AN INTEGRATED APPROACH FOR DETERMINING THE SIZE OF HARDWOOD GROUP-SELECTION OPENINGS

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ABSTRACT

The use of group-selection methods is becoming more widespread as landowners and forest managers attempt to respond to public pressure to reduce the size of clearcut blocks. Several studies have shown that harvesting timber in smaller groups or clumps increases the cost of operations for both cable and ground-based logging systems. Recent regeneration studies have shown that the number of stems, numbers of shade-tolerant and intolerant species, basal area, and volume are affected by the size of the opening created. The size of the opening and resulting vegetation also affects the wildlife species that use these small openings. We integrated the results from several cable and ground-based logging studies with those from several regeneration studies to determine the most effective size of group-selection openings. Managers can maximize financial yields by using group-selection units of 1.25 acres or larger. These results should be valuable to managers, loggers, and planners considering group-selection methods.

Public concern about clearcutting has resulted in the increased use of group-selection methods by landowners and forest managers. The small openings created by these techniques allow for the harvesting of timber without impairing the visual quality of the site. However, managers interested in keeping logging costs to a minimum are concerned about the potential loss of production and profit in choosing group-selection over conventional forms of clearcutting. The challenge to managers is to define the size of group-selection units that will maximize financial returns over the life of the stand.

Group-selection entails harvesting small groups or clumps of trees in a somewhat random pattern across a stand to capture mortality and insect and disease infestations, regenerate stands, and harvest financially mature trees. Group-selection has certain advantages over single-tree selection: 1) older mature trees can be harvested more economically and with less damage to the residual stand; 2) managers are afforded greater flexibility in creating environmental conditions that favor successful reproduction; and 3) reproduction develops in well-defined, even-aged aggregations. The latter is a substantial advantage over single-tree selection in developing good tree form, particularly in hardwoods (21).

Group-selection cuttings also create openings or gaps in the forest canopy that can increase the area of desirable habitat for wildlife. Many species of wildlife benefit from the combination of environmental conditions existing within and along the boundaries between the young reproduction and older adjacent trees. A wide array of protective cover is available in proximity to various food plants that may be created by the broad spectrum of microclimatic conditions existing between the edges and the centers of the young groups.

Although size of opening and resulting vegetation also affect wildlife species that use these small openings, we did not analyze the relationship between size of opening and wildlife impacts. The effects of group selection versus clearcutting on breeding birds were compared in the Southern Appalachian hardwood forests of Virginia (10,11). Clearcuts and large group selection cuts (> 2.7 ac.) provided breeding habitat for the same bird species. Both methods negatively impacted forest-interior species in the adjacent forest. However, the net negative effect was substantially less for clearcuts than for an equivalent area harvested by group selection. In other studies (4,5,8), conventional clearcutting was compared with group selection cutting in northern hardwood stands in New Hampshire and Vermont. Group selection appears to retain much of the mature forest bird community while providing benefits for only a small number of early successional species. Size of opening and its use by wildlife is best evaluated in the field by managers familiar with actual conditions. For example, several small openings located close to each other among different types of forest cover will be used differently by wildlife than one large opening surrounded by a single type of forest cover.

Harvesting studies of group selection in eastern hardwoods have shown that the economic success of such harvests relies heavily on product markets, tree species and quality, and logging costs (1-3,

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TABLE 1. — Most common species and their relative frequency by shade tolerance and desirability for timber products (6).

