USING ECONOMIC FACTORS IN MANAGING HARDWOODS FOR HIGH QUALITY[1/]

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Abstract.--Because of the extremely wide range in product values from hardwood stands, harvest decisions must consider a multiplicity of factors, many of them economic. Among these are species, tree size, tree quality, logging costs, and market alternatives. This study demonstrates how to incorporate these, using a new microcomputer program with growth projection, YIELD-MS (Hepp, 1986), to find the thinning regime with a high economic advantage for a particular hardwood stand.

Keywords: Hardwoods, economic, quality, computer simulation

INTRODUCTION

In the management of hardwoods, there are many alternative treatments that need consideration each time an owner is ready for some activity, or each time a stand is re-examined for prescription in the progress of a management plan. Each alternative involves both economic factors of markets and harvesting costs peculiar to that location and also silvicultural factors of growth rates and species composition. The combinations of all these factors are so numerous that all of them are almost never given full consideration, and each stand often seems to require its own analysis. Add to these the infinite variety of mixtures of species and tree sizes, and the selection of a suitable cutting plan from a simple cruise or diagnostic tally is difficult, and the choice of an optimum cutting plan nearly impossible. The result has been that hardwood management decisions on both public and private lands have been reduced to a few simple alternatives, none of which is satisfactory to all the parties involved.

Four recent developments give hope that we can move beyond this situation in the near future. First, we have begun to have some solidly based growth functions for stands of mixed species and sizes of hardwoods (Harrison et al.,1986b: Hilt, 1983: Marquis et al, 1984: USDA, 1984). With these we can begin to project stand growth for one to several decades with some degree of reliability, in order to forecast the composition of both treated and untreated stands.

Second, economic evaluation approaches using discounted cash flow have developed to examine complex management regimes over extended periods of time, with a choice of economic criteria.

Third, computers have increased so much in computing speed and memory, while being reduced in size and cost, that problems involving many factors, such as the hardwood prescription problem, can soon be approached in the many field locations where they are encountered, or at least generalized guidelines can be developed to fit a wide range of situations.

Therefore, it is the objective of the project being reported here to develop a computerized hardwood stand prescription management system that will encompass most of the significant factors, both economic and biologic, that should be considered whenever a logging operation or other stand treatment is contemplated for a hardwood stand. Obviously, our knowledge is incomplete of all responses of all species in all conditions, but we hope to demonstrate the principles of such a system, so that it can be expanded to include other information as that becomes available.

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MARKET OPPORTUNITIES

The fourth factor expanding the possibilities, and at the same time the complexities, is the increasing variety in the markets for hardwoods. Not only are some of these providing new outlets for lower quality and smaller hardwood trees, but others are rewarding the forest owner who makes the effort to produce logs of higher grades and more valuable species.

Fuelwood is an outlet that has emerged in the past 12 years since energy prices have risen sharply. More recently fuel prices have receded from their high point, as the oil glut has appeared, but demand appears to be remaining almost as strong, especially in areas where many homes have made a conversion to stoves, or have traditionally used wood for heating. Fuelwood harvesting provides a means of doing improvement cuts and thinnings, especially on public lands where a good road network exists.

Pulpwood from hardwoods has never provided the opportunity for improvement cuts that it should, because loggers have preferred the easier operations of land clearing and clearcutting. Recently in some areas the demand for pulpwood sizes has increased, especially where new mills are making oriented strand and wafer boards. These frequently prefer the less dense hardwoods. The forest owner who will insist upon the special arrangements necessary for partial cuts for these products should find new opportunities.

The market for small hardwoods continues in many areas, especially where there are pallet mills, and occasionally where other types of wooden containers are made. The wood tie is still manufactured in some areas, but these mills often buy small logs in mixture with larger logs.

Graded sawlogs, especially of the higher valued species, can bring premium prices at larger sawmills. Where these mills are supplying the furniture industry, the demand remains strong, and tends to be partially correlated with housing start trends.

