AN EVALUATION OF FOREST MANAGEMENT ALTERNATIVES IN SOUTHEAST OKLAHOMA UNDER DIFFERING ECONOMIC AND SILVICULTURAL ASSUMPTIONS

By

PHILIP LANCE TEDDER

Bachelor of Science
Oklahoma State University
Stillwater, Oklahoma
1969

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1973

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Thesis Approved:

David D. Kletke
Thesis Advisor

Marc A. Johnson

J. E. Langwig

Harry P. Mapp Jr.

Daryll E. Ray

Norman N. Durham
Dean of the Graduate College

PREFACE

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CHAPTER I

INTRODUCTION

The demand for industrial timber products in the United States increased 65 percent during the past three decades. From 1942-1972, lumber consumption rose 27 percent, pulpwood 157 percent, and veneer and plywood over 438 percent. Projection of demand for the year 2000 indicates that the demand for roundwood will rise from a 1970 level of 12.7 billion cubic feet per year to nearly 23 billion cubic feet per year, an 81.1 percent increase. On the other hand, the supply of timber products, assuming 1970 levels of management, timber cutting practices and policies similar to those of recent years, and only a minor reduction in areas of commercial timber land, are estimated to increase about 31 percent by the year 2000. This increases supply from 8.8 billion cubic feet to about 11.5 billion cubic feet. Thus, for softwood sawtimber products, which are of particular importance for lumber and plywood, projections of potential supply show limited changes from the 1970 level (26).

Another factor affecting the future supply of timber is the demand for non-commodity products and services and for environmental protection. Sizable areas of public forest land have been withdrawn from timber use for wilderness and scenic areas. Also, extensive areas of forest lands have been shifted to non-timber uses such as reservoirs, highways, airports, urban expansion, and recreational developments. As the demand for these non-timber land uses increases, the ability to produce timber on those lands is reduced to zero.

The effective supply of timber can be increased by 1) importing more timber from areas that have abundant timber supplies, such as Canada; 2) increasing the use of non-wood materials, such as steel and concrete; 3) utilizing better the available supplies or 4) intensifying forest management while maintaining an acceptable forest environment and 5) selecting better sites for intensive management.

Of the five ways of increasing supply, only the last two have long-range potential. Of the 67 million acres of commercially owned timber-land, the production average per acre in 1970 was 52 cubic feet per acre. This is approximately 60 percent of the average attainable in fully stocked natural stands and less than one-third the amount attainable in some intensively managed plantations. Of the 256 million acres of commercial forest land in farm and miscellaneous private ownership, net annual average growth per acre is only 36 cubic feet per acre. This relatively low figure is mostly the result of short planning horizons, limited capital, and the lack of technical forest management skills. Timber production on National Forest land could also be increased through intensified forest management and planning. Fedkiw (10) relates, however, that the probability of major increases in timber supplies from Federal lands would be correspondingly low because of other land uses and environmental objectives. Consequently, prices and the corresponding responses of private producers and importers will determine how much timber is supplied.

In Oklahoma, 4.8 million acres are classifed as commercial timber land by the U.S. Forest Service. Commercial forest land is land capable of producing at least 20 cubic feet of industrial wood per acre annually. At present, net annual forest growth averages about 13 cubic feet per acre, however, Oklahoma forest land has the potential of producing at least 50 cubic feet per acre per year (30). Therefore, the problem that exists in Oklahoma, as well as other Southern states, is determining which alternative courses of action in forest management must be followed to achieve the forest land's potential. Attaining this potential will depend upon future research, regeneration of desirable species, improving protection, determining optimum levels of stocking and harvest, and favorable national, regional, and state forest policies for commercial and private forest landowners.

Problem Considerations

Forestry is a science, an art, a business, and a public policy capable of, and occupied with, effecting continuous production and management of forests on suitable lands and promotion of their beneficial use by mankind (1). The management of forested areas for timber production is a highly complex discipline involving a multitude of biological and economic interrelationships. In addition, the impact on the ecology and externalities affecting other citizens must be analyzed. Management became even more complex as the number of alternative goals specified for each forested area increases.

