NEW SILVICULTURAL PRACTICES UNDER ECOSYSTEM MANAGEMENT

R. James Barbour
Research Scientist
USDA Forest Service,
PNW Research Station,
PO BOX 3890
Portland, OR 97208-3890
USA

Steven Tesch
Chair, Dept. of
Forest Engineering
Oregon State University
Peavy Hall A108
Corvallis, OR
97331-5703 USA

Susan Willits
Research Forest Products Technologist
Roger Fight
Principle Economist
USDA Forest Service,
PNW Research Station, PO Box 3890
Portland, OR 97208-3890
USA

Richard Gustafson
Professor, Pulp and Paper Science
Saket Kumar
Graduate Student
Department of Paper Science and Engineering
College of Forest Resources,
396 Bloedel Hall, Box 352100
University of Washington,
Seattle, WA 98195-2100
USA

Joseph McNeel
Professor
College of Forestry,
University of British Columbia,
Vancouver, B.C.
Canada

Andrew Mason
Ecosystem Management Staff 0fficer
USDA Forest Service,
Colville National Forest,
765 S. Main
Colville, WA 99114
USA

Ken Skog
Project Leader
USDA Forest Service,
Forest Products Laboratory,
One Gifford Pinchot Dr.
Madison. WI 53705-2398

ABSTRACT

The Colville Study is a partnership between three National Forests, three forest products companies, five universities. the USDA Forest Service Forest Products Laboratory, and the USDA Forest Service Pacific Northwest Research Station. The objective of the study is to understand the potential role of wood removals in financing forest operations intended to change the growth trajectory of densely stocked smalldiameter stands. We evaluated the long-term ecological implications of a range of silvicultural regimes intended to promote development of late-successional structure, wildlife habitat, reduce risk of insect attack and disease, and improve aesthetics of such stands. We also measured the productivity of a cut to length harvesting system and the product potential of treatments. To help forest managers understand the complex interactions between forest operations and value of small-diameter trees we are developing a software tool for performing financial analysis of silvicultural treatments. The study was implemented as a case study of the Rocky II Timber Sale on the Colville National Forest. Results so far suggest that active management is needed to alter growth trajectories to satisfy management goals. The costs associated with achieving silivicultural objectives are highly dependent on the harvesting sysstem employed and the objectives of silvicultural regimes. It is important for Forest Service personnel to understand what characteristics generate value in these marginally economic stands in order to design timber sales that both meet ecological objectives and are economically feasible.

INTRODUCTION

Under a program known as CReating OPportunities or CROP, the Colville National Forest has recently completed a survey of 44,500 hectares of densely stocked, small-diameter stands (l). These stands are generally considered unmerchantable or at best economically marginal since they have many trees with diameters of 10 to 18 cm and volumes of less than 120 m^3/ha. CROP stands represent about 18% of the area on the Colville National Forest planned for active timber management in the ten year period covered by the current forest plan (2). Other national forests in the interior West manage comparable proportions of stands of similar size and age class. The question of their management is a major issue facing Federal land managers in the coming decade.

Analyses conducted by the Colville NF concluded that development of many CROP stands is slow and may even be regressing away from desired future conditions. These stands present opportunities to improve biological diversity and ecosystem health through thinning and other silvicultural treatments. The Colville Study was designed to test the hypothesis that, in some situations, active management may redirect stand development towards more desirable ecological conditions. It was also intended to collect information on the costs associated with forest operations used to implement silvicultural prescriptions in densely stocked srnall-diameter stands and to evaluate the range of wood products options for trees removed from these stands. This study was organized to answer two general questions:

1. What is the range of silvicultural treatments available to achieve desired future conditions for the different types of CROP stands?
2. What factors control the economic and technical feasibility of silvicultural treatments in CROP stands?