Veneer logs bring the highest prices, but this is a speciality market, and the landowner must make special efforts to attract these buyers. To receive the prices paid for the best quality logs, the land owner must be able to recognize that he has them, and then to obtain competitive bidding; otherwise they will be sold on the stump with other logs. Recently a market has developed for yellow poplar veneer logs.

Export of high quality logs has shown a remarkable increase in recent years, in both volume and price, and there is every indication that it will remain high in the foreseeable future. Hardwood logs from the central U.S. set the standard of trade in Europe and Japan, and the demand will remain or grow, as long as this country can supply high quality logs in dependable volumes.

Obviously, all these market outlets do not exist in every location. Not only market availability but also the immediate accessibility of the stand, conditioned by the existing or prospective road system, will determine the possibility of selling various products. Therefore the landowner, or the forester assisting him, must become familiar with local markets and the best ways of attracting a reliable logger and obtaining the price justified by the quality of the products sold. In some instances it may be best for the landowner, if he has a large acreage and plans to continue marketing, to learn to do his own logging. However, he must be warned that good logging requires experience and special skills, and that high quality logs can be ruined by inexperienced cutters.

In this study we assume that, as higher quality products are grown, the landowner does receive a proportionately higher stumpage price. But it must be understood that this receipt is not automatic, but must be earned by skillful marketing as well as by skillful silviculture.

GROWTH FUNCTIONS FOR MIXED HARDWOOD STANDS

Fortunately, within the past three years growth studies have produced four new sets of growth functions adaptable to hardwoods in the Appalachian region.

G-HAT (Growth of Hardwoods After Thinning), developed by Harrison et. al. (1986, 1986b) is a series of microcomputer programs that predict growth and yield of Appalachian mixed hardwoods after thinning. This is an individual tree model, and the equations are developed for even-aged stands where no single species constitutes more than 60 percent of stocking. This model is limited in that illogical results may occur for stands which have been thinned from above, thinned more than once, or are high-graded.

SILVAH, an individual tree growth and survival model for multiple species, was developed by Marquis et al. (1984) for Allegheny hardwood forests consisting primarily of cherry and maple. The maximum projection period is 10 years after which the stand can be projected again, and variations in site quality and growth response after thinnings are not considered.

A third individual tree growth model, OAK-SIM, for managed even-aged upland oak stands was presented by Hilt (1983). Growth functions were developed from stands "free thinned" for improvement in tree quality. As a result, its applica-

tion is directed to stands between 30 and 120 years old. The maximum projection period is 10 years, after which the stand can be projected again.

For natural stands of the Central States, TWIGS (USDA, 1984) is a good multiple species individual tree growth and yield model. As compared with the previous models, it has the longest projection period, 30 years. Information needed for projection include: tree species, dbh, basal area/acre by size class, site index, and crown ratio.

All four of these growth models have been programmed into the YIELD-MS system which is described in the next section.

ECONOMIC EVALUATION

The usual way to select the most economically advantageous logging or stand treatment method for a particular stand is to select successively two of the most likely alternative methods and then to generate the future cash flows that will come from each. (Methods of systematizing this search among alternatives is discussed more fully in the next section.) These two cash flow streams are then discounted, and the one showing the highest internal rate of return, or the highest net present value, is considered the preferable of the two treatments, possibly then to be compared to another likely alternative.

For this analysis we will use internal rate of return (IRR), because it requires no assumption of an alternative rate of return, a widely varying factor when interest rates are as unstable as they are today. IRR is directly interpretable in a context of many alternatives of various magnitudes, and the program is designed to check for abnormal cash flows that might give erroneous rates.

Hepp (1986) is currently developing a computer software package entitled Yield-MS: Timber Yield Planning Tool for Mixed Stands. Although it still contains some problems that make its use cumbersome, in concept it is suited exactly for the type of prescription problem being approached here. He has worked closely with us remedying operational difficulties, and a very useful piece of software should evolve.

