8%
	SEV diff.	$8553	$6,066	$1,062	$602	$2,575	$1,682	$1,778	$1,103
	% diff.	75%	67%	9%	5%	20%	14%	10%	8%

These findings suggest that investing in weeding of low sites might be more productive than the same investment in high sites. Weeding was productive at sites 121 and 128 indicating that weeding is effective on higher sites also. The value differences found here (See figures 1 and 2) should raise interest for further study of financial benefits of weeding. This thesis did not study whether 100% weeding in the first two years is cost-effective, or whether spraying for hardwoods in later years is productive on higher sites. Additional research might address those topics.

Figure 1. The value in net present amount for DFSIM projections.

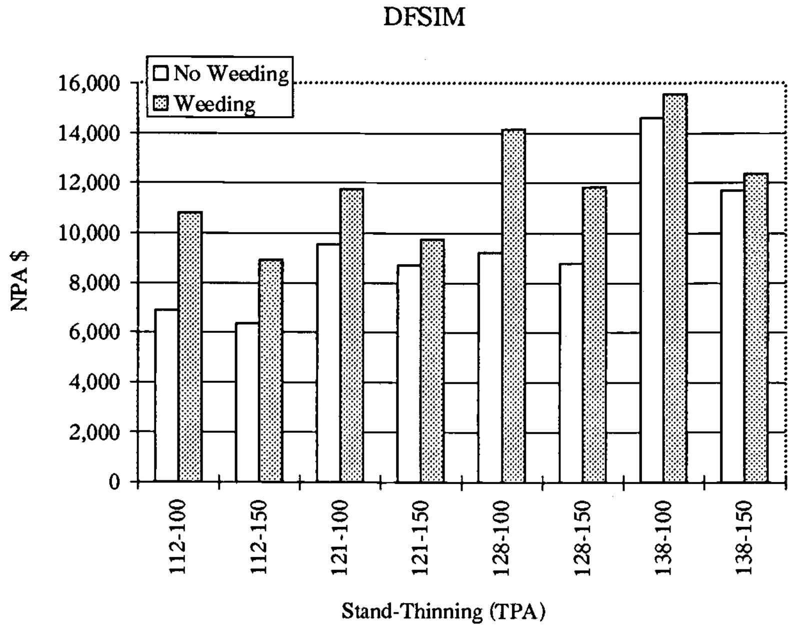
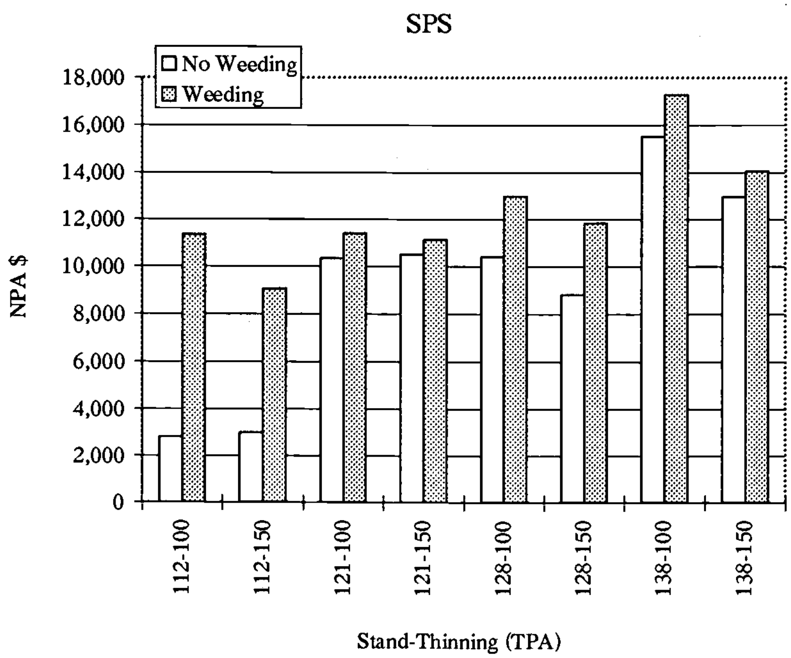


Figure 2. The value in net present amount for SPS projections.



Growth and Yield Models

This thesis relied on projections by four different growth and yield models DFSIM, WWV ORGANON, SW ORGANON, and SPS to predict timber yields under various scenarios. The model projections are at best good approximations of the yields that will actually grow from the forests standing now. Yield predictions are net of competition-induced mortality but gross volumes before cull. There were no stipulations made for defects of disease or breakage. The predictions are only as good as the program and the programmer, and are not a substitute for experience. Growth models are another tool to complement experienced foresters, or in my case a tool for learning.

The yields predicted by growth models may only be good approximations but the projections are helpful for comparing different alternatives. Birch and Johnson (1992) made projections with a growth and yield model to find the opportunity costs associated with retaining trees on-site after harvest. The important findings were not the actual timber yields but the percentage of the total timber yields of various amounts of leave trees that were left in the woods. They came up with an operational rule of thumb that each large leave tree reduced the total yield by about 1%. That is the power of the growth and yield model. It might have taken a forester an entire career to notice the relationship that was seen with the growth and yield model.

A model is only as good as the modeler who designed it and the judgment of the practitioner who uses it. Models are simplified versions of a forest but models are still intricate. There are many opportunities to make mistakes in the model and by the nature of the model the errors tend to compound themselves. No doubt this thesis has errors in it. The projections are relatively correct because most of the mistakes are repeated across all the alternatives and they are stated in the assumptions for setting up the model.

Since it is easy to make mistakes when setting-up a projection it is important to understand the model well. It is important to understand how the model was designed, exactly how the input parameters are defined, and what the output means. The models are designed for a specific forest type in a specific region. They are designed for specific management such as commercial thinning and fertilization. SPS, for example, is based on a data set compiled by several government agencies in 1974 in Oregon, Washington, and British Columbia. Using SPS on an even-age stand of Douglas-fir growing in California may over-predict the productivity. One problem with the current models is trying to predict the growth of stands that are under 15 years total age. Young plantations are harder to predict accurately due to competition between trees and brush. The models in this thesis are limited to a minimum of 15 years.