Goal selection for a forested area is an extremely important facet and starting point for proper forest management as the goals selected determine how the forest will be used. The goal selection process involves a consideration of all factors involved in or affected by the final results. Baumol (3) states:

> Peoples' objectives are whatever they are. Irrationality surely must be defined to consist of decision patterns that make it more difficult to attain ones' own ends, and not in choosing ends that for some reason are considered to be wrong. Unless we are prepared to determine other peoples' values, or unless they pursue incompatible goals, we must class behavior as rational if it efficiently pursues whatever goals happen to have been chosen (3).

Forest managers, local communities, recreation enthusiasts, state and national lobby groups, and state and national legislators are just a small portion of those who should be involved in the decision making process involving the use of forested areas. Therefore, by just considering those few listed above, it becomes clear that there will exist many diverse objectives and opinions on how to best use a forested area.

One procedure for selecting goals is:

1. Problem identification.
2. Potential goal or objective identification.
3. Development of alternative courses of action.
4. Appraisal of and selection from the laternative course of action.

Alston (2) states that the goal selection process must include consideration of availability of information, complexity, and consistency. Each is extremely important even when dealing with the smallest of problems. An illustration of the above process is a manufiacturer who wishes to replace a certain machine in his production line with an improved machine. In this case, the course of action is clear, the manufacturer must determine the cost and revenues associated with acquiring and implementing the piece of machinery. On the other hand, consider a manager who must determine the cost and revenues associated with setting aside 500 acres of prime quality timber located on excellent soil conditions in order that a recreation area be established. The manager has a complicated problem because the availability of information is uncertain, the management situation is complex, and achieving goal consistency through all levels of management is difficult. Goal selection and implementation are a diffcult yet integral part of a proper and successful management program for forested areas.

The Resources Planning Act

The current policy of the Forest Service is being affected by a stipulation included in the Forest and Rangeland Renewable Resources Planning Act (RPA) of August, 1974. The RPA directs that long-range plans be developed to provide the nation with a continuous, steady flow of renewable resources from the 1.6 billion acres of public and private forests and rangelands, while maintaining the integrity and quality of the environment.

The RPA directs that these goals and methods of attaining the goals be presented to the Congress at specific times. The RPA while being specific in its requirements, leaves considerable doubt as to the methods with which the requirements are to be satisfied. The Forest Service is using a planning tool utilizing linear programming to fulfill the requirements of the RPA. This method requires the use of a totally elastic demand curve in the solution process. A totally elastic demand curve in the solution process. A totally elastic demand curve indicates a constant price may be charged by the supplier of goods regardless of the quantity that he may supply. On the other hand, controversy has arisen over the fact that linear programming is non-dynamic in nature and that there are other means available to meet the requirements of the RPA (25). Walker (29) has shown for forests in the Western United States that long-run management plans developed using the linear programming method yield significantly lower levels of present net worth and present net benefits than the same forest evaluated with a method similar to quadratic programming. This method involves use of a difference equation and maximizing a quadratic objective function. The model requires that a negatively sloped demand curve be utilized in the process. A negatively sloped demand curve indicates that as quantities supplied on the market increase, the price offered by the buyers decrease. These two methods will be discussed further in Chapter III. One important consideration is that each method has been evaluated only on Western forests. Western forests are different than Southern forests because they have an abundance of old-growth timber where the Southern forests do not. Evaluation of Southern forests using similar techniques is yet to be accomplished. Attaining the long-range goals of the RPA requires that Southern forests be evaluated on an equal basis with the Western forests to determine what similarities or differences exist.

Objectives

The problem, as stated previously, is to determine which alternative courses of action in forest management must be followed in order to attain the potential of Oklahoma's forests. The section concerning the Resources Planning Act indicated two modern forest management techniques which are being used to determine future uses and potential of forest land in the Western United States.