YIELD-MS is an integrated collection of programs from several sources. All the four growth and yield models mentioned above are available to the user. Some other program segments are:

1) Estimation of stand value at any stage in stand projection, according to tree species, size, product, and grade.
2) Harvest simulation, for any kind of partial cut or complete harvest.
3) Projection of growth and yield, using stand table projection method, in yearly increments.
4) Estimation of future cash flows, including incomes from any harvests simulated.
5) Calculations of different financial criteria for investment analysis.
6) Options to input local growth factors and individual stand data.

YIELD-MS has the ability to incorporate changes in tree grade as part of its growth projection, an essential feature in management for high quality. A major part of the increase in stand value may be the increase in tree grade that comes with increasing tree diameter. Numerous sawmill grade recovery studies, such as Hanks (1976), have shown that larger diameter is the main factor that leads to higher percentage yields of higher grade lumber. Therefore, an important feature in Hepp's program is the probability factors, taken from Ernst and Marquis (1979), for an increase in tree grade with the increase in tree dbh into the lowest sizes of each grade.

These probabilities give a highly conservative estimate of value change from tree grade increment. An important modification we are making in the program allows these probabilities to be adjusted by a stand prescription tally that estimates the probability of each tree moving to the next higher tree grade with added diameter growth.

THE STAND TREATMENT DECISION

In the section above, it was mentioned that an evaluation must be made between two likely stand treatments. Obviously there are more than two possible treatments, so the question arises of how to select the first two to compare. Here is proposed a systematic way of reviewing possibilities, two at a time until the best decision is reached, beginning with the most desirable from both a silvicultural and financial viewpoints. In this way most possibilities will be considered, and, in the process of gathering market and cost data for them, the forester or owner will be forced to make a thorough analysis of all economic factors surrounding the logging decision.

The "decision tree" chart for comparing treatments is given in Figure 1. It can lead to one of eight conclusions. If a regeneration cut seems indicated (estimated future growth does not indicate a suitable rate of return), three methods of regeneration are possible, but that decision involves a number of silvicultural factors considered beyond the scope of this paper.

One major question in the use of such an approach is the period of future time to consider in the analysis. This will depend upon several