One of the difficulties in working the growth models is to convert a set of data to the format that the model requires. This is why it is important to understand the exact parameters specified by the model. ORGANON is able to process data straight from a cruise. Whole-stand models require data processing before the model can run. The Black Rock data and Norton Hill Data were easy to convert to a format that ORGANON would understand. For the weeding study the data set was not ready for the models and required the data conversion described in Calculating Stand Parameters for SPS and DFSIM. Spreadsheets and databases are essential for manipulating large amounts of data. The weeding study had eight stands of 120 trees. With the spreadsheet, I was able to calculate the standard deviation without much trouble. The spreadsheet was particularly helpful for finding the 40 largest basal area trees (Top Height). This was accomplished by sorting the diameter in descending order and selecting the first 40 tree heights.

Unfortunately, the user's manuals of the growth models do not explain all the intricate variables of input and output. The forester who knows the definition of Scribner volume to a six inch top may not know that DFSIM output is in 16 foot logs. The definition of top height and average diameter are not defined in the SPS user's manual. SPS uses average diameter and DFSIM and ORGANON use quadratic mean diameter, but forest scientists use diameter at 15 cm height and mills pay by tip diameter. As a result growth modelers may use clever tricks to convert data to a form that the model manipulates, such as form class theory to convert tip diameter to DBH.

I have found that it is easy to use the wrong model in the wrong situation. There are not many good models available and when the model does not match the data set perfectly the tendency is to use it anyway. I tried to use WWV ORGANON for the Black Rock forest data set and ran into a problem. The hemlock understory was a species that WWV ORGANON was not capable of projecting. Hemlock is a common species in the coast range but not on the McDonald and Dunn Forest where the data set was derived. There were two ways to solve this dilemma and both would introduce error into the projection. First, I could have projected the hemlock understory as grand fir under the species code. I would have to assume that hemlock grows exactly the same as grand fir. Second, I could use the Southwest version of ORGANON which has the capability to grow hemlock as long as there is Douglas-fir on the site. Black Rock is significantly north of the area intended to run the Southwest version. None of the stands used to create SW ORGANON have a site index as high as Black Rock therefore the projections are an extrapolation of the data set the model was derived from.

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Appendix

Appendix

Table 1. DFSIM Projections.

DFSIM Stand	Total Age	DBH 1301	DBH 1305	TPA 1301	TPA 1305	BA 1301	BA 1305
Growing Stock	38	17.8	18.2	68	66	119	120
Commerc. Thin	38	13.2	13.7	159	150	152	154
Final Harvest	68	27.4	29.1	66	61	270	275

Table 2. ORGANON Projections.

ORGANON Stand	Total Age	DBH 1301	DBH 1305	TPA 1301	TPA 1305	BA 1301	BA 1305
Growing Stock	38	16.5	17.7	81	70	120	120
Commerc. Thin	38	12.3	13.6	282	156	130	115
Final Harvest	68	24.6	26.1	74	66	247	245

Table 3. DFSIM Volume Projections.

DFSIM Stand	Total Age	Volumes BF 1301	Volume BF 1305	Difference	Diff. %
Growing Stock	38	21,024	20,805	219	4.1
Commerc. Thin	38	26,090	27,171	1,081	1
Final Harvest	68	87,998	89,011	2,013	1.8
Total Removal		114,088	116,182	2,094	

Table 4. ORGANON Volume Projections.

ORGANON Stand	Total Age	Volumes BF 1301	Volume BF 1305	Difference	Diff. %
Growing Stock	38	19,268	20,774	1,506	4.4
Commerc. Thin	38	17,003	16,266	-737	<1
Final Harvest	68	80,883	81,531	648	<1
Total Removal		97,886	97,797	-89	

Table 5. DFSIM with Economics Financial Returns:

DFSIM	Stand 1301	Stand 1305	Difference	Diff. %
PNW year 0	$10,426	$10,809	$383	3.6
PNW year 18[1]	$16,692	$17,305	$613	3.6
SEV year 0	$10,035	$10,460	$426	4.2

Table 6. ORGANON Volume Projections and Financial Returns.

ORGANON	Stand 1301	Stand 1305	Difference	Diff. %
PNW year 0	$10,289	$10,625	$336	3.2
PNW year 18	$16,473	$17,011	$538	3.2
SEV year 0	$9,897	$10,276	$378	3.7

[1] PNW includes first rotation only

Table 7. Log Prices for Black Rock from mill values[2].

Log Grade Douglas-fir	Average Value $/MBF
#3 Peeler	$1,358
Special Mill	$856
#2 Sawmill	$754
#3 Sawmill	$679
Hemlock	
#3 Sawmill	$475
#4 Sawmill	$400

[2] Prices from Log Lines, (1995).

Table 8. Costs for each alternative.

