United States
Department of
Agriculture

Forest Service

**Northeastern Forest
Experiment Station**

NE-GTR-112

MANAGE: A computer program to estimate costs and benefits associated with eastern hardwood management

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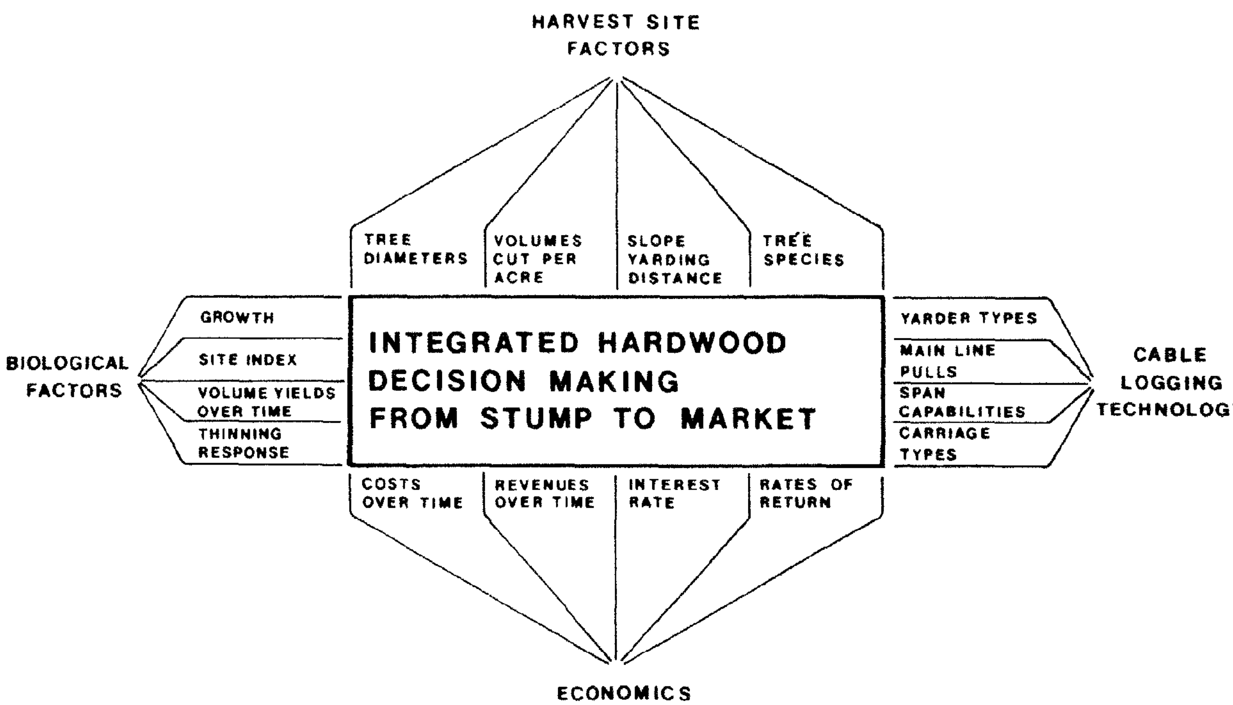

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Manuscript received for publication 31 January 1986.

Abstract

The integration of harvesting, silviculture, and market and economic concerns is demonstrated with a complete systems simulation model called MANAGE. The application of MANAGE and decisionmaking output are emphasized. A 40-year-old red and white oak stand was selected for demonstration. Results indicate that the use of cable logging technology to manage young hardwood stands on steep terrain will dictate few entries with heavy volume removals to maximize net values. MANAGE can be used to evaluate other combinations of harvesting, silviculture, and market and economic scenarios.

Northeastern Forest Experiment Station
370 Reed Road, Broomall, PA 19008
August 1986

Introduction

Precommercial and commercial thinning tree removals based on desired spacing of the residual stand have shown to increase net yields in eastern hardwood stands (Boyette and Brenneman 1978; Della-Bianca 1969, 1975, 1983; Lamson 1983; Marquis 1969; Smith 1981; Smith and Lamson 1983; Trimble 1974). However, other thinning studies have shown questionable to no increase in young stands (Beck 1977, Hilt and Dale 1982, Smith 1979, Trimble 1973). The most common thinning approaches are crop-tree releases and cleanings that favor leaving the most desirable trees for the future crop.