The objective of this study is to utilize these two management techniques on an Oklahoma forest to determine the forest land's potential under economic and biological assumptions. The study area will be the Tiak Ranger District located in extreme Southeastern Oklahoma. Utilizing this area, various alternative goal situations will be analyzed reflecting several forest management choices. Specific alternative situations to be evaluated are:

1. Evaluation of the maximum discounted cash flow returned from the forest, given a perfectly elastic demand curve and a negatively sloped demand curve representative of the area.
2. Evaluation of the maximum discounted value of net social benefits and a negatively sloped demand for soical benefits.
3. Determination of the maximum discounted cash flow resulting from highly intensive management under totally elastic and negatively sloped demand curves.

These objectives will also be explored under four separate discount rates, and secondary assumptions including:

1. Increased cost of logging.
2. Increased recreational acreage requirements.
3. Increased cost of logging and an increase in recreational acreage requirements.

The specified objective will be evaluated on the basis of harvest levels, cash flows, and prices generated by each individual plan at each discount rate. The analysis presented for each objective will be useful in analyzing the impact of the various secondary assumptions on the future of the forest.

In addition to the introductory chapter describing the objective of the study, six other chapters are included. Chapter II deals with the geographical description of the study area and the necessary stand data needed for inclusion in the two models used in the analysis. Chapter III relates previous work done in forest management and some of the naive analytical tools used in calculating harvest levels and annual cuts. It also includes the relatively few current examples of studies done utilizing methods similar to those employed in this study. Chapter IV is an in-depth study relating the mathematical development of the two models used in the study. Chapter V begins with the standardization of the stand data and is concluded with the development of the alternative management situations used in the analyses. Chapter VI presents the results and conclusions obtained when the various alternative forest management situations are simulated using the models. Chapter VII includes a summary of the study and recommendations for future research work in the State.

CHAPTER II

DESCRIPTION OF THE STUDY AREA AND STAND DATA

The Tiak district is included in the Ouachita National Forest and is geographically situated in McCurtain County. McCurtain County has five general areas: 1) timbered sandstone and shale, 2) timbered rolling southern coastal plain, 3) the lowlands or "flatwoods", 4) prairie, and 5) bottom lands of streams and rivers. The main part of the county is the timbered sandstone and shale area, which is made up of steep mountainous areas and smooth sloping crests and ridges (23).

Physiography, Drainage, and Relief

McCurtain County has an area of 1,167,846 acres of which most are covered with forests. Only 40,693 acres of the county are considered prairie. The topography of McCurtain County is nearly level to very steep and the general slope is towards the South and East. The Little River is the largest drainage system in the county and is the northern boundary of the study area. The average elevation of the county is approximately 860 feet above sea level. The highest point in the northwestern corner reaches a height of about 1500 feet and the lowest point is only about 350 feet above sea level on the north bank of the Red River at the Oklahoma-Arkansas Boundary (23).

Climate

McCurtain County has a warm, moist subtropical climate in which seasonal changes are gradual. Summers are hot and humid and long periods of severe cold in winter are infrequent. Average daily minimum temperatures range from 30 degrees in January to 68 degrees in July. The average number of days in which freezing temperatures are experienced is 65 per year near the study area.

Precipitation averages about 50 inches per year in the County. Most precipitation falls in the Spring (31 percent) while Fall receives the least (21 percent). The growing season averages about 220 days per year in the study area and the average date of the last freeze is near April 1.

The Tiak Ranger District

The Tiak ranger district is the smallest of the 12 districts that comprise the Ouachita National Forest. Figure 1 illustrates the location of the Ouachita National Forest and the Tiak district in Oklahoma. Although the boundary of the Tiak ranger district encompasses approximately 150,000 acres, actual area included in the district is 43,220 acres. The discrepancy occurs because the U.S. Forest Service is allowed to buy, sell, or trade land only with in the national forest boundary.

Breakdown of the Forest

The forest service classifies every acre included in national forest ownership. Following are the acre classifications.