	Age	Variety	Harvest Volume Bd Ft /Acre	Stump to Truck Costs $/MBF	Total Stump to Truck Costs $/Acre	Total Hauling Cost Fixed at $25/MBF Total in $/Acre	Regen Costs $/Acre
	46	Df	24,169	55 Thin	1,329	604	400
	78	Df	78,490	50 HVST	3,925	1,962	400
Stand 1	78	Hm	0				
	46	Df	24,169	55 Thin	1,329	604	400
	113	Df	138,732	45 HVST	6,243	3,468	400
Stand 2	113	Hm	5,052	65 HVST	328	126	
	46	Df	24,169	55 Thin	1,329	604	400
	78	Df	77,514	100 Stage	7,751	1,938	
	113	Df	3,195	50	160	80	400
Stand 3	113	Hm	18,956	65	1,232	474	
	46	Df	24,169	55 Thin	1,329	604	400
	78	DF	76,560	100 Stage	7,656	1,914	
	78	Hm	0	40/A. PCT	40		
	113	Df	2,116	50 HVST	106	53	
Stand 4	113	Hm	17,388	65 HVST	1,130	435	400
	46	Df	24,169	55 Thin	1,329	604	400
	78	Hm	0	50/A. PCT	50		
	98	Df	120,965	50 HVST	6,048	3,024	400
Stand 5	98	Hm	3,014	65 HVST	196	75	
	46	Df	24,169	55 Thin	1,329	604	400
	78	Df	63,671	75 Stage	4,775	1,592	
	78	Hm	0	40/A. PCT	40		
	98	Df	14,608	50 HVST	730	564	400
Stand 6	98	Hm	5,271	65 HVST	343	132	
	46	Df	24,169	55 Thin	1,329	604	400
	133	Df	165,197	45 HVST	7,434	4,130	400
Stand 7	133	Hm	9,068	65 HVST	589	227	
	46	Df	24,169	55 Thin	1,329	604	400
	78	Df	70,535	85 Stage	5,995	1,763	
	113	Df	17,753	65 Stage	1,175	444	
	113	Hm	13,264	65 Thin	862	332	
	148	Df	7,849	45 HVST	353	196	400
Stand 8	148	Hm	21,165	55 HVST	1,164	5,461	

Table 9. Volume Yield Table for each alternative.

	Age	Variety	Harvest Volume BF /Acre	Total Volume Harvested Bd Ft /Acre	SEV $/Acre Future Rotations	NPA $/Acre	Stand Rank
	46	Df	24,169				NPA 2
	78	Df2	78,490				
Stand 1	78	Hm	0	102,862	$3,317	$53,051	SEV 1
	46	Df	24,169				NPA 7
	113	Df	138,732				
Stand 2	113	Hm	5,052	168,227	$1,995	$28,550	SEV 7
	46	Df	24,169				
	78	Df	77,514				NPA 4
	113	Df	3,195				
Stand 3	113	Hm	18,956	124,187	$3,076	$51,970	SEV 2
	46	Df	24,169				
	78	DF	76,560				NPA 3
	78	Hm	0				
	113	Df	2,116				
Stand 4	113	Hm	17,388	120,665	$3,048	$52,775	SEV 4
	46	Df	24,169				
	78	Hm	0				NPA 6
	98	Df	120,965				
Stand 5	98	Hm	3,014	148,473	$2,754	$44,612	SEV 6
	46	Df	24,169				
	78	Df	63,671				NPA 5
	78	Hm	0				
	98	Df	14,608				
Stand 6	98	Hm	5,271	108,123	$2,916	$49,673	SEV 5
	46	Df	24,169				NPA 8
	133	Df	165,197				
Stand 7	133	Hm	9,068	198,753	$1,886	$25,200	SEV 8
	46	Df	24,169				
	78	Df	70,535				
	113	Df	17,753				NPA 1
	113	Hm	13,264				
	148	Df	7,849				
Stand 8	148	Hm	21,165	155,389	$3,071	$53,532	SEV 3

Table 10. Black Rock stumpage valuation

Stand 1	QMD	Average Log Grade	Log Price $/MBF	Harvest or Thin COST $/MBF Stump to Truck	Hauling Cost $/MBF	Stumpage
	10.80	#3 Saw	$679	$55	$25	$599
	28.47	#2 Saw	$754	$50	$25	$679
Stand 2	10.80	#3 Saw	$679	$55	$25	$599
	33.48	Special Mill	$856	$45	$25	$786
	7.69	#4 Saw	$400	$10		$390
	7.69	#4 Saw	$400	$65	$25	$310
Stand 3	10.80	#3 Saw	$679	$55	$25	$599
	28.79	#2 Saw	$754	$100	$25	$629
	2.00		$0	$0	$40/Acre	($40)
	26.90	#2 Saw	$754	$50	$25	$679
	8.78	#4 Saw	$400	$65	$25	$310
						$0
Stand 4	10.80	#3 Saw	$679	$55	$25	$599
	29.68	#2 Saw	$754	$100	$25	$629
	2.00		$0	$0	$40/Acre	($40)
	21.19	#2 Saw	$754	$50	$25	$679
	11.35	#3 Saw	$475	$65	$25	$385
Stand 5	10.80	#3 Saw	$679	$55	$25	$599
	2.00		$0	$0	$40/Acre	($40)
	31.56	Special Mill	$856	$50	$25	$781
	7.78	#4 Saw	$400	$65	$25	$310
Stand 6	10.80	#3 Saw	$679	$55	$25	$599
	29.90	#2 Saw	$754	$75	$25	$654
	2.00		$0	$0	$40/Acre	($40)
	26.82	#2 Saw	$754	$50	$25	$679
	9.02	#4 Saw	$400	$65	$25	$310
Stand 7	10.80	#3 Saw	$679	$55	$25	$599
	35.68	#3 Peeler	$1,358	$45	$25	$1,288
	9.90	#4 Saw	$400	$65	$25	$310
Stand 8	10.80	#3 Saw	$679	$55	$25	$599
	29.87	#2 Saw	$754	$75	$25	$654
	29.23	#2 Saw	$754	$100	$25	$629
	8.48	#4 Saw	$400	$65	$25	$310
	35.82	#3 Peeler	$1,358	$45	$25	$1,288
	2.00	#3 Saw	$475	$55	$258	$162

Table 11. DFSIM growth projections.

	Total Age	DBH 1301	BH 130	TPA 1301	PA 130	BA 1301	BA 1305	Vol. 1301	Vol 1305	Vol. Differ.
Grow Stock	38	17.8	18.2	68	66	119	120	21,024	20,805	
Thinning	38	13.2	13.7	159	150	152	154	26,090	27,171	1,081
Harvest	68	27.4	29.07	61	66	270	275	87,998	89,011	1,013
							Totals	114,088	116,182	2,094
				Regen	1301	1305		1301	1305	
				Costs	$454	$414		PNW 18	PNW 18	Difference
								$16,692	$17,305	$613
				Factors				1301	1305	
				Discount	Growth	Rotation	Last cut	SEV1301	SEV 1305	
				0.04	12	62	64	$9,219	$9,610	$391
								PNW yr 0	PNW yr 0	
								$10,426	$10,809	$383

Table 12. ORGANON growth projections.