Intolerant		Intermediate		Tolerant	
Preferred					
Yellow-poplar	.148	White oak	.051	Sugar maple	.017
Black cherry	.049	Chestnut oak	.045		
White ash	.013	Black oak	.010		
Scarlet oak	.010	N. red oak	.009		
S. red oak	.010				
Nonpreferred					
Hickory	.047	Red elm	.004	Red maple	.240
Sweet birch	.043	Cucumber tree	.003	Hemlock	.035
Black locust	.008	American elm	.001	Beech	.027
Aspen	.003	Yellow birch	.001	Blackgum	.025
Virginia pine	.002			Basswood	.003
Other					
Sassafras	.053	Fraser magnolia	.025	Dogwood	.050
Sumac	.001	Magnolia spp.	.012	Sourwood	.028
				Redbud	.014
				Serviceberry	.005
				Holly	.003

TABLE 2. — Attributes of reconstructed stands at age 30, by opening size (6).[a]

Size of opening	Tolerance class	No. of trees	Basal area	Total volume	Merchantable volume	Quadratic diameter by tolerance class
(ac.)			($ft.^2$)	------- ($ft.^3$/ac.) -------		(in.)
0.25	Intolerant	138	17.92	470.64	167.83	4.87
	Intermediate	69	8.57	215.71	51.43	4.77
	Tolerant	123	12.47	294.15	51.43	4.31
0.50	Intolerant	163	23.59	627.82	207.84	5.15
	Intermediate	62	11.52	306.61	94.88	5.83
	Tolerant	163	19.75	525.61	149.10	4.71
1.00	Intolerant	145	27.23	811.38	371.22	5.86
	Intermediate	92	16.48	425.00	91.17	5.73
	Tolerant	203	27.94	695.46	188.86	5.02
1.50	Intolerant	187	36.13	1,032.85	421.09	5.95
	Intermediate	59	10.99	337.25	81.26	5.84
	Tolerant	211	31.42	737.75	236.40	5.22

[a] Species composition: Refer to Table 1 for relative frequency by shade tolerance and desirability for timber products.

7,13,14). Other studies have attempted to define group-selection harvests and when they can be used (18). In general, total harvesting costs increase as size of opening decreases. Results suggest that costs may be prohibitive for groups smaller than 0.50 acre when harvested with cable-logging systems (13).

Regeneration studies have shown that species composition can be affected by group-selection treatments (6,22). Small clearcuts also have a larger proportion of their total area influenced by the surrounding forest compared to larger clearcuts (15). The increased competition for water and nutrients due to these edge effects influences tree growth (6,17,20). Reductions in total height and merchantable height growth of new regeneration were reported near the opening edge for 10 to 30 years following small group-selection cuts (6,9,16,19,23).

Our objective in this study was to integrate harvesting data available from studies by LeDoux et al. (13,14) with data from Dale et al. (6) to determine the size of group-selection openings that would maximize financial yields for upland oak forests in the central hardwood region. The results presented here combine the most recent data available on logging costs and regeneration responses for group-selection treatments.

METHODS

A 1995 study (6) reported 30-year regeneration results from 89 group-selection plots located in the central hardwood upland oak forest region of West Virginia, Illinois, Ohio, and Kentucky. The units ranged in size from 0.04 to 1.61 acres. Because the stand characteristics were so highly correlated with opening size, the data from all regenerated plots were pooled (6) and they used non-linear regression techniques to develop equations for estimating number of trees, basal area, total cubic-foot volume, and merchantable volume as a function of opening size. Using these equations, species numbers, and species relative frequency distribution data (**Table 1**), we reconstructed the 30-year-old individual-tree stands for 0.25-, 0.50-, 1.0-, and 1.5-acre groups (**Table 2**). In the 1995 study, there was a higher proportion of shade-tolerant species in small openings, particularly on those of less than 0.1 acre (6). As opening size increased up to 1 acre, the proportion of shade-intolerant and intermediate species increased (6). Generally, smaller groups had less trees/acre, smaller trees, and more shade-intolerant and intermediate species. Larger groups had more trees/acre, larger trees, and more shade-tolerant species (6).

Data on individual-tree stands by unit size was input to the MANAGE simulation model (12). A computer program written in FORTRAN V, MANAGE integrates harvesting technology, silvicultural treatments, market price, and economic concerns over the life of a stand. The simulation is a combination of discrete and stochastic subroutines. Individual subroutines model harvesting activities, silvicultural treatments, growth projections, market prices, and discounted present net worth (PNW) economic analysis.