Results from thinning studies are generally reported in terms of growth or quality response to individual tree attributes such as diameter breast height (d.b.h.), height, potential log grade, biomass, or volume. The results, although valuable, do not provide data on the costs and benefits of alternative silvicultural treatments over the life of a stand. We need a method to evaluate the long-term costs and benefits of the harvesting and silvicultural treatments that form the chain of activities and yields in the life of a stand. The methodology should provide insight into the decisionmaking process concerning the different steps in the chain of activities.

In this paper, the integration of harvesting, silviculture, and market and economic concerns is demonstrated with a complete systems simulation model called MANAGE.[1] The results can be used to help managers understand the interaction of harvesting, silviculture, markets, and economics during the rotation period of a hardwood stand.

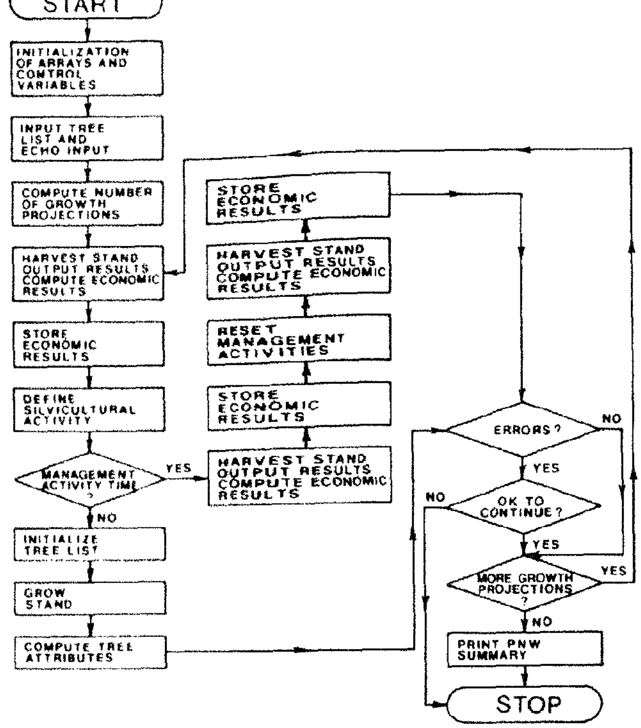

Figure 1.—Flow diagram of Program MANAGE.

Description of MANAGE

MANAGE, 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 and stochastic subroutines. Individual subroutines model harvesting activities, silvicultural treatments, growth projections, market prices, and discounted present net worth (PNW) economic analysis (Fig. 1).

Subroutine GROW (Brand 1981) is used for the growth projection. Programs ECOST (LeDoux 1985) and PNW (LeDoux 1983) project the harvesting activities and economic analysis, respectively. 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 inputs 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. The process is repeated for user-specified alternative mixes of entry timing, logging equipment, silvicultural treatments, and economic conditions for the life of the stand in question. The results are stored by entry and also for the life of the stand. Users can specify numerous management scenarios during the life of the stand and evaluate the outcomes.

It is beyond the scope of this paper to discuss the details and use of MANAGE. Work is underway to document MANAGE methodology and to provide a detailed user's manual. This article emphasizes the application of MANAGE and the types of decisionmaking output provided.

[1]LeDoux, Chris B. Users guide for program MANAGE. 1986. Morgantown, WV: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. Unpublished document in preparation.

Application of MANAGE

Forest model Plot 3 was the stand chosen for analysis.[2] Plot 3 is representative of many Appalachian red and white oak stands: Stand age—40 years, average tree d.b.h.—8.6 inches, number of trees per acre—201, cubic-foot volume per acre—1,945 (Smalian's method), and basal area—81.3 square feet per acre. The stand was subjected to three area-wide thinning treatments with the explicit objective of producing sawlogs in the final harvest. A secondary objective was to provide enough wood and value to cover harvesting costs.