Silvicultural prescriptions for these stands and the forest operations chosen to implement them must be selected carefully since small changes in diameter can result in relatively large changes in recovered product value and costs of operations (Figure 1). Recent fluctuations in the price of lumber and chips have made Federal land managers acutely aware of the challenges associated with using timber sales as a way to finance ecosystem restoration or forest health improvement treatments in stands dominated by small stems. Densely stocked, small-diameter stands are typically among the least cost effective to treat and often yield small volumes of *what* is perceived as low quality wood and fiber. They are the last stands to be entered as raw material prices rise and the first to be abandoned as prices fall. Thus, the continued practicality of forest operations in them is especially vulnerable to changes in short term economic conditions. Federal land managers find this situation praticularly perplexing because laws governing forest practices force management activities to be planned many months, or more often several years, in advance. This makes it almost impossible to time treatments to the peaks in the market.

The Colville Study was intended to help land managers understand the changes in costs and values depicted in Figure 1 and assist them in designing economically feasible treatments. It was a case study of the Rocky II Timber Sale on the Colville Ranger District of the Colville NF. The case study evaluated the long-term ecological implications of different silvicultural options for a set of representative stand types. It identified the costs and revenues associated with various silvicultural prescriptions and forest operations for these stands along with manufacturing options for the wood removed from them. Some of preliminary results from the study have already been reported (3, 4, 5). This report covers additional information on the silviculture, forest operations, kraft pulp quality and economics of stand manipulations. Details on the thermomechanical pulping of materials from the study are covered in a separate paper in this volume (6).

RESULTS AND DISCUSSION

Silviculture Modeling

The objective of the silvicultural modeling exercise was to evaluate the ability of a range of silvicultural treatments to speed the development of desired stand characteristics for stand types common on the Rocky II Timber Sale Area (4). The stand characteristics that the Colville NF staff wanted to enhance were: 1) late-successional stand structure, 2) wildlife habitat, 3) forest health, 4) stand aesthetics.

Late-successional stand structure is scarce on the Colville NF. Forest staff felt that given the high proportion of the landscape currently occupied by srnall-diameter densely stocked stands, there is an opportunity to use active management to move some of these stands toward late-successional structure. A range of silvicultural treatments was tested to evaluate their influence on desirable features such as hiding and thermal cover for whitetail deer and elk. Priority was also given to structures such as large snags($\geq$ 41 cm dia.) as habitat for primary cavity excavating birds and large green trees to provide other late-successional structural characteristics. Although the stands on the Rocky II Timber Sale Area are not greatly at risk of insect attack or disease, treatments were designed to avoid future conditions that increase risk. A major aesthetic consideration was to increase the number of larger western larch to provide fall colors. Since tree size and spacing are two of the main components of the objective to develop late-successional structural, emphasis on larch, which is an early seral species, is not necessarily inconsistent with the goal of producing these structural characteristics. A range of treatments was also desired to extend management options. For example, small clear-cuts might be acceptable in some areas but inappropriate in visually sensitive areas where thinnings or group selections are preferable. In other cases, sparse crown development might warrant a series of small clear-cut/green tree retention treatments in areas where poor response to thinning or post treatment blowdown are concerns.

Stand exam data from hte Rocky II Timber Sals Area were used to create three composite stand types. They were: western larch/Douglas-fir (WLDF), western larch/lodgepole pine (WLLP), and western red cedar (WRC). The Inland Empire variant of the Forest Vegetation Simulator (FVS; 7) was used to model stand growth under four silvicultural prescriptions: no treatment (NT), thinning (TH), clear-cutting with green tree retention (CC), and group selection (GS). Not all treatments were appropriate for all stand types.

Results from a 150 year simulation with FVS are reported in Table 1. The model suggests that without active management none of the stand types will develop late-successional structure over the 150 year modeling period. The active management options all tend to promote characteristics such as larger green trees ($\geq$ 51 cm) and more large snags ($\geq$ 41 cm). None of the treatments significantly harmed the capability of the stands to provide hiding or thermal cover for deer and elk nor did they increase the forest health risk. Only the thinning and group selection treatments in the WLDF stand type provided nesting habitat for primary cavity excavating birds but all of the treatments, in all of the stand types, resulted in an improvement in the characteristics important to these species when compared to the no treatment prescription.

