HARVESTING STRATEGIES FOR INCREASING THE AVAILABILITY AND QUALITY OF HARDWOOD FIBER

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Abstract—Worldwide demand for wood and wood products will continue to increase as global human population increases. These increasing demands for wood will continue to provide economic incentives for non-industrial private forest-land (NIPF) owners to increase the availability and quality of wood fiber harvested from their lands. The challenge is to encourage and facilitate NIPF owners and other commercial forest industries to support these demands without compromising their own short- and long-term economic and other ownership goals.

Over the years silvicultural researchers have developed methods for growing quality trees faster and in more ecologically, environmentally, and socially acceptable ways. Simultaneously, harvesting researchers have developed an enormous database on alternative logging technologies to harvest timber in economically and environmentally acceptable ways. This study demonstrates that integrating what we know about growing trees with what we know about harvesting them can increase the availability of wood fiber and add value to future crops.

Results for the oak/hickory forest type in West Virginia show that up to 1,736.61 ft^3/acre of wood fiber can be harvested 10 years sooner than usual by simply matching size of machine to wood harvested. Specifically, the study focused on the gains that can be made by matching size of machines to size of wood harvested, by utilizing harvesting machines better and more efficiently, and by training machine operators to be more efficient. Gains of up to 40 percent in present net worth can be attained by early thinning of a stand when harvesting machines are matched to wood size harvested. Results of the study benefit loggers, planners, managers, forest industry, NIPF owners, and society in general.

INTRODUCTION

As global human population increases, worldwide demand for wood and wood products will continue to increase. Because the majority of the hardwood forested land in the United States is owned by non-industrial private forest-land (NIPF) owners (Birch 1996), they will be asked to increase the availability and quality of wood fiber harvested from their lands. The challenge for forest industry and NIPF owners is to meet these demands while simultaneously meeting their own short- and long-term economic and ownership goals (Sampson 1996). Another challenge is to communicate the silvicultural and harvesting technology advances to the forest industry and NIPF owners so they can continue to provide wood products to society in a sustainable manner over time (Cantrell 1996).

Researchers have accumulated volumes of knowledge about how to regenerate and grow trees (Smith and others 1988). We know a great deal about how different species of trees respond to alternative silvicultural treatments. Stocking guides have been developed to maximize tree growth for selected species (Lancaster and Leak 1978, Sampson and others 1980). Over the same time, research in logging methods has been accumulated on production, cost, and applicability for a wide range of cable logging (LeDoux 1985), ground-based (Huyler and LeDoux 1989) and cut-to-length/forwarding machines (Huyler and LeDoux 1996). Harvesting studies in clearcuts, thinnings, shelterwoods, and group-selection applications (LeDoux and others 1991, LeDoux and others 1993) evaluate these different processes and silvicultural systems. We know a great deal about how to regenerate, grow, and harvest trees in environmentally acceptable ways. The need is to integrate what we know about silviculture with what we know about logging technology and then to get the information to loggers, land managers, forest industry, and NIPF owners.

METHODS

Description of ECOST Version 3 and MANAGE

ECOST Version 3 and MANAGE were the models used in this study. ECOST Version 3 is a stump-to-mill logging cost-estimating model for Eastern hardwoods. ECOST Version 3 allows for the stump-to-mill cost estimation for cable and ground-based systems. The difference from previous versions is that it includes skidding cost and production functions for four small farm/skidding tractors and for three skidders with small, medium, and large capacity. Specifically, ECOST Version 3 allows the user to estimate the felling, bucking, limbing, yarding/skidding, loading, hauling, and unloading costs for several cable yarders, small tractors, and skidders. The costs can be estimated in components or as stump-to-mill for most conditions loggers will encounter when logging Eastern hardwood stands.