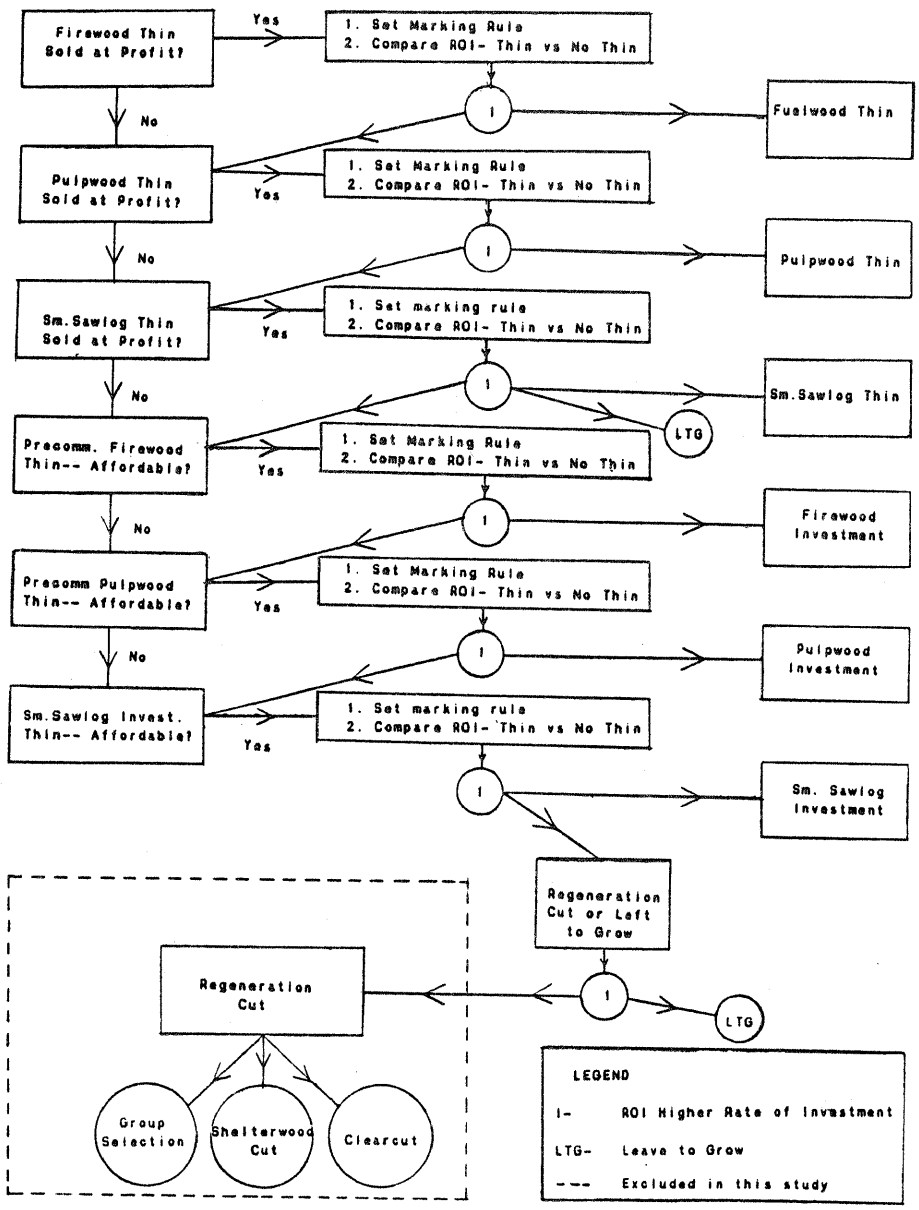

Figure 1.--Mixed Species Prescription - Decision Tree

factors, including the age of the stand and the period for which the growth projection model is deemed suitable. In the example below we used a period of 20 years.

DEMONSTRATION TRIAL

To demonstrate the process involved, we have taken actual data from a plot in southwestern Virginia, with a wide range of species and sizes, with a few sawlog trees that show potential for growing into higher grades in the next 20 years, and with pulpwood-size trees that will grow into small sawlogs. This stand was previously thinned in 1978 and therefore the G-HAT growth projection model was used. Initial stand conditions included basal area of 167 sq. ft./acre, site index 85 (yellow poplar), and an average stand age of 45 years.

In order to incorporate the data into YIELD-MS the species were grouped into 3 classes based on similar stumpage values (Hardwood Market Report, 1986). Table 1 shows the species groups that were found on the particular plot. Table 2 shows stand composition delineated by individual tree diameter class and tree grade.

Table 1.--Species Group

Group	Name	Species
1	Oak	red oak, white ash
2	Bass/Pop/Maple	yellow poplar, basswood, red maple, sugar maple, yellow birch
3	Hic/Cuc/Mag	hickory, cucumber, magnolia

Besides tree species, other information collected for each tree included diameter at breast height, total and merchantable height, age, and tree grade. All trees were graded according to US. Forest Service guidelines (Rast and others, 1973). In addition to the 3 sawlog grade classes used by the Forest Service, we made note of trees with defects or stoppers which would prohibit

Table 2.--Stand Composition: Number of trees in individual diameter class and tree grade (Initial Basal Area: 167 sq. ft.)