	Total Age	DBH 1301	DBH 1305	TPA 1301	TPA 1305	BA 1301	BA 1305	Vol 1301	Vol 1305	Difference
Grow Stock	38	16.5	17.7	81	70	120	120	19,268	20,774	
Thinning	38	9.2	11.6	282	156	130	115	17,003	16,266	-737
Harvest	68	24.6	26.1	247	245	74	66	80,883	81,531	648
							Totals =>	97,886	97,797	-89

		Regen	1301	1305				1301	1305	
		Costs	$454	$414				PNW 18	PNW 18	Difference
								$16,473	$17,011	$538
Factors										
Discount	Growth	Rotation	Last cut		TPA	BA	QMD	SEV1301	SEV 1305	
0.04	12	62	64	1301	222	130	10.36	$9,897	$10,276	$378
				1305	165	116	11.35			
DBH	Stumpage	QMD	Stumpage					1301	1305	
6	$350							PNW yr 0	PNW yr 0	
10	$500	10.36	$509	1301				$10,289	$10,625	$336
10	$500	11.35	$534	1305						
14	$600	16.5	$631	1301						
22	$700	24.6	$743	1301						
		17.7	$646	1305						
		26.1	$768	1305						

Table 13. Black Rock calculations stands 1 - 4.

Stand 1	Total Age	TPA	Volume Scribner	BA	QMD	Log Price $/MBF	Harvest Cost $/MBF	Net Harvest Return	Hauling Cost $/MBF	Regen Cost $/acre	$PNW 78	$NPA
Thin 1958	46	241	24,169	153.32	10.80	$679	$55	$4,340	$25	$400	$14,477	$53,051
Doug-fir	78	51	78,490	225.5	28.47	$754	$50	$52,895	$25		$52,895	
Hemlock	78	699	126	60.5	3.98	$0	$10	$40			$0	$SEV
										Subtotal	$52,895	$3,317
										Total	$67,372	
Stand 2												
Thin 1958	46	241	24,169	153.32	10.80	$679	$55	$4,340	$25	$400	$14,477	$28,550
Doug-fir	113	46.2	138,732	282.5	33.48	$856	$45	$108,644	$25		$27,532	
Hemlock	113	244	5,052	78.6	7.69	$100	$10	pulp lower $			$128	
Hemlock	113	244	5,052	78.6	7.69	$400	$65	$1,566	$25		$512	$SEV
							Subtotal	$110,210		Subtotal	$28,044	$1,995
							Total	$114,550		Total	$42,521	
Stand 3												
Thin 1958	8	241	24,169	153.32	10.80	$679	$55	$4,340	$25	$400	$14,477	$NPA
DF Thin	78	49	77,514	221.5	28.79	$754	$100	$48,756	$25		$50,694	$51,970
to 2 TPA	78	0	0	0	2.00	$0	$0	0			$0	
Harvest Df	113	1.9	3,195	7.5	26.90	$754	$50	$2,169	$25		$570	
Hemlock	113	539	18,956	226.5	8.78	$400	$65	$5,476	$25	$400	$1,388	
										Subtotal	$52,652	$SEV
										Total	$67,129	$3,076
Stand 4												
Thin 1958	46	241	24,169	153.32	10.80	$679	$55	$4,340	$25	$400	$14,477	$52,815
DF Thin	78	47	76,560	225.8	29.68	$754	$100	$48,156	$25		$50,070	
PCT hem	78	418	3	20.6	2.00	$0	$0	$0			$0	
Harvest Df	113	4	2,116	9.8	21.19	$754	$50	$1,436	$25		$377	
Hemlock	113	240	17,388	168.4	11.35	$475	$65	$6,294	$25	$400	$1,595	$SEV
									PCT Cost	Subtotal	$52,043	$3,048
									$/Acre	Total	$66,520	

Table 14. Black Rock calculations stands 5 - 6.

Stand 5	Total Age	TPA	Volume Scribner	BA	QMD	Log Price $/MBF	Harvest Cost $/MBF	Net Harvest Return	Hauling Cost $/MBF	Regen Cost $/acre	$PNW 78	$NPA
Thin 1958	46	241	24,169	153.32	10.80	$679	$55	$4,340	$25	$400	$14,477	$44,612
Grow Df	78	0	0	0	0.00	$0	$50	$0			$0	
PCT hm 159	78	540	0	32.9	2.00	$0	$0	($40)			($40)	
Harvest DF	98	50.8	120,965	275.9	31.56	$856	$50	$94,074	$25	$400	$42,934	
Hemlock	98	146	3,014	48.2	7.78	$400	$65	$934	$25		$461	$SEV
									PCT Cost	Subtotal	$43,355	$2,754
									$/ACRE	Total	$57,832	
									$40			
Stand 6												
Thin 1958	46	241	24,169	153.32	10.80	$679	$55	$4,340	$25	$400	$14,477	$49,673
Thin Df 10	78	40.4	63,671	197	29.90	$754	$75	$41,641	$25		$43,233	
PCT hm 151	78	548	0	33.9	2.00	$0	$0	($40)	$25		($40)	
Harvest	98	10.5	14,608	41.2	26.82	$754	$50	$9,519	$25	$400	$4,344	
yr 98	98	144	5,271	63.7	9.02	$400	$65	$1,634	$25		$806	$SEV
									PCT Cost	Subtotal	$48,343	$2,916
									$/ACRE	Total	$62,820	
									$40			

Table 15. Black Rock calculations stands 7 - 8.