Volume production

Volume production was more consistent among prescriptions in some stand types than in others (Table 1). The WLLP and WRC stand types both produced between 145 and 150 m^3 per hectare over the 150 year period. The WLDF stand type was more sensitive to treatment with a difference of about 75% between the high and low volume treatment. The small differences between treatments may, however. be misleading since the volume comes at different times in each treatment and the size of the removed stems is also treatment dependent. For example the clear-cut/green tree retention regimes may produce more volume in the early years but it will include a higher proportion of the smallest stems than the thinning regimes. On the other hand, thinning regimes may yield larger stems in earlier years but clear-cut/green tree retention regimes are likely to produce larger pieces in later years since seediings planted at the initiation of the clear-cut regimes eventually become quite large (4).

Forest Operations

A harvester-forwarder combination was used to implement silvicultural prescriptions on the Rocky II Sale Area. Data recorders were used to measure the the activity of the harvester and forwarder. Preliminary results from this work have already been presented (3, 6) and detailed analysis is in preparation (8). An important finding is that the harvester cost relationship (5) is in fact shaped like the hypothetical relationship proposed in Figure 1. Willits et al. (5) have also reported that the shape of the product value curves for lumber and veneer have similar shapes to the relationship shown in Figure 1.

Kraft Pulps

A range of investigations were designed to measure wood product outputs from the study area (5). These included lumber, veneer, composite products, engineered wood products, TMP, CTMP, and kraft pulps.

Kraft pulping trials were conducted using three species: lodgepole pine *(Pinus contorta),* western larch *(Larix occidentals),* and Douglas-fir *(Pseudotsuga menziesii).* Two samples representing the small diameter resource and one representing the existing commercial resource were obtained for each species. Submerchantable sawlogs (SML) were collected from the Rocky II Timber Sale Area by the company harvesting the timber. These were logs at least 3.8 m long with a small-end diameter (SED) of $\geq$ 8.9 cm. This class of material represents one of the more economically marginal products from this type of stand since even with very efficient saw milling equipment logs of this size class are rareIy profitable. Small-diameter trees (SDT) ranged from 12 cm to 17.5 cm at the butt (15 cm from the ground). These trees were collected from stands on the Priest Lake Ranger District of the Idaho Panhandle NF. The stands were of similar age, size, and structure to those on the Rocky II Timber Sale Area. The small trees were intended to represent a part of the resource that is generally unmerchantable except when chip prices are unusually high. Trees of this size are often slated for removal under ecosystem management prescriptions. Pulping characteristics of the submerchantable sawlogs and small-diameter trees were compared to those of sawmill residual chips (C.) from a mill in Colville, WA. This mill processed the materials from the Rocky II Timber Sale but the chips came from larger logs representative of the commercial resource typically processed in the area. industry practice is to saw larch and Douglas-fir together so these species were mixed in the sawrnill residual chip sample.

Chips were air-dried for two weeks and screened to 2-10 mm thickness. Air-dried chips were stored at room temperature in plastic bags until used. Based on the kinetics obtained in the previous experiments (5), chips from all eight raw material sources were cooked to produce 30 kappa number pulp. These pulps were also used in fiber and handsheet studies.

Fiber characteristics

The weighted-average fiber length (WAFL) and fiber coarseness of the unbeaten, unbleached kraft pul;ps were determined using a Kajaani FS200 fiber analyzer(Table 2). Fiber lengths were similar for the submerchantable sawlgs and small-diameter trees for all species. Except for the western larch submerchantable sawlogs, the fibers from sawmill residual chips were always longer. The fibers from the small diameter resource tended to be between 0.25 and 0.5 mm shorter then those from the commercial resource.

Larch had nearly identical fiber coarseness among the three raw material sources. The other two species were more variable with the greatest difference in lodgepole pine where the range was from 118 µg/m to 155 µg/m. The differences in both fiber length and coarseness are moderate and would probably not interfere with mixing the pulps in the papermaking process.

