THE INTERACTIVE IMPACT OF FOREST SITE AND STAND ATTRIBUTES AND LOGGING TECHNOLOGY ON STAND MANAGEMENT

Chris B. LeDoux and John E. Baumgras[1]

Abstract: The impact of selected site and stand attributes on stand management is demonstrated using actual forest model plot data and a complete systems simulation model called MANAGE[2]. The influence of terrain on the type of logging technology required to log a stand and the resulting impact on stand management is also illustrated. The results can be used by managers and planners in making decisions on how best to manage the hardwood resource.

INTRODUCTION

Intensive management of immature eastern hardwood stands has received increased attention (U.S. Department of Agriculture 1981, Smith and Eye 1986). Economic returns to management activities in these stands are affected by logging and processing technology and transport costs (LeDoux 1988a). Hardwood market trends, stand growth-and-yield response, stand composition, and landowner objectives also influence hardwood management decisions.

Decision makers and planners need to know which site and stand attributes affect costs and benefits and to understand how these variables interact for a particular management plan. Plans must incorporate short- and long-term effects of site and stand variables on management. Additionally, the choice of logging technology significantly can constrain stand management options.

---

[1]Industrial Engineer and Project Leader, and Research Forest Products Technologist, U.S. Department of Agriculture, Forest Service, 180 Canfield Street, Morgantown, WV 26505

[2]The computer program described in this publication is available on request with the understanding that the U.S. Department of Agriculture cannot assure its accuracy, completeness, reliability, or suitability for any other purpose than that reported. The recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a Government-produced computer program.

METHODS

In this article, the effect of site and stand attributes, and logging technology on stand management is evaluated with a complete systems simulation model called MANAGE (LeDoux 1986). MANAGE, a computer program written in FORTRAN 77, integrates harvesting technology, silvicultural treatments, market prices, and economic criteria over the life of a stand. The simulation combines discrete and stochastic subroutines to model harvesting cost, silvicultural treatments, growth projections, and to conduct discounted cash flow (SEV) analysis. The model can be used to develop optimal management guidelines for eastern hardwoods. The results also can help planners and managers understand the impact of site and stand variables on costs, benefits, and returns to management practices.

Stand Tables

The stand tables used to initiate the simulations were those published by Schnur (1937) for even-aged upland oak forests (Table 1). These tables represent projected conditions by site index and age for fully stocked upland oak stands. To insure that all first thinning entries were economically feasible, the ages of the stand tables selected to initiate the simulations varied by site index. For example, the average diameter of the initial stands averaged about 8 inches and the starting volume averaged about 2500 ft^3/acre (Table 1). Because it takes longer to attain average d.b.h. of 8 inches or poor sites than better sites, simulation begins later for low site indexes.

The initial tree lists by site index were entered into MANAGE and the growth and yield was projected for a variety of management scenarios. Cable and ground-based logging technology were evaluated by site index for each stand. The costs and benefits by site index were simulated and summarized on a cash flow and discounted cash flow soil expectation basis.

Logging Technology

The interaction of logging technology and stand attributes by site index was evaluated by assuming that the stands shown in Table 1 were located on both steep and gentle terrain. The Clearwater[3] yarder (LeDoux 1987) was used to simulate harvesting of the stands for the steep terrain applications. The Clearwater yarder is a medium size yarder capable of yarding small and large logs. A John Deere 540B rubber-tired skidder was used to simulate the harvest of

---

[3]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

the stands on gentle terrain applications (LeDoux 1985; LeDoux 1988b). The John Deere 540B is a medium size skidder capable of skidding small and large logs. Figures 1 and 2 show the John Deere 540B and Clearwater yarder, respectively. The costs for the above machines were estimated using EASTCOST (LeDoux 1988b). The streams of cost and benefits were summarized by treatment, site index, and logging technology and presented on a soil expectation basis. The delivered product prices used are shown in Table 2 and were obtained from Coastal Lumber Company, Hopwood, PA and Forest Product Price Bulletins (Ohio, 1989; Penn State, 1989; Tennessee, 1989).

Table 1.--Initial attributes of timber stands; average d.b.h., ft^3 volume, age, trees, and species mix, by site index, for even-aged upland oak stands.