MANAGE was calibrated to produce stand attributes that are identical to those calculated from data in (6) for the initial 30-year-old stands. Three replications per group size were simulated using different initial random number seeds. The growth and products development of each stand was then projected to a rotation age of 90 years for comparison. MANAGE then calculated the harvesting cost for each unit size based on the volume/acre harvested and the average diameter of the wood removed. The delivered log prices used in this integration by species and grade are shown in **Table 3**. The comparison criterion used was the PNW at age 30 of a 90-year-old stand. The simulated average PNW by unit size is shown in **Table 4**.

RESULTS

The results in **Table 4** show that larger groups are cheaper to harvest than smaller ones, i.e., larger groups start out with more and larger trees/acre than smaller ones. The interactive effect of larger groups, larger trees, and more trees/acre results in increased revenue as size of opening increases. This effect integrated with harvesting efficiencies results in greater PNW yields per acre at age 90 for larger units. For example, units of 1.5 acres return \$37.86/acre in PNW. By contrast, units of 0.25 acre return \$10.73/acre in PNW, a 72 percent reduction in financial yields over a 60-year period. This equates to a net loss in PNW of \$0.45/acre/year. Because PNW was so highly correlated with size of opening, we used nonlinear regression techniques to predict PNW as a function of opening size. Size of opening was included as both linear and squared terms in the regression model because a curvilinear relationship between PNW and size of opening was observed. The computed regression parameters shown in **Figure 1** include the results from all the simulation runs. The terms of the regression model (intercept, size of opening-x_1, and size of opening-x_1^2) were highly significant ($p < 0.01$). When PNW is graphed by size of opening (**Fig. 1**), PNW yields/acre level off with units of 1.25 acres or greater. These results approach the results of other studies (6,13,14) for cable and ground-based logging of group-selection units. Time study results (13,14) found that production rates and yarding costs for units of 1.0 acre were similar to those for large clearcuts. However, field studies (13,14) found that total logging and layout costs for 1.0-acre groups were four to six times more expensive than those for large clearcuts. Regeneration in blocks of 1.0 acre or larger was similar to that in large clearcuts (6).

The major differences in the PNW in **Table 4** are due to the interactive effects of logging costs, species composition, mill prices, volume/acre, average stand diameter at breast height (DBH), and size of unit. For example, logging costs decrease with increasing opening size on a per unit produced basis because more volume/acre is being harvested. For example, the logging cost per cubic foot for 0.25-acre units is \$0.68. The logging cost per cubic foot for 1.0-acre units is \$0.56, which is a 17.65 percent reduction. The average piece size harvested is also larger in the larger units. The move-in-and-out costs associated with starting up and finishing a logging operation are prorated over the volume removed. In smaller units, the volume removed is low, thus

TABLE 3. — Delivered log prices by species and grade (24).[a]

Species group	Grade 1	Grade 2	Grade 3	Pulpwood
	($/MBF)[a]			($/cord)
Hickory	210	160	100	40
Black oak	450	250	100	40
White oak	450	250	100	40
Chestnut oak	450	250	100	40
Scarlet oak	450	250	100	40
Northern red oak	561	397	138	40
Yellow poplar	268	174	98	40
Red maple	200	125	50	40
Black cherry	571	400	259	40
Ash	420	297	169	40
Birch	107	86	85	40
Beech	106	91	86	40
Elm	76	76	76	40
Other hardwoods	76	76	76	40

[a] International 1/4-inch rule.

TABLE 4. — Simulated average logging cost, present net worth present net worth (PNW), mill price, and stand attributes for reconstructed stands at age 90, by size of opening.

Size of opening	Total volume	Average stand DBH	Logging cost	PNW[a]	Cash flow	Mill price
(ac.)	(ft.^{3}/ac.)	(in.)	($/ac.)			
0.25	2,507.37	10.02	1,697.33	10.73	63.22	1,760.55
0.50	3,134.22	10.87	1,942.59	16.92	99.69	2,042.28
1.00	4,123.97	11.57	2,289.27	33.58	197.84	2,487.11
1.50	4,259.74	11.75	2,325.07	37.86	223.06	2,548.13

[a] PNW at age 30 of a 90-year-old stand; real discount rate = 3 percent.