The stand was evaluated with no management and light, medium, and heavy thinning treatments. Rotation ages between 80 and 150 years were considered (Fig. 2). With site index 70, real interest rate of 4 percent, and a minimum merchantable d.b.h. of 5 inches, the optimal rotation for no treatment of Plot 3 would be as follows: at 110 years, volume removed—5,244 cubic feet per acre (mean annual volume removed per acre is 47.67 cubic feet), average d.b.h.—16 inches, number of stems removed per acre—133, cumulative present net worth per acre—$105.10, soil expectation value—$109.27 per acre, harvested by the Ecologger I cable yarder. Soil expectation (Se) value is used to compare returns.[3] The Ecologger I is a medium-sized machine capable of harvesting the final stand.

Light, medium, and heavy thinnings were evaluated with the objective of covering logging costs at each entry and producing sawlogs in the final crop. The three area-wide thinning treatments removed trees less than 8.0, 9.0, and 10.0 inches d.b.h., respectively. The thinning treatment was scheduled at age 40, and the residual stand was projected

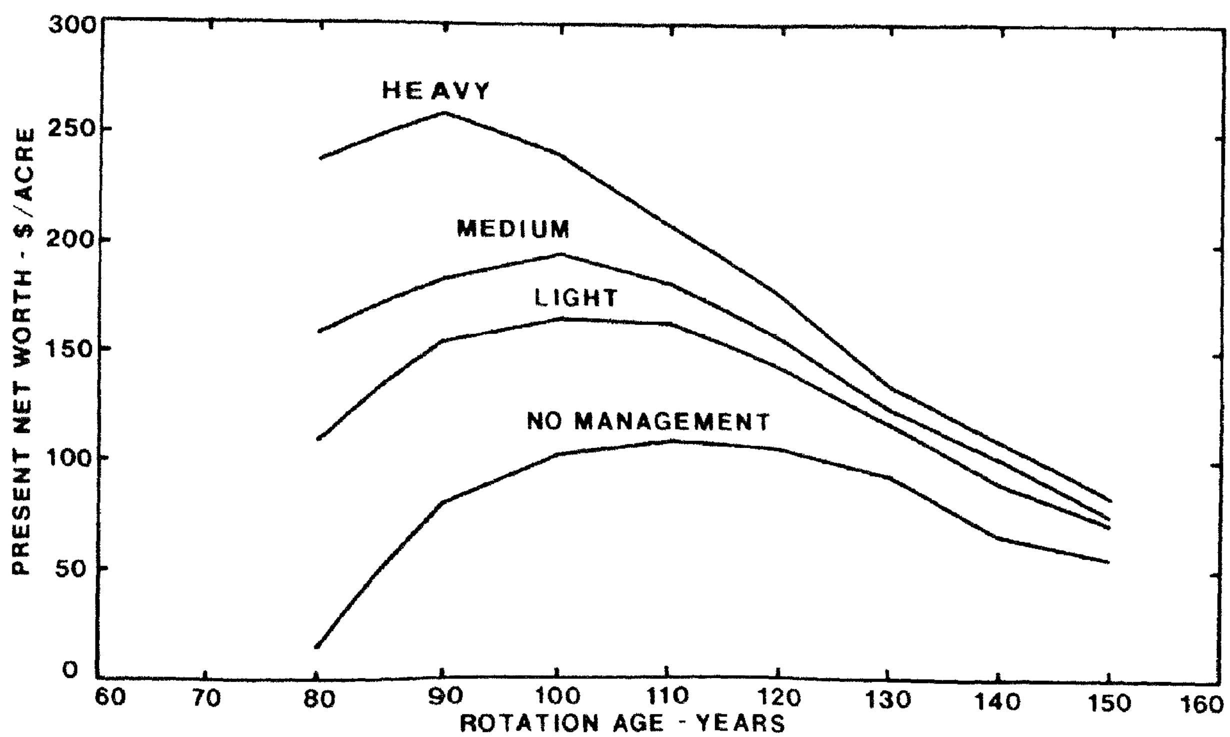

Figure 2.—Heavy, medium, and light thinnings and no management treatments by rotation age for forest model Plot 3.