					Species				
Site index	Mean DBH	Vol	Age	Trees/ acre	Red maple	White ash	White oak	Red oak	Hickory
	Inches	Ft^3/ acre	Years		Percent				
50	8.3	2535	90	284	5.0	6.0	57.0	25.0	7.0
60	8.4	2474	70	271	6.0	6.0	51.0	32.0	5.0
70	8.8	2596	60	258	5.0	6.0	45.0	38.0	6.0
80	8.9	2612	50	249	5.0	6.0	38.0	45.0	6.0

Table 2.--Delivered prices for sawlogs and fuelwood/pulpwood by species.

Species	Large[1] sawlogs	Medium[2] sawlogs	Small[3] sawlogs	Fuelwood/[4] pulpwood
	$/Mbf (Doyle Rule)			-$/Cord-
Red Maple	210	160	80	30
White Ash	500	300	100	30
White Oak	500	300	100	30
Red Oak	600	350	100	30
Hickory	210	160	100	30

[1]Minimum small end diameter ≥ 13 inches, length ≥ 10 feet.
[2]Minimum small end diameter ≥ 11 inches, length ≥ 8 feet.
[3]Minimum small end diameter ≥ 10 inches, length ≥ 8 feet.
[4]89 ft^3/cord, minimum small end diameter ≥ 4.0 inches that will not make large, medium, or small sawlogs.

Figure 1. The John Deere 540B skidder.

Management Objectives

For comparison purposes, the stands were subjected to one thinning and then projected to optimal (The maximizing of SEV.) rotation age by logging technology. Soil expectation value (SEV) is used to compare returns[4]. Initial thinning ages were defined as the earliest age that a stand could be commercially thinned by the logging technology specified and pay for itself or at least break even. Area versus crop-tree-release thinnings were simulated with the objective of producing quality sawlogs at final harvest.

---

[4]The soil expectation value is a maximizing of the present net worth of revenues minus costs from an acre of bare ground and all future stands on that acre.

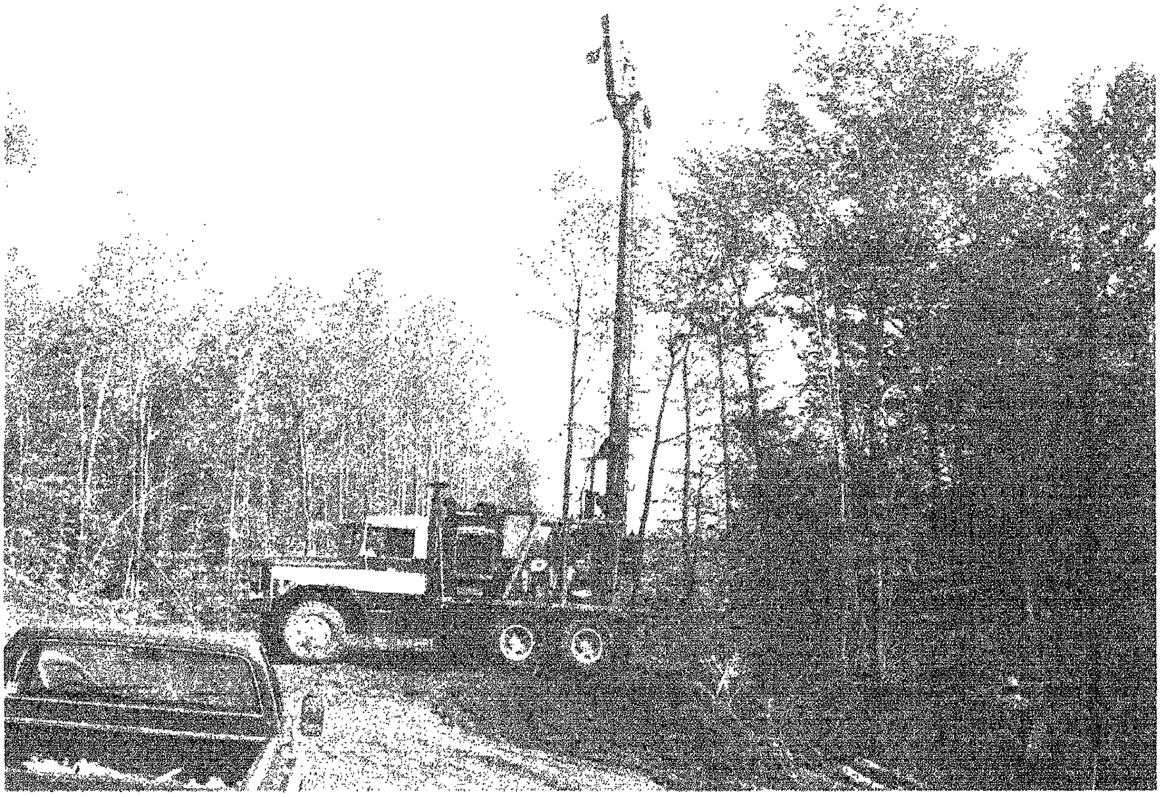

Figure 2. The Clearwater cable yarder.