1. Land Area. The area of dry land and land temporarily

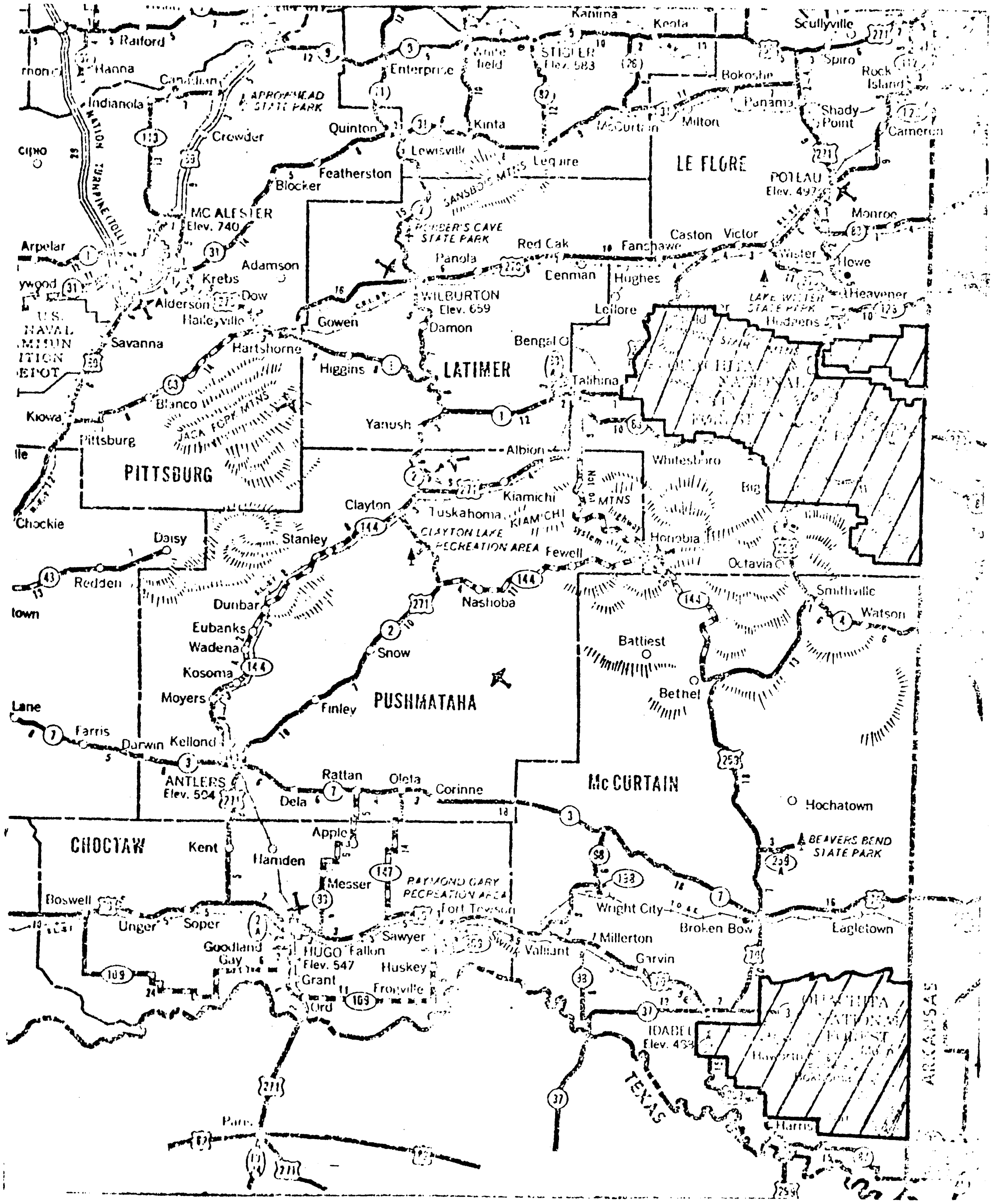


Figure 1. The Ouachita National Forest in Oklahoma.

covered by water, such as marshes, swamps, and river flood plains (omitting tidal flats below mean high tide); streams, sloughs, estuaries, and canals less than 120 feet in width; and lakes, reservoirs, and ponds less than 1 acre in area.

2. Water. Streams, sloughs, estauaries, and canals more than 120 feet in width; and lakes, reservoirs, and ponds more than 1 acre in area.

3. Forest Land. Land at least 10 percent occupied; stocked by trees of any size, or formerly having had such tree cover, and not currently developed for nonforest use.

4. Nonforest Land. Land that has never supported forests and lands formerly forested where use for timber utilization is precluded by development for other uses.