		Two-Inch Diameter Class											
Species Group	Grade	2	4	6	8	10	12	14	16	18	20	22	24
Oak	1												
	2						10						
	3					5							
	2/stop												
	3/stop							5	5				
	pulp												
Bass/Pop/Maple	1								5	10		5	
	2							15					
	3					5							
	2/stop							10	5				
	3/stop							10					
	pulp		60	30	30	10	5						
Hic/Cuc/Mag	1												
	2												
	3					5							
	2/stop												
	3/stop					15	15						
	pulp			5	10								
TOTALS = 275 /ac			60	35	40	40	30	40	15	10	0	5	

them from increasing in grade even though tree diameter satisfies minimum grade class standards. For example, there could be two 12-inch grade 3 red oak trees, one free of defect and the other with some crook and several live limbs on the butt log. Based on external qualities the tree without defect will improve to grade 2 as it grows into the 13 inch diameter class, whereas the second tree will remain grade 3 even though it has the minimum diameter for grade 2. Therefore, trees in the classes Grade 2 Stoppers and Grade 3 Stoppers cannot improve in grade, thus the only value increase results from increases in tree volume. By incorporating the Grade 2 and 3 stopper classes, a better estimate of potential stand value can be made.

To demonstrate the methodology of our proposed system, it is used here to compare 2 possible stand treatments. One treatment is a profit-yielding firewood thinning and salvage cut of the stand immediately, after which the stand grows for 20 years. The alternative will be to let it grow, uncut in any way for the same period. Using the decision tree (fig. 1), we asked if a thinning for firewood could be made at a profit - without an initial investment. Since we are in an area where firewood cutters are active, we assume that a firewood thinning removing 2.5 cords per acre can be made, along with 5.2 mbf/acre in sawtimber trees with little prospect to increase in value. To generate the cash flows from the two stand treatments over 20 years the following assumptions were entered into the program:

1) Location is in a fairly good firewood market, to which stumpage may be sold for $17.00 per ton.
2) Stumpage prices will remain constant over the projection period, as do other prices. (The program permits specification of an estimated price inflation rate.)
3) Tree quality classes have dollar values that represent a wide value spread based on the value of the lumber that could be cut from them. Tree grade one has the highest value, grade three much lower, but above pulpwood.
4) Thinning reduces stand basal area to 110 square feet per acre.
5) Both stands clearcut at the end of the 20-year projection period.
6) The G-HAT growth projection model was used.

Timber prices vary greatly from one location to another, depending upon site, stand location, road access, local timber markets, species, quality and number of harvestable trees. Stumpage prices used here are given in Table 3. Lumber grade yields from Hanks (1976) were used, in conjunction with the Hardwood Market Report (1986), to determine the value by grade for each tree, by species, tree grade, diameter and merchantable height. Region specific average logging and milling costs were subtracted, resulting in stumpage prices shown in the table.

Table 3.--Stand Stumpage Price by Species Group and Tree Grade

Species Group	Grade	Price $/mbf
Oak	1	196.79
	2	186.50
	3	84.51
	2/stopper	186.50
	3/stopper	84.51
	pulpwood	17.00/ton
Bass/Pop/Maple	1	135.41
	2	96.40
	3	71.79
	2/stopper	96.40
	3/stopper	71.79
	pulpwood	17.00/ton
Hic/Cuc/Mag	1	77.53
	2	64.09
	3	44.51
	2/stopper	64.09
	3/stopper	44.51
	pulpwood	17.00/ton

The actual financial analysis results of these two treatments are given in Table 4. It uses the new income tax law and allows capital gains treatment of timber income at the new individual rate of 28 percent, with a basis value of $529.00/acre at which timber was carried in the accounts. The absolute values of the internal rates of return are of little significance, but the comparative rates between the 2 treatments indicate that the fire-wood and salvage thinning can result in a significant increase in the return on invested capital.

The results show that an after tax internal rate of return was 5.5 percent greater with the fuelwood alternative than with the leave-to-grow option. The fuelwood alternative also showed a $262/acre increase in net cash flow.

Figure 2 illustrates the value growth of the thinned stand over the entire 20-year projection period. The vertical scale is both basal area per acre and total stumpage value per acre. It's important to note that the thinning in the first year removed much more proportionately of basal area (and volume) than of value, but that subsequent value growth was at a greater rate than basal area growth. Stand value ended much higher than before thinning, although basal area (and volume) were lower. The rise in value is not only due to the earlier income from the thinning, but also to the growth of higher valued timber, as shown by the greater cash flow (undiscounted) generated by the thinning program.