RESULTS

The results indicate that lower site-index stands have lower soil expectation values and longer optimal rotations. Comparing the optimal rotation length for the John Deere 540B skidder by site index shows the effect of site index on soil expectation and rotation length. For example, site index 50 has a soil expectation value of $2.03/acre with an optimal rotation age of 195 years. By contrast, a site-index-80 stand has a soil expectation value of $32.55/acre with an optimal rotation age of 130 years (Fig. 3). Higher site indexes generally resulted in larger average d.b.h. trees at optimal rotation and greater yields. It is interesting to note that the optimal rotation ages generally are producing trees that average 15 to 16 inches d.b.h.

The effects of logging technology also are shown in Figure 3. Generally, use of cable logging to harvest the stands resulted in optimal rotation lengths 10 years longer than when using the ground-based system, the John Deere 540B skidder. This is due to delaying of thinnings by 5 years and harvesting more trees and volume from thinnings to offset the high

Figure 3. Soil expectation, average d.b.h., optimal rotation length, and total volume harvested at optimal rotation age by site index and logging technology.

costs of expensive skyline logging systems. As a result, the average d.b.h. and value of trees removed in thinning were greater when cable logging technology was applied. The increase in average d.b.h. results from stands being grown 10 years longer than when ground-based systems were used. Figure 3 shows the soil expectation value for the optimal rotation length by site index. The results include cash flows from both thinnings and final harvests.

Table 3.--Net cash-flow components from commercial thinning (CT) and final harvest (FH) by logging technology and site index.

Entry (years)	Average d.b.h.	Volume removed	Gross revenue	Total stump-to-mill cost	Net cash flow
	Inches	ft^3/acre	----------- Dollars/acre	-----------	
		Site Index 50 and John Deere 540B			
CT-110	12.51	2304.80	1063.09	939.94	123.15
FH-185	12.59	3952.73	3435.14	1368.7	22066.42
		Site Index 50 and Clearwater			
CT-115	13.05	2493.32	1280.99	1180.98	100.01
FH-195	16.08	4149.84	3692.20	1749.54	1942.66
		Site Index 60 and John Deere 540B			
CT-90	12.65	2558.52	1142.38	1019.43	122.95
FH-160	16.09	3989.97	3690.82	1364.11	2326.71
		Site Index 60 and Clearwater			
CT-95	13.17	2781.67	1477.27	1307.57	169.70
FH-160	15.47	3689.72	3051.62	1589.45	1462.17
		Site Index 70 and John Deere 540B			
CT-75	12.65	2462.80	1089.15	987.70	101.45
FH-145	16.19	4256.28	4469.47	1443.78	3025.69
		Site Index 70 and Clearwater			
CT-80	12.94	2911.28	1533.95	1379.20	154.75
FH-155	17.40	4075.24	4496.52	1655.87	2840.65
		Site Index 80 and John Deere 540B			
CT-65	12.83	2663.76	1187.14	1047.97	139.17
FH-130	16.91	4313.79	4960.93	1438.74	3522.19
		Site Index 80 and Clearwater			
CT-70	13.11	3096.87	1712.40	1455.60	256.80
FH-140	18.07	4108.00	4893.95	1641.78	3252.17

Table 3 shows the average d.b.h., volume harvested (ft^3), undiscounted cash flows by entry and final harvest for each site index and logging technology. Generally, stands could be thinned at an earlier age for each site index when using ground based systems. This is due largely to the use of cable systems resulting in higher harvesting cost and the thinning delayed by 5 years until the trees were larger and were valuable. Thinnings become economical for the rubber-tired skidder when the trees average about 12 inches d.b.h. By contrast, the stands need to average about 13 inches for the Clearwater. The 12- and 13-inch-d.b.h. economic-feasibility limits range from a stand age of 70 to 110 years for site index 80 versus a site index of 50. Further, in most cases the initial commercial thinning must remove approximately 2,300 ft^3/acre when using ground-based systems and approximately 2,500 ft^3/acre when using cable technology. Earlier thinnings would require either subsidy by the landowner or higher prices for low quality roundwood.