[2]U.S. Department of Agriculture, Forest Service. One-acre forest model plot. Unpublished data on file at Morgantown, WV: U.S. Department of Agriculture, Forest Service. Northeastern Forest Experiment Station.

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

to a maximum rotation of 150 years. The value and volume of wood harvested from the initial treatment dictated a firewood roadside sale. The Bitterroot cable yarder was chosen to do the yarding for the thinnings. The Bitterroot is a small, relatively inexpensive machine suited for harvesting the small diameter wood removed. The Ecologger I was chosen to harvest the larger logs and volumes from the final harvest. Wood from the first thinning at age 40 was sold as firewood at roadside, and wood from the final stand was hauled to sawmills and sold as sawlogs. The results of the three thinning treatments are summarized in Figure 2 and Tables 1, 2, and 3.

Thinning produces larger d.b.h. trees, and more net return in a shorter rotation period than no treatment. Our thinning results confirm Schlaegel's[4] studies for bottomland hardwoods. Although the heavy thinning produces less total volume than that in other treatments, the wood is large sawlogs. Large logs coupled with a shorter (90 year) rotation period result in the best soil expectation value. Larger logs are also cheaper to harvest.

Table 1.—Optimal rotation length for light commercial thinning and final harvest of forest model Plot 3.[a] All values except d.b.h. are per acre. Mean annual volume removed per acre is 49.73 cubic feet.

Entry age (years)	Machine configuration	Average stand d.b.h.	Number of stems removed	Volume removed	Cumulative present value worth
		Inches		*ft*[3]	*Dollars*
40	Yarding				
	Bitterroot	6.3	87	405	0.06
100	Yarding				
	Ecologger I	17.9	91	4,568	164.51
				Se	171.09

[a]Conditions: site index, 70; real interest rate, 4 percent; minimum merchantable d.b.h., 5 inches.

Table 2.—Optimal rotation length for medium commercial thinning and final harvest of forest model Plot 3.[a] All values except d.b.h. are per acre. Mean annual volume removed per acre is 48.48 cubic feet.

Entry age (years)	Machine configuration	Average stand d.b.h.	Number of stems removed	Volume removed	Cumulative present net worth
		Inches		*ft*[3]	*Dollars*
40	Yarding				
	Bitterroot	6.9	119	677	5.89
100	Yarding				
	Ecologger I	19.6	68	4,171	194.31
				Se =	202.08

[a]Conditions: site index, 70; real interest rate, 4 percent; minimum merchantable d.b.h., 5 inches.

Table 3.—Optimal rotation length for heavy commercial thinning and final harvest of forest model Plot 3.[a] All values except d.b.h. are per acre. Mean annual volume removed per acre is 47.78 cubic feet.

Entry age (years)	Machine configuration	Average stand d.b.h.	Number of stems removed	Volume removed	Cumulative present net worth
		Inches		*ft*[3]	*Dollars*
40	Yarding				
	Bitterroot	7.4	146	978	16.0
90	Yarding				
	Ecologger I	20.2	50	3,322	258.43
				Se =	268.77

[a]Conditions: site index, 70; real interest rate, 4 percent; minimum merchantable d.b.h., 5 inches.

Thinning hardwood stands also benefit the management of nontimber resources. The larger and more vigorous trees in the stand will bear fruits that are eagerly sought by squirrels, deer, turkey, grouse, and other wildlife. For example, thinning stands can result in increased seed production (Liscinsky 1984). Liscinsky's (1984) results show that lightly and heavily thinned stands outproduced the unthinned stand by as much as 56 pounds of acorns per acre in the 10th year following thinning. In oak country, about 85 pounds of fresh acorns per acre will provide the food needed for all wildlife in the area (USDA 1970).