	Total Age	TPA	Volume Scribner	BA	QMD	Log Price $/MBF	Harvest Cost $/MBF	Net Harvest Return	Hauling Cost $/MBF	Regen Cost $/acre	$PNW 78	$NPA
Stand 7	46	241	24,169	153.32	10.80	$679	$55	$4,340	$25	$400	$14,477	$25,196
Thin 1958	133	43.4	165,197	301.3	35.68	$1,358	$45	$212,374	$25	$400	$24,562	
Doug-fir	133	167	9,068	89.4	9.90	$0	$10	pulp lower $			$32	
Hemlock	133	167	9,068	89.4	9.90	$400	$65	$2,811	$25		$419	$SEV
							Subtotal	$215,185		Subtotal	$24,982	$1,857
							Total	$229,662		Total	$64,053	

	Total Age	TPA	Volume Scribner	BA	QMD	Log Price $/MBF	Harvest Cost $/MBF	Net Harvest Return	Hauling Cost $/MBF	Regen Cost $/acre	$PNW 78	$NPA
Stand 8	46	241	24,169	153.32	10.80	$679	$55	$4,340	$25	$400	$14,477	$53,332
Thin 1958	78	40.7	70,535	198.1	29.87	$754	$75	$46,130	$25		$47,893	
DF Thin	78	0	0	0	0.00	$0	$0	$0			$0	
to 10 TPA	113	8.2	17,753	38.2	29.23	$754	$100	$11,166	$25		$2,942	
DF Thin	113	423	13,264	165.9	8.48	$400	$65	$4,112	$25		$1,126	
Hemlock	148	2	7,849	14	35.82	$1,358	$45	$10,110	$25		$662	
Hvst DF	148	99.2	21,165	131.4	15.58	$475	$55	$7,960	$258	$400	$511	$SEV
Hemlock										Subtotal	$53,135	$3,071
										Total	$67,612	

Table 16. Black Rock total costs and returns stands 1 - 4.

Stand 1 Average Log Grade	Min Tip Diameter Inches	Min Log Length Feet	Total Stump to Truck Cost	Total Hauling Cost	Regen Cost	Gross Harvest Return	Net Harvest Return	Period of Analysis	Year of Harvest Return
#3 Saw	6	12	$1,329	$604		$16,411	$4,340	48	1958
#2 Saw	12	12	$3,925	$1,962	$400	$59,182	$52,895	78	1990
Stand 2									
#3 Saw	6	12	$1,329	$604		$16,411	$4,340	48	1958
Special Mill	16	17	$6,243	$3,468	$400	$118,755	$108,644	113	2025
#4 Saw			$328	$126	$400	$2,021	$1,566	113	2025
Stand 3									
#3 Saw	6	12	$1,329	$604		$16,411	$4,340	48	1958
#2 Saw	12	12	$7,751	$1,938	$400	$58,446	$48,756	78	1990
#2 Saw	12	12	$160	$80		$2,409	$2,169	113	2025
#4 Saw	6	12	$1,232	$474	$400	$7,583	$5,476	113	2025
Stand 4									
#3 Saw	6	12	$1,329	$604		$16,411	$4,340	48	1958
#2 Saw	12	12	$7,656	$1,914	$400	$57,726	$48,156	78	1990
#2 Saw	12	12	$106	$53		$1,595	$1,436	113	2025
#3 Saw	6	12	$1,130	$435	$400	$8,259	$6,294	113	2025

Table 17. Black Rock total costs and returns Stands 5 - 6.

Stand 5 Average Log Grade	Min Tip Diameter Inches	Min Log Length Feet	Total Stump to Truck Cost	Total Hauling Cost	Regen Cost	Gross Harvest Return	Net Harvest Return	Period of Analysis	Year of Harvest Return
#3 Saw	6	12	$1,329	$604	$400	$16,411	$4,340	48	1958
								78	1990
Special Mill	16	17	$6,048	$3,024	$400	$103,546	$94,074	98	2010
#4 Saw			$196	$75		$1,206	$934	98	2010
Stand 6									
#3 Saw	6	12	$1,329	$604	$400	$16,411	$4,340	48	1958
#2 Saw	12	12	$4,775	$1,592	$400	$48,008	$41,641	78	1990
#2 Saw	12	12	$730	$584	$400	$11,014	$9,519	98	2010
#4 Saw			$343	$132		$2,108	$1,634	98	2010

Table 18. Black Rock total costs and returns for Stands 7 - 8.

Stand 7 Average Log Grade	Min Tip Diameter Inches	Min Log Length Feet	Total Stump to Truck Cost	Total Hauling Cost	Regen Cost	Gross Harvest Return	Net Harvest Return	Period of Analysis	Year of Harvest Return
#3 Saw	6	12	$1,329	$604	$400	$16,411	$4,340	48	1958
#3 Peeler	24	17	$7,434	$4,130	$400	$224,338	$212,374	133	2045
								133	2045
#4 Saw			$589	$227	$400	$3,627	$2,811	133	2045
Stand 8									
#3 Saw	6	12	$1,329	$604	$400	$16,411	$4,340	48	1958
#2 Saw	6	12	$5,290	$1,763	$400	$53,183	$46,130	78	1990
			$0	$0		$0	$0	78	1990
#2 Saw	12	12	$1,775	$444	$400	$13,386	$11,166	113	2045
#4 Saw			$862	$332	$400	$5,305	$4,112	113	2045
#3 Peeler	24	17	$353	$196	$400	$10,659	$10,110	148	2060
#3 Saw	6	12	$1,164	$5,461	$400	$10,053	$7,960	148	2060