5. Productive Forest Land. Forest land which is producing or capable of producing crops of industrial wood. This includes areas of a site quality capable of producing in excess of 20 cubic feet per acre of annual growth. This includes both accessible and inaccessible areas. Permanently inoperable or nonstockable areas are excluded because they are not suitable for silvicultural management. Conversely, nonstocked areas which are stockable and otherwise meet this definition, are included.

6. Unproductive Forest Land. All forest land not included in the productive forest land classification.

7. Productive Reserved Forest Land. Productive forest lands withdrawn from timber utilization by statute, administrative regulation (Federal Code of Regulations), or by designation in land-use plans approved by the Regional Forester.

8. Deferred Forest Land. Productive forest land that has been administratively identified for study as possible additions to the Wilderness System or other withdrawal from timber utilization under authority granted in the Federal Code of Regulations.

9. Commercial Forest Land. Forest land which is producing crops of industrial wood and has not been reserved or deferred. This includes areas of a site quality capable of producing in excess of 20 cubic foot per acre of annual growth. This includes both accessible and inaccessible areas. Permanently inoperable or non-stockable areas are excluded because they are not suitable for silvicultural management. Conversely, nonstocked areas which are stockable and otherwise meet this definition are included.

10. Standard. The component of the regulated commercial forest land areas on which crops of industrical wood can be grown and harvested with adequate protection of the forest resources under the usual provisions of the timber sale contract. This area includes stands of immature trees or areas not yet accessible, but which will be in the future under the normal course of event. This area is capable of producing timber crops that have a reasonable probability of demand under the accessibility and economic conditions projected for a 10-year plan period. Economic conditions projected for the plan period should generally assume continuation of average forest product prices experienced during the past 3 years.

11. Special. The component of the regulated commercial forest land area that is recognized in the multiple use plan as needing specially designed treatment of the timber resource to achieve landscape or other key resource objectives. Areas where timber management activities are informally delayed pending multiple use planning studies and management decisions, travel and water influence zones, peripheral portions of developed sites, and classified recreation areas, such as Whiskeytown - Shasta Trinity National Recreation Area where timber harvest is a secondary or minor management objective should be included in this classification. Areas indentified as special will be included in this component whether or not there is a reduction in yield or no harvest at all expected in the 10-year plan period.

12. Marginal. This component of the regulated commercial forest land includes areas not qualifying as standard or special components primarily because of excessive development cost, low product values or resource protection constraints. Included may be drainages requiring unusual logging techniques, such as helicopters, areas where harvesting is blocked until government constructed roads are in place, or species types not presently in demand. Also included is the backlog of nonstocked areas that would otherwise be classed as standard, but are in need of reforestation that cannot be accomplished with Knutson-Vandenberg Act funds.

13. Unregulated. This is commercial forest land that will not be organized for timber production under sustained yield principles. It includes:

- Experimental Forests.

- Recreation and administrative sites. Existing and planned recreation development sites, Special Interest Areas and those administrative sites where timber harvest is permissable but not a goal of management, such as Ranger Stations, Guard Stations, nurseries, etc.

14. Un-Inventoried. Land which has not been classified. (U.S. Forest Service (26)).

According to the guidelines set forth in the forest service land classification definitions, the Tiak district land classifications are presented in Table I. The Tiak ranger district is an excellent representation of the entire southeastern conner of McCurtain county and the entire timber producing region of Oklahoma. The forest data used was obtained through the Southern Regional Office of the U.S. Forest Service in Atlanta. The "Continuous Inventory of Stand Conditions" or CISC data utilized in this study for the Tiak ranger district was:

CISC code	DESCRIPTION
CPO 1 -	Area as of June 30, 1975 under Forest Service Administration.
CPO 3 -	Stand condition by Forest Type - Non-Modified acres - Working Circle.
CPO 4 -	Stand condition by Forest Type and Management Type-Non-Modified acres by Working Circle.
CPO 6 -	Age Distribution by Management Type-by Working Circle.
CPO 7 -	Acres by Management Type and Class Site Index by Working Circle.
CPO 8 -	Acres by Management Type and Productivity Class by Working Circle.