Table 4 summarizes the thinning treatments simulated. Many other treatment options exist and the results summarized for Plot 3 are not globally optimal. Of the four treatments simulated, a heavy thinning would be the optimal when using cable logging technology to harvest the stand. A heavy thinning is likely to result in the production of epicormic branches in the residual stand (Smith 1966, Sonderman 1984), reducing tree quality and value. In this simulation, the quality reduction due to heavy thinning was handled by allowing only select butt logs to receive premium grade. The results of this assumption are consistent with Dale and Brisbin's (1985) research findings. Other quality reduction assumptions could be evaluated by simply making additional simulation runs.

[4]Schlaegel, Bryce E. Thinning bottomland hardwoods makes dollars and sense. 1982. (Unpublished paper presented at the Southeastern Section, Society of American Foresters Annual Meeting: 1982) January 20-22; Mobile, AL.

Table 4.—Simulated silvicultural treatments for forest model Plot 3. All values are per acre.

Silvicultural treatment	Removed stems integer	Basal area removed	Residual tree spacing
	Percent		*Feet*
No treatment	0	0	15 × 15
Light thinning	43	23	20 × 20
Medium thinning	59	38	23 × 23
Heavy thinning	73	53	28 × 28

The results summarized for Plot 3 should not be construed as the way to manage all 40-year-old red and white oak stands on steep terrain. Rather, the results are specific to Plot 3 and each set of conditions should be evaluated under its own constraints. Although the management scenarios selected to illustrate MANAGE may seem odd to many managers, they are feasible when using expensive cable logging systems to harvest the stands. Additionally, the MANAGE model allows for 10 other management activities to be applied to the stand. Table 5 summarizes the available management activities. Additional documentation and detailed descriptions are available.[1] Other stands or scenarios could be evaluated easily by making additional simulation runs.

Table 5.—Management activities that can be applied to the forest stand using MANAGE.

Activity	Activity description
0	Change logging system without changing timber stand.
1	Cut all trees less than given d.b.h.
2	Cut all trees greater/equal to given d.b.h.
3	Cut species listed and all trees less than given d.b.h.
4	Keep species with diameter greater/equal to given d.b.h.
5	Reduce stand until this number of trees remain per acre.
6	Reduce stand by this number of trees per acre.
7	Reduce each 2-inch diameter class by this number of trees.
8	Reduce each 2-inch diameter class by this percentage.
9	Reduce basal area to this amount per acre.
10	Reduce basal area by this amount per acre.
11	Reduce each timber product class by percent by class.

Decisionmaking Output

In addition to the results summarized, MANAGE provides additional output entry by entry for the treatment and rotation period. The output is detailed and useful in decisionmaking while planning logging and silvicultural treatments. Figures 3 and 4 depict the types of decisionmaking output available for each evaluation. The results are stored in files following a run and users can specify the printing of part or all of the output. MANAGE produces the desired output in standard computer tabular format.

The detailed results of the heavy thinning treatment are summarized in Figure 3: (a) the basal area over time, (b) the mean annual increment, (c) the average log size, (d) the undiscounted cash flows, (e) the merchantable height, and (f) the average log length. Knowledge of the future log size and length is useful to equipment manufacturers and loggers. Basal area and annual increment measures are useful to silviculturists and planners. The average log lengths and sizes shown in Figure 3(c) and (f) result from a bucking rule that specifies 16 feet as the preferred length. Other bucking rules can be simulated using MANAGE.

Figure 4 shows: (a) the volume cut, (b) the volume by species, (c) the soil expectation value, (d) the product yield by log grade, (e) the average d.b.h., and (f) the 2-inch stand structure. The output provides the planner with a detailed look at the projected stream of products, stand and tree attributes, and costs and benefits over the life of the stand. For example, although the optimal rotation is age 90 (Fig. 4c), the final harvest could be scheduled in year 80 or 100. The 80 to 100 year period gives the manager flexibility in scheduling the final harvest without sustaining large losses in net worth. In fact, the stand could be harvested at age 70 and still produce more net value than that in the no treatment stand (Fig. 4c). The detailed output should provide insight into the decisionmaking process and the related chain of activities that integrate to form a whole system of harvesting and stand development.