Table 19. Weeding Study Thin 100 SPS

Stand 7.6 + SV6"16'	SPS Thin 100 True DBH	Pond Value $/MBF	Logging Cost $/MBF	Hauling Cost $/MBF	Net Rev Stumpage $/MBF	Harvest Volume X 1000 BF	PNW Age 3 Jan (1981)	SEV Rot (67) Jan (1981)	NPA Age (15) Jan (1994)	PNW Age (15) Jan (1994)
Thin 40	16.20	628	100	50	478	23.160	$2,594			$4,153
Harvest 70	23.30	757	75	50	632	87.220	$3,983			$6,377
112-1					Totals	110.380	$6,577	$7,089	$11,350	$10,530
Thin 40	9.40	504	100	50	354	4.360	$362			$580
Harvest 70	17.60	654	75	50	529	32.970	$1,259			$2,015
112-0					Totals	37.330	$1,621	$1,747	$2,797	$2,595
Thin 40	14.90	604	100	50	454	28.050	$2,987			$4,782
Harvest 70	23.70	764	75	50	639	78.190	$3,612			$5,782
121-1					Totals	106.240	$6,598	$7,112	$11,387	$10,564
Thin 40	14.10	590	100	50	440	25.720	$2,651			$4,244
Harvest 70	23.30	757	75	50	632	72.970	$3,332			$5,335
121-0					Totals	98.690	$5,983	$6,449	$10,325	$9,579
Thin 40	16.00	624	100	50	474	28.020	$3,115			$4,987
Harvest 70	24.90	786	75	50	661	92.430	$4,415			$7,069
128-1					Totals	120.450	$7,530	$8,116	$12,994	$12,055
Thin 40	14.00	588	100	50	438	27.550	$2,828			$4,527
Harvest 70	23.20	755	75	50	630	70.500	$3,210			$5,140
128-0					Totals	98.050	$6,038	$6,508	$10,420	$9,667
Thin 40	17.90	659	0	0	659	28.270	$4,365			$6,988
Harvest 70	26.50	815	75	50	690	113.370	$5,654			$9,052
138-1					Totals	141.640	$10,018	$10,798	$17,289	$16,040
Thin 40	17.60	654	100	50	504	27.860	$3,287			$5,262
Harvest 70	26.60	817	75	50	692	114.030	$5,701			$9,128
138-0					Totals	141.890	$8,988	$9,688	$15,511	$14,390

Table 20. Weeding Study Thin 150 SPS

Stand 7.6 + SV6"16'	SPS Thin 150 True DBH	Pond Value $/MBF	Logging Cost $/MBF	Hauling Cost $/MBF	Net Rev Stumpage $/MBF	Harvest Volume X 1000 BF	PNW Age 3 Jan (1981)	SEV Rot (67) Jan (1981)	NPA Age (15) Jan (1994)	PNW Age (15) Jan (1994)
Thin 40	16.00	624	100	50	474	13.400	$1,490			$2,385
Harvest 70	22.40	741	75	50	616	84.260	$3,748			$6,001
112-1					Totals	97.660	$5,238	$5,646	$9,039	$8,386
Thin 40	9.00	497	100	50	347	2.080	$169			$271
Harvest 70	16.10	626	75	50	501	42.900	$1,553			$2,487
112-0					Totals	44.980	$1,723	$1,857	$2,973	$2,758
Thin 40	14.50	597	100	50	447	17.310	$1,814			$2,904
Harvest 70	22.30	739	75	50	614	104.360	$4,629			$7,411
121-1					Totals	121.670	$6,442	$6,944	$11,117	$10,314
Thin 40	15.60	617	100	50	467	16.400	$1,795			$2,874
Harvest 70	21.60	726	75	50	601	98.960	$4,298			$6,881
121-0					Totals	115.360	$6,093	$6,568	$10,515	$9,755
Thin 40	15.60	617	100	50	467	15.650	$1,713			$2,743
Harvest 70	23.50	761	75	50	636	114.280	$5,249			$8,403
128-1					Totals	129.930	$6,962	$7,504	$12,014	$11,146
Thin 40	13.60	581	100	50	431	18.070	$1,824			$2,920
Harvest 70	21.60	726	75	50	601	95.850	$4,163			$6,665
128-0					Totals	113.920	$5,987	$6,453	$10,332	$9,585
Thin 40	17.30	648	0	0	648	12.560	$1,907			$3,053
Harvest 70	25.20	792	75	50	667	129.560	$6,240			$9,990
138-1					Totals	142.120	$8,147	$8,781	$14,059	$13,043
Thin 40	16.80	639	100	50	489	11.770	$1,348			$2,159
Harvest 70	25.30	794	75	50	669	127.540	$6,159			$9,861
138-0					Totals	139.310	$7,508	$8,092	$12,956	$12,020

Table 21. Weeding Study Thin 100 DFSIM

7.6 + SV6"16'	Thin 100 True DBH	Pond Value $/MBF	Logging Cost $/MBF	Hauling Cost $/MBF	Net Rev Stumpage $/MBF	Harvest Volume X 1000 BF	PNW Age 3 Jan (1981)	SEV Rot (67) Jan (1981)	NPA Age (15) Jan (1994)	PNW Age (15) Jan (1994)
Thin 40	16.00	624	100	50	474	15.258	$1,696			$2,715
Harvest 70	27.80	839	75	50	714	88.587	$4,569			$7,315
112-1					Totals	103.845	$6,265	$6,753	$10,811	$10,030
Thin 40	12.60	563	100	50	413	9.499	$918			$1,470
Harvest 70	23.20	755	75	50	630	67.452	$3,071			$4,917
112-0					Totals	76.951	$3,990	$4,300	$6,885	$6,388
Thin 40	15.60	617	100	50	467	17.589	$1,925			$3,082
Harvest 70	26.80	821	75	50	696	97.204	$4,886			$7,822
121-1					Totals	114.793	$6,811	$7,341	$11,754	$10,904
Thin 40	13.00	570	100	50	420	17.761	$1,747			$2,798
Harvest 70	24.20	774	75	50	649	80.653	$3,778			$6,049
121-0					Totals	98.414	$5,526	$5,956	$9,536	$8,847
Thin 40	19.05	680	100	50	530	12.384	$1,537			$2,462
Harvest 70	32.26	920	75	50	795	116.078	$6,667			$10,674
128-1					Totals	128.462	$8,204	$8,843	$14,158	$13,135
Thin 40	12.20	555	100	50	405	18.792	$1,785			$2,857
Harvest 70	23.31	757	75	50	632	78.415	$3,582			$5,735
128-0					Totals	97.207	$5,367	$5,785	$9,261	$8,592
Thin 40	21.20	719	100	50	569	15.610	$2,081			$3,332
Harvest 70	29.90	877	75	50	752	127.656	$6,936			$11,105
138-1					Totals	143.266	$9,017	$9,719	$15,560	$14,436
Thin 40	16.80	639	100	50	489	18.913	$2,167			$3,469
Harvest 70	27.90	841	75	50	716	121.981	$6,307			$10,098
138-0					Totals	140.894	$8,474	$9,134	$14,624	$13,567

Table 22. Weeding Study Thin 150 DFSIM.