Economic Return from Alternate Products

A study was conducted which evaluated the general economic feasibility of converting small-diameter timber to a range of wood products including: oriented strand board (OSB), stud lumber, random-length dimension lumber, machine stress rated lumber, laminated veneer lumber (LVL), and market pulp (9). The analysis indicated that LVL promises the best ratio of revenue per unit of roundwood, followed by marked pulp and OSB. Amoung the lumber alternatives, machine-stress-rated lumber provides the greatest return. In terms of investment risk, the low cost lumber alternatives are favored over more capital-intensive OSB, market pulp, and LVL (9).

Tree Size and Economic Return

A conceptual model illustrating how harvfesting costs and product value interact is shown in Figure 1. To further illustrate the importance of changing tree size and market conditions, a simple example is provided using four Dough-fir trees from the Colville Study. The trees were approximately 10, 15, 20, and 25 cm DBH and 11, 13.7, 16.5. and 19.5 m tall. They were bucked into 4.9 m sawlogs to a minimum small-end diameter of 10.7 cm. The portion of the tree above this diameter was bucked into chip logs up to a 5 cm top. The volume of lumber produced from the each sawlog was estimated using the cubic recovery relationship for Douglas-fir developed for the Colville Study (5). Ten percent of the log volume was deducted as sawdust and planer shavings. The remaining volume was manufactured into chips. Chip logs were assumed to convert 100% to chips.

Lumber was priced assuming a yield of 85% light framing (equivalent to Standard and Better) and 15% Utility using prices reported in Table 9 of the USDA Forest Service's PNW Quarterly Price Report (10). Published lumber prices were reduced by $73.5 per m^3 to account for manufacturing costs. Chip prices were obtained from Ekstrom (11) for delivered sawmill residual chips and roundwood chips for Northeastern Washington. The delivered price for the roundwood chips was reduced by $7 per m^3, solid wood equivalent, to account for manufacturing costs. No reduction was made to account for the manufacturing costs of sawmill residual chips since this is incorporated into the price of lumber. A transportation cost of $17 per m^3 was assumed for both chip sources. The adjusted chip prices were used as the F.O.B. mill price for each chip source.

Stumpage value of the trees was calculated for four market scenarios i.e., high chip and lumber prices. low chip and lumber prices, high chip low lumber, and low chip high lumber. A low chip price of $26.50 per m^3, solid wood equivalent ($64 per BDU) for residual chips and $35 per m^3 ($85 per BDU) for roundwood chips was chosen from the fourth quarter 1996. These delivered prices were adjusted as described above and resulted in F.O.B. mill prices of $9.50 per m^3 for residual chips and $11 Per^{3}m for roundwood chips. The corresponding high chip prices came from the third quarter of 1995 $61 per m^3 ($149 per BDU) for residual chips and $68 per m^3 ($166 per BDU) for roundwood chips were both adjusted to $44 m^3 F.O.B. mill. The 1990 average lumber price of $116 per m^3 was used as the low value and the 1993 lumber price of 197 per m^3 was used as the high lumber price.

The harvesting forwarding, and transportation costs are shown in Table 3. Volumes for each tree were converted to weight using a specific gravity (oven-dry weight green volume basis) of 0.45 and average moisture content of 80% (oven-dry weight basis). Bark volume was assumed to be 10% of the wood volume with a specific gravity of 0.5 (oven-dry weight, green volume basis) and moisture content of 110% (oven-dry weight basis; 12, 13). The harvesting and forwarding cosrs were estimated from data collected on the Rocky II Timber Sale Area (5, 8). The 10 and 15 cm trees were too small to accurately estimate harvesting or forwarding costs but these costs were assumed to be much higher than for the larger trees. Since operations require similar times for any size tree within this size range and volume from smaller trees is much less, harvesting costs are assumed to rise almost geometrically (5, 8). The per tree cost was arrived at by multiplying the total cost per tonne by the tonnes per tree. This resulted in a fairly constant "minimum" cost per tree of between $5 and $6 (Table 3).