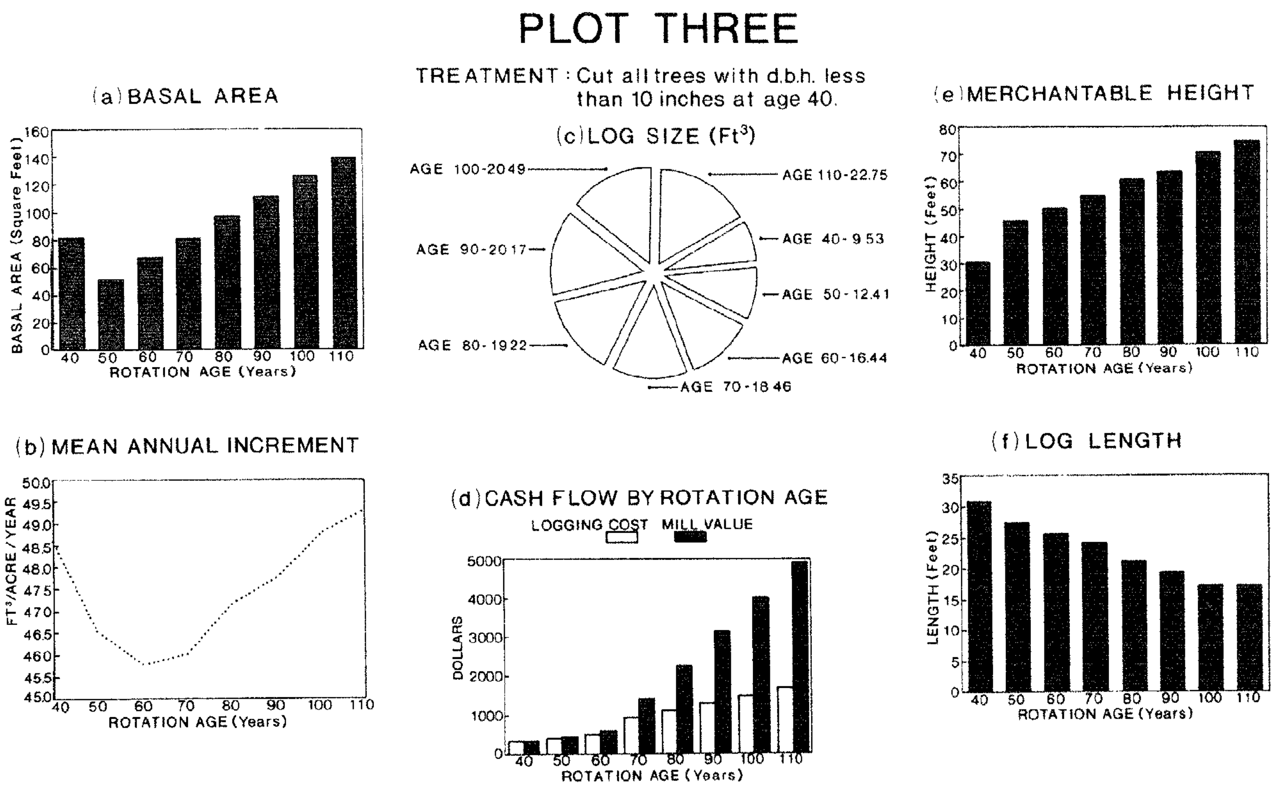

Figure 3(a-f).—MANAGE decisionmaking output for forest model Plot 3.