Appendix A includes the raw data utilized in this study. The CPO code number is the designator given for each description listed that permits computer processing of the data.

TABLE I

STANDARD LAND USE CLASSIFICATION FOR TIMBER MANAGEMENT IN THE TIAK RANGER DISTRICT OF THE OUACHITA NATIONAL FOREST

Gross NF Area	Water						161
	Land	Non-Forest					557
		Forest	Unproductive				0
			Productive	Reserved			0
				Deferred			0
				Commercial	Standard		42099
					Special		180
					Marginal		95
					Unregulated	Exper. For.	0
						Rec. Sites	128
						Admin. Sites	0
Total Gross National Forest Area							43220

Source: (Appendix A)

Stand Data

The initial stand data utilized consisted of 25,253 acres of loblolly pine (Pinus taeda). Loblolly pine is the type that predominates throughout the study area although other pine species are present such as slash pine (Pinus ellioti) and shortleaf pine (Pinus echinata). There are 17,967 acres in the Tiak ranger district that are not loblolly pine. This is comprised of the various categories listed in Table I other than the standard commercial forest acres and additional acreages of various hardwood and pine varieties. The breakdown of these acreages is presented in Appendix A. The 25,253 acres of loblolly pine were used to eliminate the need for multiple yield equations involving hardwood species. Table II lists the initial age class distribution of the loblolly pine on the 25,253 acres.

TABLE II

INITIAL AGE CLASS DISTRIBUTION OF THE LOBLOLLY PINE OF THE TIAK DISTRICT

AGE	0-10	11-20	21-30	31-40	41-50	51-60	61-70	Total
ACRES	4441	7681	4034	2481	1740	4380	257	25,253

From Table II and personal consultation with the resident Forest Service personnel on the Tiak district, the original age class distributions were divided into specific ages.

The initial distribution for the district is in ten year age distributions. Therefore, it was more feasible to use the upper end of the age class division as the starting point for the management plan. This was done for each age class except the 0-10 year class where more specific data were available. The 0-10 year class was divided into timber that had just been regenerated and timber that was already established. Table III gives the adjusted age classes after the re-distribution. Table III indicates that the 0-10 year age class was divided into two parts; the first being 2217 acres of newly regenerated acres and, the second being 2224 acres of 10 year age class. Table III is felt to be representative of the entire area of high intensity wood production in Southeast Oklahoma.

TABLE III

ADJUSTED AGE CLASS DISTRIBUTIONS FOR LOBLOLLY PINE ON THE TIAK RANGER DISTRICT

AGE	0	10	20	30	40	50	60	70	Total
ACRES	2217	2224	7681	4034	2481	1835	1524	257	25,253

Site Index

Site index is the total height in feet of trees in a dominate position in well-stocked stands at specified key ages, usually 25, 50, and 100 years (8). An example would be a tree which was found to have a site index of 100 with a base age of 50 years. This information indicates that the height attained by the dominate trees in the stand would on the average, be 100 feet in 50 years. Site index is important because stands which have different site indices yield different volumes of wood. The original site indices of the loblolly pine found in the Tiak district are presented in Table IV.

TABLE IV

INITIAL SITE INDEX (BASE AGE 50) OF THE LOBLOLLY PINE STAND IN THE TIAK RANGER DISTRICT

Site Index	70	80	90	100	110	Total
Acres	200	8022	13041	3490	500	25,353

To simplify use of the data, the distribution of site indices found in Table IV was converted to a single site index. A site index of approximately 90 was selected.[1]

This completes the description of the study area and stand data. The data were arranged and aggregated in such a fashion to allow for easy entry into each model used in this study.

[1]The selection was discussed with U.S. Forest Service personnel on the district and they concurred with the selection.

CHAPTER III

LITERATURE REVIEW

Two advanced models for forest management are utilized in this study. To appreciate their applicability, models used in the past must be understood. This chapter reviews those studies which provide the broad base upon which this study is founded.