The results from this example demonstrate the marginal nature of forest operations in stands dominated by very small trees (Figure 2). Even when efficient harvesting systems are used there will be many situations where operations in stands with average diameters of less than 20 cm, such as the Colville NF's CROP stands or many others in the West, will simply not be economical. In other situations, operations need to be planned and timed carefully to take advantage of market conditions that only occur occasionally. This example did, however, only included individual trees not stands. Stands have a distribution of tree sizes and analysis of the financial feasibility of forest operations for distributions of trees is considerably more complex then the one presented here. The results of the Colville Study are being combined with existing data to develop a software tool to assist forest managers in performing financial analysis on stands. This example none-the-less shows that the types of treatments being proposed for many acres of Federal land are marginal and must be carefully thought out to avoid spending scarce planning funds on projects that are not financially sound.

SUMMARY AND CONCLUSIONS

Results from the FVS modeling exercise suggested that without active management the stands on the Rocky II Timber Sale Area are not on a trajectory to develop late-successional structure before the next stand replacement fire. Maintenance of deer and elk habitat should not pose a problem but development of snags and large trees needed for cavity nesting habitat is mote difficult. The forest health risk is moderate for these stands and with active manegement it can generally be reduced but it may not deteriorate to a high risk state even without treatments. Finally, it should be possible to increase the size and number of larch in stands where this species is present and the range of treatments modeled should provide managers with options appropriate to a number of stand conditions and aesthetic constraints.

If the USDA Forest Service is to successfully implement ecosystem management in small-diameter densely stocked stands, field personnel who design treatments need a better understanding of the features that create value for manufacturers or add costs to forest operations. The results of this study suggest that harvesting costs and product value change very rapidly in the diameter ranges typical in small-diameter densely stocked stands found in the western United States. Small changes in average stand diameter result in large differences in costs and product recovery. Forest operations in these stands are sensitive to relatively minor fluctuations in market prices for products such as chips, lumber and veneer. This may make implementation of many silvicultural prescriptions uneconomical under certain market conditions. As a result the ability of the USDA Forest Service to implement ecosystem management in these stand types is much more dependent on the market and the design of timber sales than has previously been the case. On the other hand, the products manufactured from these raw materials often have quality characteristics similar to other more traditional raw material sources. Manufacture of a wide range of products is technically feasible given the properties of the raw materials but may not be economically feasible given the costs associated with harvesting, transporting, and processing small diameter raw materials.

REFERENCES

1. Colville National Forest. *USDA Forest Service, Colville National Forest, CROP Report.* "CROP CReating Opportunities: A study of Small-Diameter Trees of the Colville National Forest." 62 pp. (1994).

2. Torrence, J.F. *Colville National Forest, USDA Forest Service [Portland].* "Record of Decision for Land and Resource Management Plan Final Environmental Impact Statement." p.7 (1988).

3. Barbour, R.J., McNeel, J.F, Tesch, S., and Ryland, D.B. *Proceedings of the Council on Forest Engineering, 18th Annual Meeting, Sustainability, Forest Health & Meeting the Nation's Needs for Wood Products, Cashiers, NC, June 5-8, 1995 A. E. Hassan (ed).* "Management and Utilization of Mixed Species, Small-Diameter, Densely Stocked Stands. p.187-195. (1995)

4. Ryland, D.B. *Unpublished Master's Paper Department of Forest Resources, Oregon State University,* "Evaluating the Impact of Four Silvicultural Prescriptions on Stand Growth and Structure in Northeastern Washington--A Modeling Approach." 61pp. (1996).

5. Willits, S.A., Barbour, R.J., Tesch, S., McNeel, J., Kumar, S., Myers, G., Olson, B. *USDA Forest Service, Forest Products Laboratory, Madison, WI. Research Paper.* "The Colville Study: Wood Utilization for Ecosystem Management." FPL-RP-559 (1996).

6. Myers, G.C., Barbour, R.J., and Abubakr, S. *Proceedings TAPPI Environmental Conference Minneapolis, MN, May5-7, 1997 (This Volume)*, Utilization of Non-Traditional Species. (1997).

7. Wycoff, W.R., Crookston, N.L., and Stage, A.R. *USDA For. Serv. Intermountain Research Station General Technical Report,* "User's Guide to the Stand Prognosis Model." INT-133 (1982).