Stand 7.6 + SV6"16'	Thin 150 True DBH	Pond Value $/MBF	Logging Cost $/MBF	Hauling Cost $/MBF	Net Rev Stumpage $/MBF	Harvest Volume X 1000 BF	PNW Age 3 Jan (1981)	SEV Rot (67) Jan (1981)	NPA Age (15) Jan (1994)	PNW Age (15) Jan (1994)
Thin 40	15.85	622	100	50	472	4.887	$540			$865
Harvest 70	27.48	833	75	50	708	90.478	$4,628			$7,410
112-1					Totals	95.365	$5,169	$5,571	$8,919	$8,275
Thin 40	12.31	557	100	50	407	3.939	$376			$602
Harvest 70	21.07	717	75	50	592	77.356	$3,306			$5,293
112-0					Totals	81.295	$3,682	$3,969	$6,354	$5,895
Thin 40	15.39	613	100	50	463	6.506	$706			$1,131
Harvest 70	26.04	807	75	50	682	100.322	$4,942			$7,913
121-1					Totals	106.828	$5,649	$6,088	$9,748	$9,044
Thin 40	12.76	566	100	50	416	10.765	$1,048			$1,678
Harvest 70	22.05	734	75	50	609	90.721	$3,994			$6,394
121-0					Totals	101.486	$5,042	$5,435	$8,701	$8,072
Thin 40	21.20	719	0	0	719	.000	$			$
Harvest 70	33.92	950	75	50	825	114.957	$6,853			$10,972
128-1					Totals	114.957	$6,853	$7,386	$11,826	$10,972
Thin 40	12.20	555	100	50	405	12.819	$1,217			$1,949
Harvest 70	21.08	717	75	50	592	90.764	$3,880			$6,212
128-0					Totals	103.583	$5,098	$5,495	$8,797	$8,161
Thin 40	20.40	704	0	0	704	.000	$			$
Harvest 70	31.45	905	75	50	780	127.261	$7,174			$11,485
138-1					Totals	127.261	$7,174	$7,732	$12,379	$11,485
Thin 40	16.67	637	100	50	487	2.737	$312			$500
Harvest 70	27.79	839	75	50	714	125.481	$6,470			$10,359
138-0					Totals	128.218	$6,782	$7,310	$11,704	$10,858

Table 23. Weeding Study Yields

Stand 7.6 + SV6"16'	Volume X 1000BF Thin 100	DFSIM % Difference	Volume X 1000BF Thin 150	DFSIM % Difference	Volume X 1000 Thin 100	SPS % Difference	Volume X 1000 Thin 150	SPS % Difference	Difference Models Thin 100	Difference Models Thin 150
Thin 40	15.258		4.887		23.16		13.4			
Harvest 70	88.587		90.478		87.22		84.26		-6%	-2%
112-1	103.845		95.365		110.38		97.66		-6.535	-2.295
Thin 40	9.499		3.939		4.36		2.08			
Harvest 70	67.452	26%	77.356	15%	32.97	66%	42.9	54%	51%	45%
112-0	76.951	26.894	81.295	14.070	37.33	73.050	44.98	52.680	39.621	36.315
Thin 40	17.589		6.506		28.05		17.31			
Harvest 70	97.204		100.322		78.19		104.36		7%	-14%
121-1	114.793		106.828		106.24		121.67		8.553	-14.842
Thin 40	17.761		10.765		25.72		16.4			
Harvest 70	80.653	14%	90.721	5%	72.92	7%	98.96	5%	0%	-14%
121-0	98.414	16.379	101.486	5.342	98.64	7.600	115.36	6.310	-.226	-13.874
Thin 40	12.384		.000		28.02		15.65			
Harvest 70	116.078		114.957		92.43		114.28		6%	-13%
128-1	128.462		114.957		120.45		129.93		8.012	-14.973
Thin 40	18.792		12.819		27.55		18.07			
Harvest 70	78.415	24%	90.764	10%	70.5	19%	95.85	12%	-1%	-10%
128-0	97.207	31.255	103.583	11.374	98.05	22.400	113.92	16.010	-.843	-10.337
Thin 40	15.610		.000		28.27		12.56			
Harvest 70	127.656		127.261		113.37		129.56		1%	-12%
138-1	143.266		127.261		141.64		142.12		1.626	-14.859
Thin 40	18.913		2.737		27.86		11.77			
Harvest 70	121.981	2%	125.481	-1%	114.03	0%	127.54	2%	-1%	-9%
138-0	140.894	2.372	128.218	-.957	141.89	-.250	139.31	2.810	-.996	-11.092

Table 24. Weeding Study Values.