Forest management models developed over the past 200 years are as varied in their construction as they are in their purpose. Basically, the models can be divided into two major groups. The first group contains those models based on the biological yield of a forest, and their end product in most cases is to determine an "allowable cut" that would eventually lead to a regulated forest. Of this major group, there are two subgroups. The first subgroup concerns volume control regulation and the second concerns area control regulation.

The second of the two major groups includes forest management models involving financial maturity models. These models may also be divided into two subgroups. The first subgroup contains models which consider a perfectly elastic factor supply and product demand curves. The first subgroup could be called a pseudo economic model in that the biological potential of the forest is still the major factor in the analysis. The second subgroup contains those models allowing a negatively sloped demand curve. Figure 2 illustrates the groupings of the models dicussed.

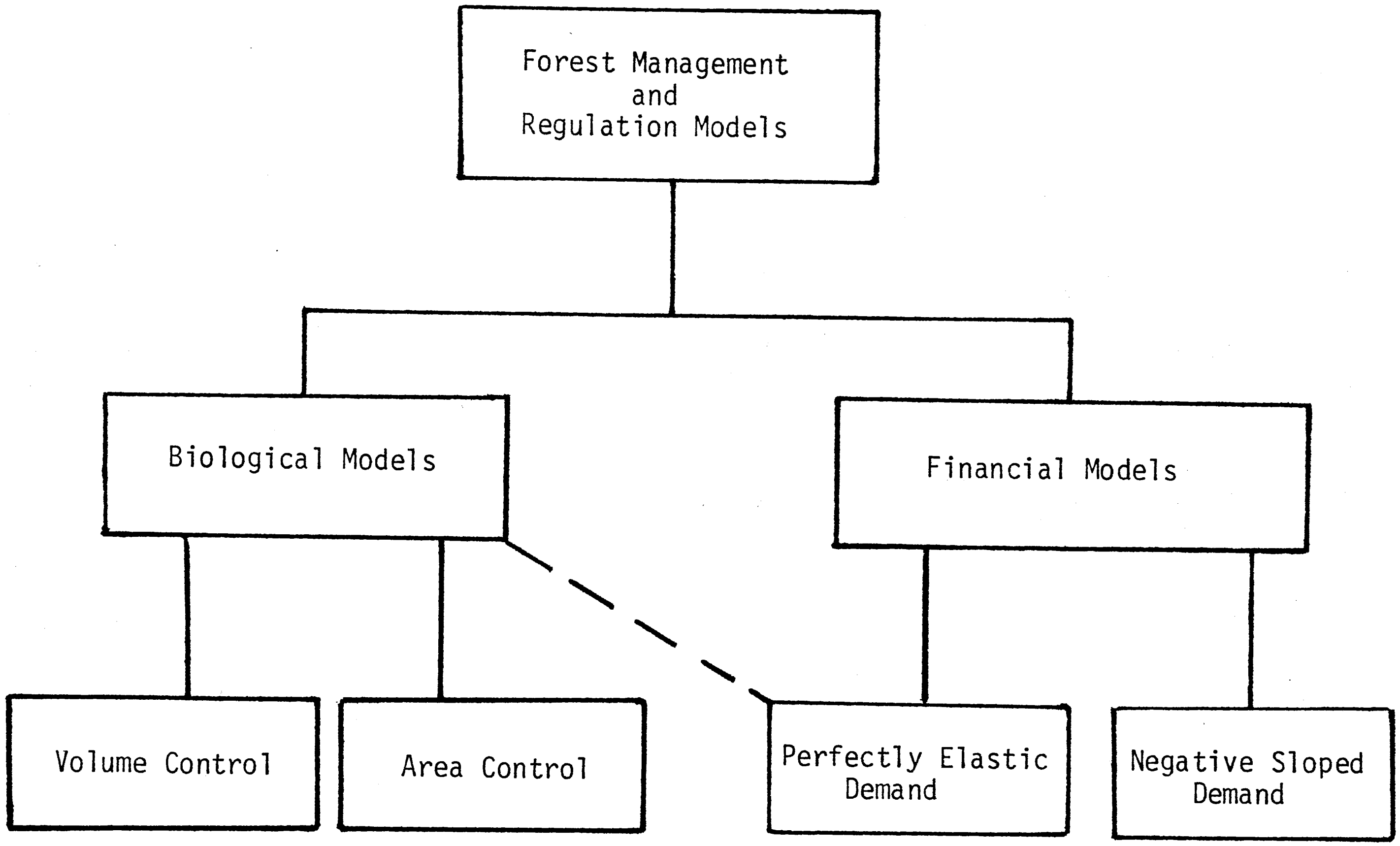


Figure 2. Forest Management Models by Groups.