8. McNeel, J.F. and Barbour, R.J. *Forest Products Journal,* Cut-to-Length System Performance in Mixed Species, Small Diameter, Heavily Stocked Stands. (In Review).

9. Spelter, H., Wang, R., Ince, P. *USDA Forest Service, Forest Products Laboratory, Madison, WI. General Technical Report.* Economic Feasibility of Products from Inland West Small-Diameter Timber. FPL-GTR-92, 17p. (1996)

10. Warren, D. *USDA Forest Service, Pacific Northwest Research Station, Portland, OR. Resource Bulletin.* "Production, Prices, Employment, and Trade in Northwest Forest Industries, Second Quarter 1996." PNW-RB-219.

11. Ekstrom, H. *Personal Communication, Wood Resources International Ltd.* Wood and Fiber Northwest Market Report.

12. Snell, J.A.K. and Max, T.A. *USDA Forest Service, Pacific Northwest Research Station, Portland, OR. Administrative Report.* "Bark-to-Wood Ratios for Logging Residue in Oregon, Washington, and Idaho." 1982 9p.

13. Smith, J.H.G. and Kozak, A. *Forest Products Journal,* "Thickness, Moisture Content, and Specific Gravity of Inner and Outer Bark of some Pacific Northwest Trees." 21(2):38-40. 1971.

ACKNOWLEDGMENT

The authors would like to thank the Wood Utilization for Ecosystem Management (WUEM) project at the USDA Forest Products Laboratory for providing partial funding for this work. We would also like to thank the many cooperators who participated in the study.

DISCLAIMER

The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Figure I. Hypothetical Product Recovery Ratio and Operating Cost by Breast Height Diameter