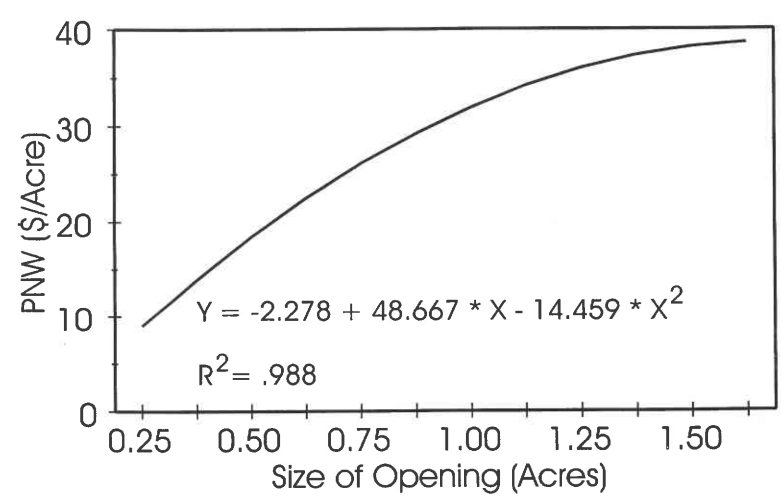

Figure 1. — Simulated present net worth (PNW) per acre by group-selection unit size.

move-in-and-out costs are higher than in larger units. Larger units harvested result in higher volumes/acre removed, larger trees, and lower move-in-and-out costs. This combination results in lower total logging costs for larger units.

Another major difference shown in **Table 4** is the effect of unit size on mill prices. Larger units result in more volume/acre, thus more value. The trees in the larger units are also bigger, which results in higher quality logs that bring higher prices at the mill. More and bigger wood from larger units results in higher mill prices/acre. For example, the mill price for 1.0-acre units is $2,487.11, a 41.26 percent increase over the mill price of 0.25-acre units. Another difference is that for units 1.0 acre in size and larger, the regeneration grows faster than in the 0.25- or 0.50-acre units. For example, at age 90, simulated results show trees reaching diameters of 10.02, 10.87, 11.57, and 11.75 for unit sizes of 0.25, 0.50, 1.0, and 1.50 acres, respectively. The 1.0-acre units have trees that average 11.57 inches in diameter compared to trees that average 10.02 and 10.87 inches in diameter from the 0.25- and 0.50-acre units. Trees averaging 11.57 inches in diameter will result in more grade 2 logs than those coming from a 10- or 10.87-inch-diameter stand. Grade 2 logs are worth more than grade 3 logs or pulpwood. This effect of faster-growing trees is reflected in the mill price for 1.0-acre units. There is an increase in mill price of $444.83 when going from 0.50- to 1.0-acre units. The difference in mill price between 0.25- and 0.50-acre units is only $281.73. Similarly, the difference in mill price between 1.0- and 1.50-acre units is only $61.02. Another difference in the mill prices by unit size is the effect of species composition. The larger units have a slightly higher proportion of shade-intolerant and intermediate species such as yellow-poplar, oaks, and other more desirable species for timber products. The more desirable species result in higher prices at the mills. Higher mill prices are the result of the interactive effect of the bigger units growing more desirable volume, growing it faster, and resulting in larger trees. This effect coupled with the logging efficiencies of harvesting more volume per unit area and larger piece sizes results in higher PNW values in the larger units.

Conclusions

Logging costs decrease and the number of regenerated trees/acre increases with increasing group size. Results from simulations show that the mean DBH of regenerated trees increases with increasing group size as the stand develops over time. More and larger trees/acre results in more merchantable volume/acre. The results of this investigation suggest that financial yields can be maximized by using group-selection units of 1.25 acres or larger to take advantage of the interactive effect of logging costs and regeneration efficiencies.

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