MANAGE (LeDoux 1986), a computer program written in FORTRAN V, integrates harvesting technology, silvicultural treatments, market price, and economic concerns over the life of a stand. The simulation is a combination of discrete

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and stochastic subroutines. Individual subroutines model harvesting activities, silvicultural treatments, growth projections, market prices, and discounted present net worth (PNW) economic analysis. Specifically, the model allows the manager to evaluate how alternative harvesting technology, silvicultural treatments, market price, and economic combinations affect costs and benefits over the life of a stand. The model uses a detailed, individual user-specified tree list and then projects stand growth based on some user-specified silvicultural treatment, harvests the desired volume or stems with the logging system specified, sells the wood, and conducts economic analysis for the respective treatment and entry. MANAGE was run for a stand in the oak-hickory forest type with alternative combinations of logging technology.

Using ECOST Version 3, the user obtains information on skidding costs for alternative logging machines and for any set of silvicultural/stand conditions. Using MANAGE, the user can project the costs and benefits of alternative combinations of silvicultural treatments and logging technology for any stand of interest.

Harvest Treatments

The harvesting treatments evaluated include no thinning and an area-wide low thinning that removed all trees below an average dbh of 12 inches. The objective for each thinning treatment was to leave the larger crop trees in order to grow quality wood products for the final harvest. The wood harvested was sold as pulpwood and sawlogs. The stand was logged with ground-based logging technology. Specifically, the stand was logged with a JD 440C, JD 540B, and a JD 640D skidder. The John Deere machines are all articulated frame, four-wheel drive cable skidders manufactured in the United States. The John Deere 440C is a 70-horsepower skidder, the 540B is 90-horsepower, and the 640D is 120-horsepower. These three machines are representative of the types of cable skidders found on logging jobs in the Eastern United States.

Site and Stand Conditions

In this study, the stand chosen for demonstration is from the oak/hickory forest type in West Virginia and represents 2,971 acres in total land area. The species mix includes northern red oak (*Quercus rubra* L.), American basswood (*Tilia americana* L.), white ash (*Fraxinus americana* L.), and black cherry (*Prunus serotina* Ehrh.). The average site index of the stand is about 70. The stand is 60 years old and contains 257 trees per acre that are more than 5 inches dbh. The stand has an average tree dbh of 11.13 inches and about 4,412.42 ft^3/acre of merchantable volume. The land is located on gentle to moderate slopes and requires ground-based systems for harvesting. It is assumed that new road construction is not required. The stand is located 25 miles from a pulpmill/sawmill.

RESULTS

Matching Machines to Wood Size

The thinning was simulated at different stand ages using JD 440C, JD 540B, and JD 640D skidders. The resulting delay-free skidding costs were graphed by machine and the average stand diameter at each age (Fig. 1). The cost curve for the JD 440C is truncated at 12.2 inches because turns containing multiple logs of this tree size exceed the capacity of the machine. At a stump-to-road cost of \$0.20/ft^3, the JD 440C would breakeven when operating in stands that average 6.6 inches dbh. The JD 540B would breakeven in stands that averaged about 8.5 inches, and the JD 640D would breakeven at average dbh of about 9.1 inches. By matching the smaller, less expensive skidder with younger stands, the manager/logger can enter younger stands earlier to conduct the thinning. Using a larger machine such as the JD 640D for the thinnings would require that the stand contain bigger trees before reaching breakeven conditions (Fig. 1). Matching skidding machines to tree size could allow managers/loggers to enter younger stands and capture all the benefits of thinning and yet breakeven. Matching the size of machine to the size wood harvested also makes the wood from the thinnings available to fiber markets earlier in the life of a stand and increases the availability of wood fiber to markets.

Impact of Utilization Rate on Entry Timing

Clearly, few logging operations/machines operate in delay-free environments. Delays range from total machine malfunction resulting in a major breakdown/delay to the machine operator taking too many breaks or failing to service the machine. The thinning was simulated at different ages with a JD 540B skidder at utilization levels of 90, 80, and 60 percent (Fig. 2). Utilization rate is measured as the percentage of working time that the machine is actually being used in a productive mode as opposed to being non-productive while in a delay mode. A machine with a high utilization rate will generally produce more wood volume/unit time and cost less/unit produced than the same machine at a lower utilization rate. For this study, at a cost/ft^3 of \$0.20, the JD 540B at 90 percent utilization would breakeven while operating in stands that averaged about 11.5 inches dbh. For the same machine