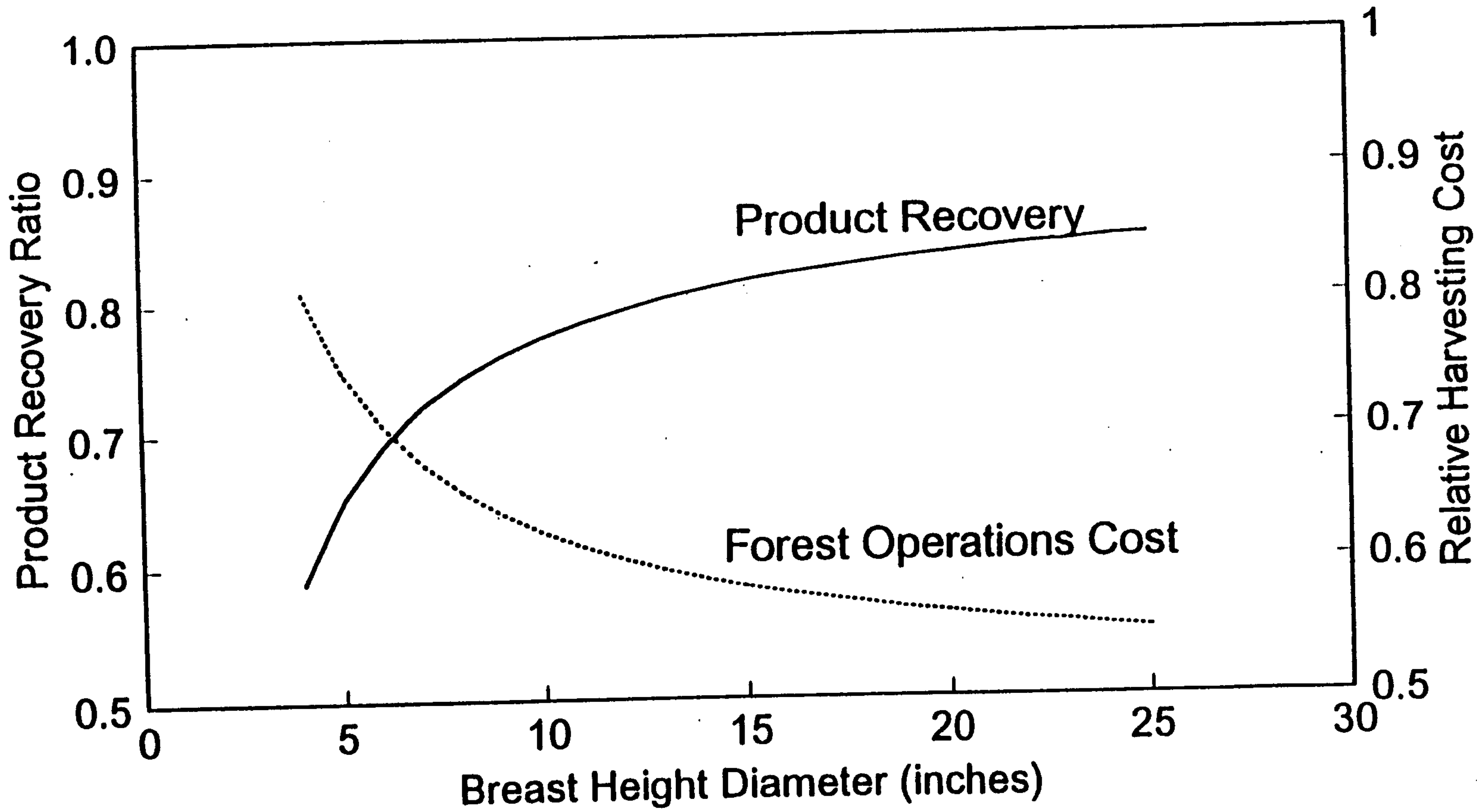

Figure 2. Total value per tree under four scenarios: high lumber/high chip prices (Hi/Hi), high lumber/low chip prices (Hi/Lo), low lumbe/high chip prices (Lo/Hi), and low lumber/low chip prices (Lo/Lo).