Stand 7.6 + SV6"16'	SEV DFSIM Thin 100	SEV DFSIM Thin 150	Diff., % Between Thinnings	NPA DFSIM Thin 100	NPA DFSIM Thin 150	Diff., % Between Thinnings	SEV SPS Thin 100	SEV SPS Thin 150	Diff., % Between Thinnings	NPA SPS Thin 100	NPA SPS Thin 150	Diff., % Between Thinnings
112-1	$6,753	$5,571	$1,182	$10,811	$8,919	$1,892	$7,089	$5,646	$1,444	$11,350	$9,039	$2,311
			18%			18%			20%			20%
112-0	$4,300	$3,969	$332	$6,885	$6,354	$531	$1,747	$1,857	-$110	$2,797	$2,973	-$176
Diff., weed	$2,452	$1,602	8%	$3,926	$2,565	8%	$5,342	$3,789	-6%	$8,553	$6,066	-6%
%	36%	29%		36%	29%		75%	67%		75%	67%	
121-1	$7,341	$6,088	$1,253	$11,754	$9,748	$2,006	7,112	6,944	$168	11,387	$11,117	$269
			17%			17%			2%			2%
121-0	$5,956	$5,435	$521	$9,536	$8,701	$835	$6,449	$6,568	-$119	$10,325	$10,515	-$190
Diff., weed	$1,385	$654	9%	$2,218	$1,047	9%	$663	$376	-2%	$1,062	$602	-2%
%	19%	11%		19%	11%		9%	5%		9%	5%	
128-1	$8,843	$7,386	$1,456	$14,158	$11,826	$2,332	$8,116	$7,504	$612	$12,994	$12,014	$980
			16%			16%			8%			8%
128-0	$5,785	$5,495	$290	$9,261	$8,797	$464	$6,508	$6,453	$55	$10,420	$10,332	$88
Diff., weed	$3,058	$1,892	5%	$4,897	$3,029	5%	$1,608	$1,051	1%	$2,575	$1,682	1%
%	35%	26%		35%	26%		20%	14%		20%	14%	
138-1	$9,719	$7,732	$1,987	$15,560	$12,379	$3,181	10,798	8,781	$2,017	17,289	$14,059	$3,230
			20%			20%			19%			19%
138-0	$9,134	$7,310	$1,824	$14,623	$11,704	$2,919	$9,688	8,092	$1,596	15,511	$12,956	$2,555
Diff., weed	$585	$422	20%	$937	$675	20%	$1,110	$689	16%	$1,778	$1,103	16%
%	6%	5%		6%	5%		10%	8%		10%	8%	

Figure 1. Use of the Weibull Function to Compare the SPS Distribution to the Actual Distribution

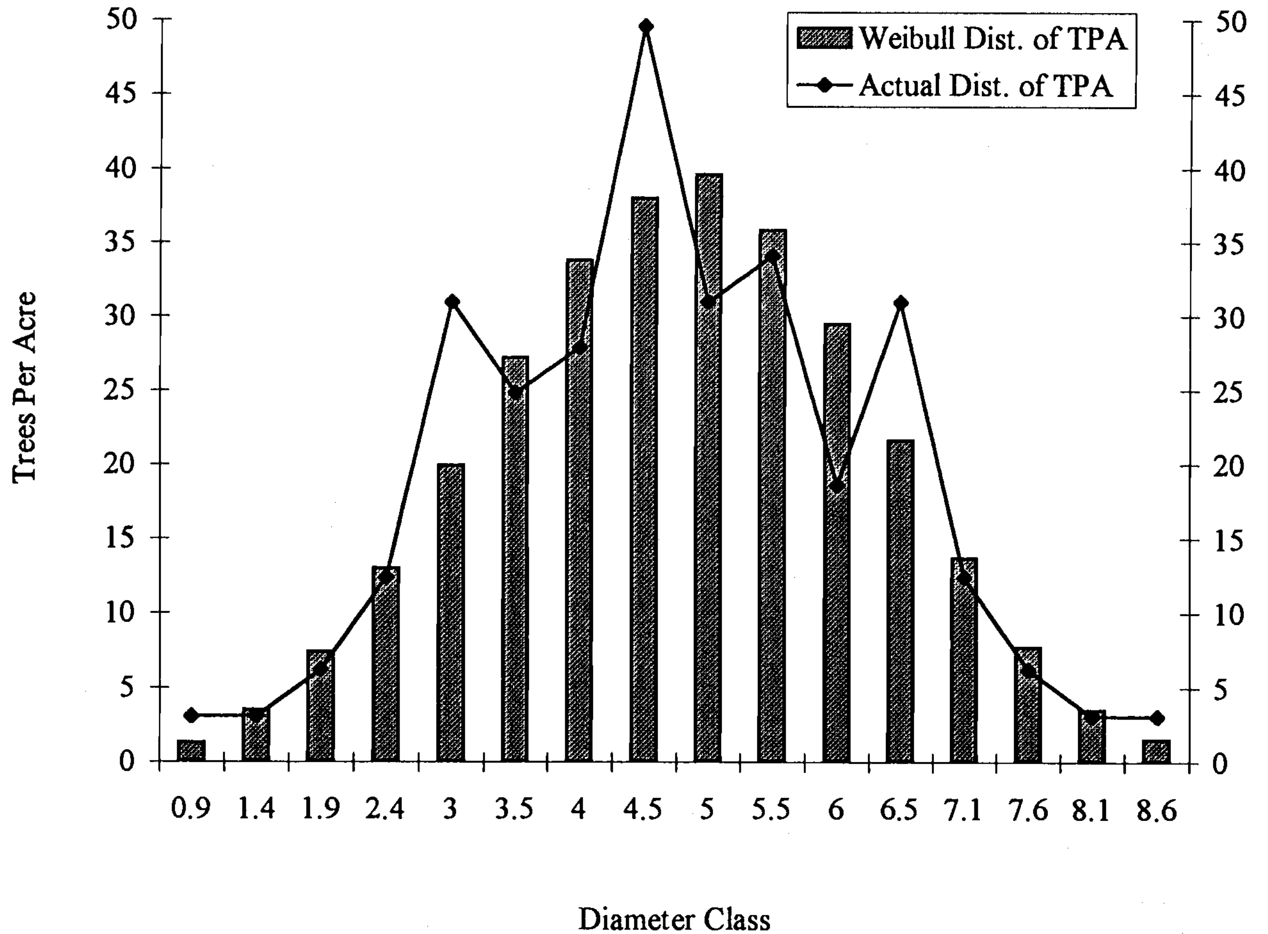

Figure 2. Log Prices for Stumpage Valuation