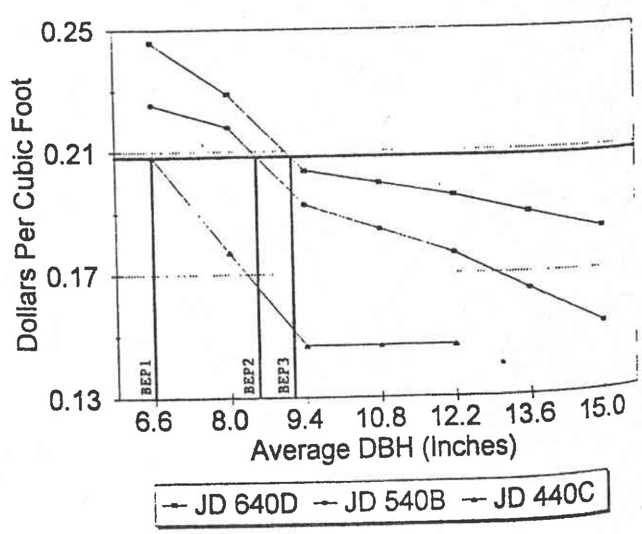

Figure 1—Simulated delay free skidding costs for JD 440C, JD 540B, and JD 640D skidders by average stand dbh (BEP = breakeven point).

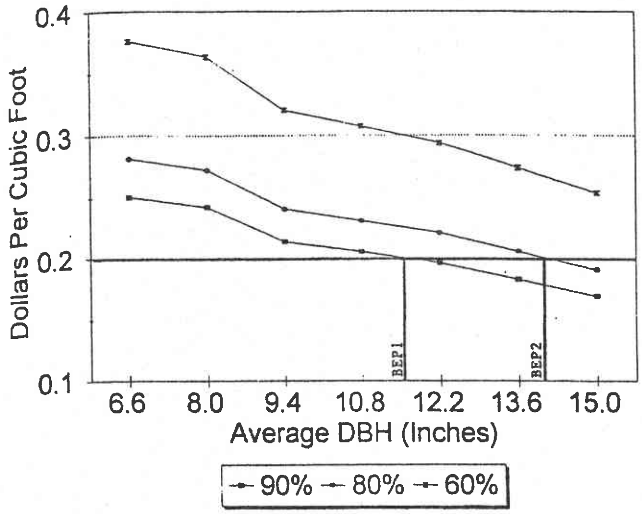

Figure 2—Simulated skidding costs for JD 540B skidder at three utilization levels by average stand dbh (BEP = breakeven point).

and conditions, but at an 80 percent utilization rate, the breakeven point occurs at about 14.0 inches dbh. At a utilization rate of 60 percent, the JD 540B would not breakeven. Operator training strategies to increase the utilization rate of machines can allow managers/loggers to operate in younger/smaller dbh stands, thus making wood fiber available to wood markets earlier in the life of a stand.

Impact on Rotation Age and Wood Quality

The advantages of entering a stand earlier in its life by matching machine size to wood size were further studied by inputting the costs from Figure 2 at the 90 percent utilization level into the MANAGE model. Initially, the stand was not thinned and was projected to its Optimal Economic Rotation Age (ORA). The stand was then thinned using a JD 440C and a JD 540B skidder at the earliest age possible that would result in an economic/breakeven entry to illustrate the impact of matching machines to wood size on rotation age, financial returns, and resulting quality development. The stand was thinned at age 60 with the JD 440C. The stand was thinned at age 70 with the JD 540B because of the higher skidding costs. The thinned stands were then projected to their ORA. The delivered product prices used in this study by species and log quality are shown in Table 1. The results from simulations for the no-thin and thinning treatments with MANAGE are summarized in Table 2. Matching machine size (JD 440C) to wood size would allow the stand to be thinned at age 60 yielding 1,736.61 ft^3/ac of wood fiber. Under the same conditions but thinning the stand at age 70 (with JD 540B), the yield is 1,484.97 ft^3/ac. Using the smaller skidder and thinning all 2,971 acres could yield 5.1 million ft^3 of wood fiber that would be economically available 10 years earlier than if a larger skidder were used in the first thinning. The thinnings do not produce more volume overall, they just make fiber available earlier.