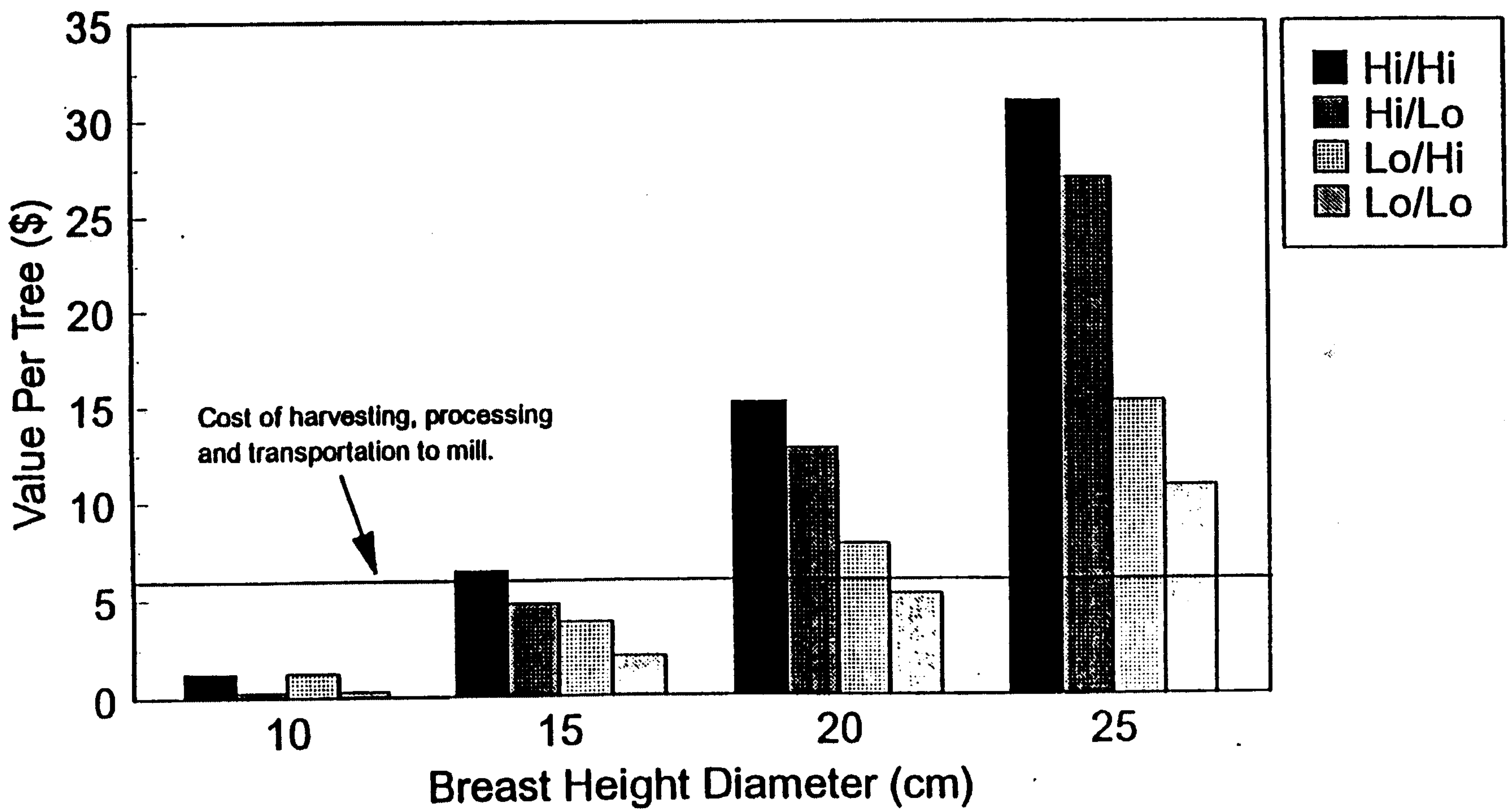

Table 1. Composite stand descriptions, initial conditions and results of Forest Vegetation Simulator (FVS) projections of numbers of large trees, snags, and removed volume after 150 years.

Stand Type	Regime	Trees/ Hectare ≥ 51 cm	Max. DBH (cm)	Snags/ Hectare ≥ 41 cm	Total Volume Removed (m^3)
WLDF	Initial	0	45	0	0
	NT	0	50	2	0
	TH	64	91	10	136
	CC	89	96	5	113
	GRP	67	91	10	202
WLLP	Initial	0	40	0	0
	NT	0	50	0	0
	TH	64	91	7	147
	CC	114	86	7	142
WRC	Initial	0	40	0	0
	NT	2	56	0	0
	TH	47	86	5	151

Table 2. Weighted average fiber length and fiber coarseness.

Raw Material	Weighted Average Fiber Length (mm)	Coarseness (μg/m)
L. Pine (SDT)	2.857	118
L. Pine (SSL)	2.877	126
L.Pine (C)	3.153	155
W. Larch (SDT)	3.090	155
W. Larch (SSL)	3.210	148
D. Fir (SDT)	2.660	133
D. Fir (SSL)	2.667	114
D. Fir/Larch (C)	3.323	155

SDT = small diameter trees, SSL = submerchantable sawlogs, C = sawmill residual chips.

Table 3. Harvesting, forwarding, loading, and hauling costs for different size trees.

Tree Diameter (cm)	Vol Inside Bark (m^3)	Cost per Tonne ($/T)			Tree Weight (T)	Total Cost per Tree ($)
		Harv	Haul	Total*		
10	0.028	>19	>12	>37.1	0.026	>6.00**
15	0.088	>19	>12	>37.1	0.080	>6.00**
20	0.176	19	12	37.1	0.161	6.00
25	0.343	6.5	4.5	17.1	0.314	5.35

* Includes $0.10/T for loading and $6.00 for hauling 40 km.
**These trees are smaller than the range covered in the study so harvesting costs can not be estimated. They would, however, be higher than the larger trees on a per tonne basis.

1997 Environmental Conference & Exhibit

Book 1

May 5-7, 1997
Minneapolis Convention Center
Minneapolis, MN

TAPPI
Technology Park/Atlanta
P.O. Box 105113
Atlanta, GA 30348-5113, USA

TAPPI PRESS