Table 4. Capital Gains Treatment for Harvest Revenues (Financial Parameter Data: planning horizon is from 1986 to 2006, marginal federal tax bracket = 28%, capital gains proportion = 28%, discount rate before tax = 7% and after tax = 5%)

Fuelwood Thin Alternative - Financial Transactions

Type	First Year	Last Year	Rep	$ Amount	Inf %	Description
Ordinary Deductible Expense	1986	2006	1	-1.75	0	Ad Valorem Tax
Capital Expense Timber DPLN ACC	1986	1986	1	-529.26	0	Adjusted for Timber Base
Ordinary Deductible Expense	1986	2006	1	-1.50	0	Annual Mgt. Fee
Ordinary Taxable Income	1986	2006	1	2.00	0	Hunting Lease Income
Capital Gains Thinning Revenues	1986	1986	1	351.90	*	From Simulated Removals
Capital Gains Harvest Revenue	2006	2006	1	3042.59	*	From Simulated Removals

Total Net Cash Flow = $2838.98 per acre Internal Rate of Return: Before Tax 15% After Tax 14.3%

Clearcut Harvest Option - Financial Transactions

Type	First Year	Last Year	Rep	$ Amount	Inf %	Description
Ordinary Deductible Expense	1986	2006	1	-1.75	0	Ad Valorem Tax
Capital Expense Timber DPLN ACC	1986	1986	1	-529.26	0	Adjusted for Timber Base
Ordinary Deductible Expense	1986	2006	1	-1.50	0	Annual Mgt. Fee
Ordinary Taxable Income	1986	2006	1	2.00	0	Hunting Lease Income
Capital Gains Harvest Revenue	2006	2006	1	3132.44	*	From Simulated Removals

Total Net Cash Flow = $2576.93 per acre Internal Rate of Return: Before Tax 9.2% After Tax 8.8%

* Inflation rate is computed as composite of specified sawtimber and pulpwood inflation rates.