Table 1—Delivered log prices by species and grade, International 1/4-inch (Worthington and others 1996)

Species group	Grade 1	Grade 2	Grade 3	Pulpwood
	- - - - - - -	*$/mbf*	- - - - - - - -	*$/Cord*
Red oak	561	397	225	40
Basswood	321	239	143	40
Black cherry	571	400	259	40
Ash	420	297	169	40

Table 2—Simulated results by size of skidding machine

Machine	JD 440C	JD 440C	JD 540B
Thinning age (yrs)	No thinning	60	70
Avg. stand d.b.h. (in)	-	8.78	9.13
Trees cut/acre	-	172	134
Vol. removed/ac(ft^3)	-	1736.61	1484.97
Present net worth (PNW-$)[a]	-	38.28	9.11
Cash flow/ac. ($)	-	38.28	12.24
Optimal rotation age (ORA, yrs)	90	100	110
Ave d.b.h. at ORA (in)	14.03	20.32	20.12
Vol/acre at ORA, ft^3	5507.94	4355.94	5047.51
Total vol/acre removed, ft^3	5507.94	6092.55	6532.48
PNW/ac at ORA ($)[b]	1360.67	1872.98	1614.78
Cash flow/ac at ORA ($)	3302.70	6109.72	7079.05

[a] Real discount rate = 3 percent.
[b] Discounted to age 60.

The unthinned stand reached its ORA at 90. The thinned 60-year-old stand would reach its optimal rotation 10 years sooner than if the stand were thinned with the larger skidder at age 70. Both thinned stands would produce wood that would average 20+ inches dbh compared to 14+ inches in the unthinned stand. The larger 20-inch dbh trees would yield higher quality logs than those from the 14-inch stand. Since the thinned 60-year-old stand reaches optimal rotation sooner than the thinned 70-year-old stand, the present net worth (PNW) is $1,872.98 compared to $1,614.78, or an increase of 15.99 percent. This could represent a gain of $853,776.27 in cumulative PNW over the thinned 70-year-old stand if all 2,971 acres were thinned at one time. It is unlikely that all 2,971 acres would be thinned at one time, but for this analysis it demonstrates the potential volume and financial yields possible. The thinned 60-year-old stand produces a cumulative PNW increase of $550.59/acre compared to the nonthinned stand. Although the thinnings do not produce more volume overall, they serve to concentrate the remaining volume on fewer stems but of higher quality.

CONCLUSIONS

Matching machine size to size of wood harvested results in wood fiber available earlier in the life of the stand, shorter ORA for similar size products, and significant gains in PNW—up to 16 percent. Strategies to improve machine utilization also allow managers/loggers to enter stands earlier making wood fiber available earlier and improving the quality/adding value to the future stands. In addition, the combination of carefully matching the size of machines to the size of wood harvested and implementing strategies to reduce skidding delays allows managers/loggers the same benefits. Up to 1.736.61 ft^3/acre of wood fiber can be made available sooner by simply using smaller, less expensive skidders to enter the stands at earlier ages. Thinned stands produce larger dbh/higher quality wood and, thus, larger economic returns compared to unthinned stands. Gains of up to 40.46 percent in discounted cumulative PNW can be realized by early thinning versus no thinning.

In this study, we did not consider the impact of residual stand damage on financial yields over time. We have found that residual stand damage from thinnings can range from none to very high levels. The impact of residual stand damage is best dealt with on a case-by-case basis. Although most NIPF owners own tracts substantially less than 2,971 acres, the results are applicable to small tracts as well. The increased availability of wood fiber along with the value added in quality to the future stand will help meet the world's demand for fiber and quality hardwoods.

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