CONSIDERATIONS FOR MANAGERS

We deliberately started with stands of different ages but similar mean d.b.h., volume, and species composition so that reasonable comparisons could be made between site indexes and logging technology. Results show that one commercial thinning can be initiated at age 65 on site index 80 with ground-based technology and at age 115 on site index 50 with cable-logging technology. Optimal rotation ages for the residual stands range from age 130 on site index 80 with ground-based technology to age 195 on site 50 with cable-logging systems. Cash flows for the thinnings range from about $100/acre on poor sites to $257/acre on good sites. Cash flows for the final harvest at rotation age range from $1,462/acre on poor sites to $3,522/acre on good sites.

The average tree d.b.h. and volume removed per acre significantly affect logging costs and the way a stand is managed to maximize soil expectation value. Site index, in turn, influences d.b.h. and volume growth, thus having an important influence on the way even-aged oak stands are managed. The terrain on which a stand is located dictates the kind of logging technology that must be used during thinnings and harvests. As we have shown, logging technology can influence timing of thinning entry and optimal rotation age. For example, soil expectation values can range from $2.03/acre on site index 50 to $32.55/acre on site index 80 or a difference of about 1503 percent when using cable-logging technology. By contrast, soil expectation values range from $30.01/acre to $32.55/acre when using the Clearwater and John Deere 540B on site index 80, or a difference of about 8 percent. The effect of logging technology on soil expectation is more pronounced on poorer sites (53 percentage difference) than on good sites (8 percentage). SEV was maximized using the John Deere 540B on all sites.

The objective of this paper was to demonstrate the interactive impacts of site and stand attributes and logging technology on the way a stand is managed. We did that for two logging technologies and five site indexes with a fixed set of delivered prices to a sawmill. Although the timing of thinning entry and optimal rotation ages are specific to the values and stands used in this evaluation, the results do show the importance of considering site and stand attributes during planning of stand management scenarios.

The results for timing of thinning entry and optimal rotation age will change with other site indexes, species composition and mix, logging technology, and delivered prices. However, the impact of site and stand attributes on stand management still remain significant. Other scenarios could be evaluated by making additional simulation runs.

LITERATURE CITED

LeDoux, C.B. 1985. Stump-to-mill timber production cost equations for cable logging eastern hardwoods. Res. Pap. NE-566. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 6 p.

LeDoux, C.B. 1986. MANAGE: A computer program to estimate costs and benefits associated with eastern hardwood management. NE-GTR-112. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 7 p.

LeDoux, C.B. 1987. Estimating yarding costs for the Clearwater yarder. Res. Pap. NE-609. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 4 p.

LeDoux, C.B. 1988a. Impact of timber production and transport costs on stand management. Res. Pap. NE-612. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 5 p.

LeDoux, C.B. 1988b. EASTCOST-- stump-to-mill timber production cost equations and computer program. Unpublished report on file at U.S.Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, 180 Canfield St., Morgantown, WV 26505.

Ohio Agricultural Statistics Service. 1989. Timber Prices. Columbus, Ohio: February. 2 p.

Pennsylvania State University. 1989. Pennsylvania woodlands timber market report. University Park, PA: April-June. 3 p.

Schnur, L.G. 1937. Yield, stand, and volume tables for even-aged upland oak forests. Tech. Bull. No. 560, Washington, D.C: U.S. Department of Agriculture. 87 p.

Smith, H. Clay; Eye, Maxine C.; eds. 1986. Guidelines for managing immature appalachian hardwood stands: Workshop proceedings; 1986 May 28-30; Morgantown, WV. SAF Publ. 86-02. Morgantown, WV: West Virginia University Bookstore. 283 p.

Tennessee Division of Forestry. 1989. Tennessee Forest Products Bulletin. April-June. Nashville, Tenn. 13 p.

U.S. Department of Agriculture. 1981. Proceedings of the national silviculture workshop on hardwood management; 1981 June 1-5; Roanoke, VA. Washington, D.C.: U.S. Department of Agriculture, Forest Service, Timber Management. 304 p.