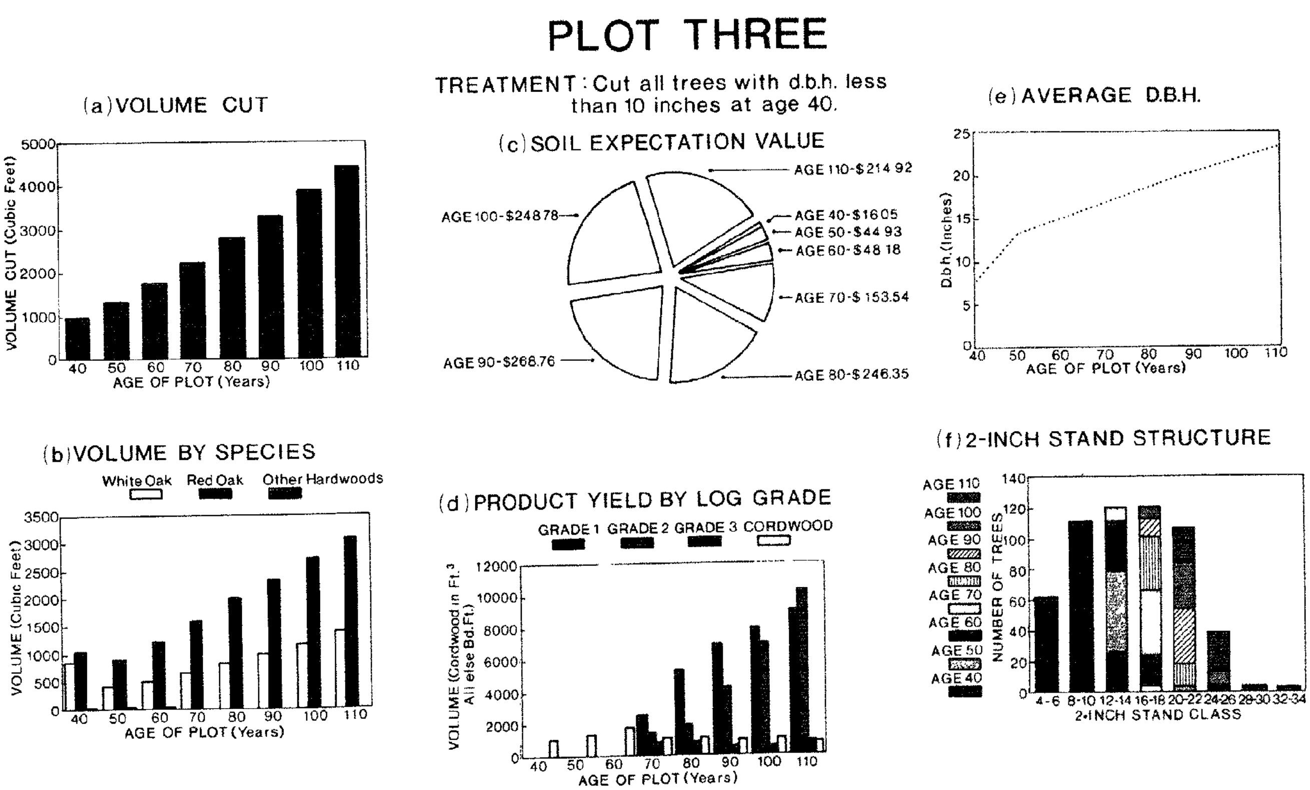

Figure 4(a-f).—MANAGE decisionmaking output for forest model Plot 3.

Conclusions

The use of cable logging technology to manage young hardwood stands on steep terrain will dictate few entries with heavy volume removals. Machinery must be matched to entry timing and the product size to maximize efficiency. A complete plan must be developed for the life of the stand that effectively integrates silviculture, harvesting technology, markets, and economic concerns. Failure to integrate any one of the above factors is likely to result in unfeasible management scenarios. For example, numerous, repeated thinnings may well benefit diameter and height growth, but the costs associated with such treatments are likely prohibitive. Management guidelines based on spacing or crown area only may result in scenarios that are simply not economically feasible.

The initial treatment for a stand largely dictates the future stream and flow of activities, products, costs, and benefits associated with such an effort. It is imperative that the decisionmaking process have insight into the numerous activities and plan them as a complete system of harvesting and silvicultural treatments to maximize net returns. It is very important to have a vision of the future crop in mind as we make individual harvesting decisions today.

Although MANAGE was applied to only one stand and four treatments, it could be used to evaluate other stands and treatments. The output from MANAGE can provide insight on how to best manage young hardwood stands.

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. For cost information, please write:

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