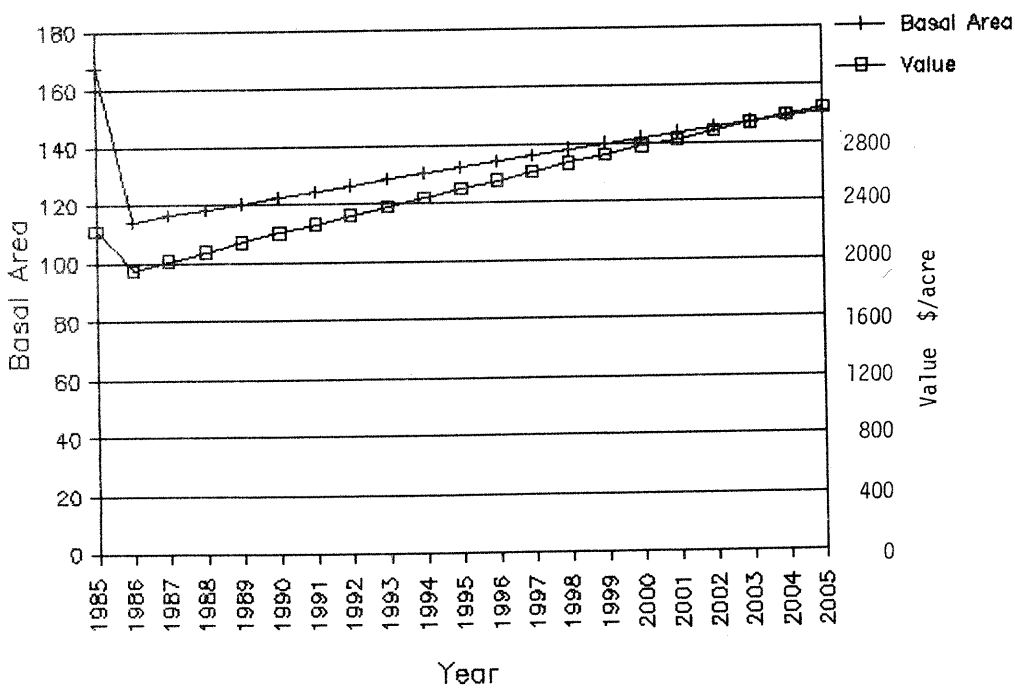

Figure 2.--Value Growth of Thinned Hardwoods

Correct evaluation of this potential for value growth and benefit from improvement cuttings is very important in prescribing treatments. After a low thinning that removes defective, cull and low value species, one could expect a sharp increase in earning rate. However, it is possible that too heavy thinning can reduce stocking so that growth will be reduced too much, and stand quality might suffer through an increase in epicormic branching.

SIMULATION TRIALS

Inspection of the decision tree indicates a great many ROI comparisons, with each involving a careful trial marking and a run thru the growth projection. This might appear to be a tedious procedure if all the comparisons must be made, even with a powerful computer. In actual practice, however, we anticipate that many of the alternatives will not be locally feasible. As part of the research project it should possible to make a number of trials, from which would emerge some general guidelines for circumstances under which various treatment and logging practices would be feasible.

Table 5 shows a list of trial simulations for the example stand with the overall management objective to leave a stand in which growth could be concentrated on the higher quality and potentially more valuable trees. The guidelines followed to determine which trees to remove in thinning were:

1) trees of low economic value species, and those with 0 percent probability of grade increase,
2) trees with the slowest growth rates,
3) residual basal area was 105 sq. ft. per acre.

Following these guidelines, each successive simulation removed additional trees to make the thinning more profitable and at the same time approach a desirable range of basal area. As shown in Table 5, application of the guidelines produced successively better financial results. With a list of simulations of the different management alternatives, the forest manager will be able to make wiser financial management decisions.

CONCLUSION

A computerized hardwood stand prescription management program has been presented that encompasses most of the significant factors, both economic and biologic, that should be considered when a logging operation or other stand treatment is contemplated. The decision tree chart can help the forester or landowner review some of the possible treatment alternatives necessary for a complete analysis. A demonstration is given of how this decision might be reached for one stand in

Table 5.--Successive Mixed Hardwood Thinning Trials (Thinned at age 45, clearcut at age 65)

Trial #	Basal Area Removed	Value Removed	NPV$ (after tax)	IRR%	Total Net Cash Flow	Description
1	0	0	553.95	8.8	2576.93	Stand projected with grade change
2	0	0	530.33	8.7	2508.42	Stand projected without grade change
3	28.3	91.94	693.84	10.1	2766.99	All pulpwood thinned except poplar and basswood
4	31.6	164.57	735.92	10.9	2766.07	Thinned same as #3, low value grade 3 stoppers
5	38.4	231.31	778.31	11.8	2774.34	Thinned same as #4, low value grade 3
6	56.55	351.90	872.89	14.3	2838.98	Thinned same as #5, low value grade 2 stoppers
7	56.55	403.84	904.01	15.9	2842.35	Thinned same as #6, removal of low value and slow growth species
8	60.32	464.41	931.77	18.6	2842.74	Thinned same as #7, removing more grade 3 & 2 with stoppers
9	65.56	485.91	960.44	20.2	2864.78	Thinned same as #8, removing more 8" pulpwood from all species

which a thinning could result in a higher rate of return than if the stand were not treated.

Research efforts have given guides for choices among individual trees based upon economic criteria, but similar studies for entire stands have been difficult until the computer has given us means of handling the large amounts of data involved. It should now be possible to evaluate economically various methods of silvicultural treatment and harvest intensities. If presented with some answers to such questions, landowners and forest managers would have a much stronger information base on which to guide effective hardwood stand management.

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