Biological Models

The biological models, or the area and volume control models, are usually based upon inputs which will determine levels of timber harvest. These variables are growing stock, growth, rotation age, cutting cycle and a liquidation time period for mature timber. Economic variables, such as stumpage prices or current demand are absent from these models.

Area control implies the volume to be harvested is determined by the area that is allocated for cutting. Cutting is scheduled on a forest under management, so that each year a certain area of timber is available for harvest. An allowable cut under this situation would be termed in acres per year to be cut, e.g., allowable cut equals 2000 acres (8).

In volume control, Davis (8) states that the determination of the cut is approached through the volume and distribution of the growing stock and its increment. Therefore, the allowable cut is based on the present amount of timber in the forest plus the annual growth of that timber. An allowable cut under this situation would be termed in volume per year to be cut, e.g., allowable cut equals 2,000,000 board feet per year.

Examples of Area and Volume Control

This study deals with an even-aged forest, and so only even-age examples are presented. An uneven-aged forest consists of trees of many different ages on a given acre while an even-aged forest is characterized by trees of a single age class on a given acre. Further complexities arise with uneven-aged management.

Davis (8) presents a simplified example of an area regulation model. The assumption is made that there is a forest operating on a 60 year regulatory rotation in which the site quality is approximately the same. The allowable cut generated by the area control would simply be 1/60 of the total area and the volume cut would be the average volume per unit of area multiplied by the area cut. The above example points out the mechanics of the area control. As site quality and species change or become more complex, the area control method becomes increasingly difficult to calculate and apply.

A summarization of the area control method presented by Davis (8) shows the advantages, applications, and limitations of the area control method:

1. It is simple and direct.

2. It has the fundamental virtue of identifying the volume to be cut with areas on the ground.

3. Area control is especially helpful in situations where the main need is to bring about general silvicultural improvement of the forest.

4. If consistently followed, it will bring about complete forest regulation in any forest after one rotation period.

5. It is particularly suited to a forest composed of even-aged stands.

Volume control examples are more numerous than area control examples. Table V indicates several formulas for volume control regulation. The formulas indicate that cuts can be developed from the volume of growing stock alone, increment alone, and growing stock and increment combined. Increment is the total amount of growth that the forest attains in a period of one year. Growing stock is defined as all live trees in the forest except rough and rotten trees. The first formula in Table I indicates a formula for calculating growth or yield in an actual forest utilizing growing stock only. Once the growth per year is determined, a decision can be made regarding what amount should be removed from the forest per year in terms of harvests. The second formula determines the amount of cut necessary to achieve a given desired level of future growing stock. This formula includes the annual increment of the forest in terms of percentage growth rates. The third formula calculates the annual cut by considering growing stock and increment. The uses and limitations of volume control may be summarized as follows:

1. Volume control is most useful as an overall guide to determining a proper cut as an initial step in bringing an unmanaged forest under some degree of regulation.

2. Being mathematical in foundation, volume methods present a quick approximation of the allowable cut, often from a limited amount of forest data.

3. Volume control is readily applicable to uneven-aged stands.

4. Increment, which is required in most volume control formulas, is a weak figure because of inadequate measurement techniques.

5. With any volume method, one is dependent on the volume and increment data used.

6. Volume methods, by their nature not being related directly to area, have the serious weakness of not providing a measure of or direct means for making progress toward a desired degree of age- and size-class regularity (8). The presentation of an area and volume control combined follows:

$$C = Vo(1+i)^{n/2} \frac{-Vn}{(1+1)^{n/2}}$$

TABLE V

FORMULAS BASED ON GROWING STOCK, INCREMENT, AND GROWING STOCK AND INCREMENT USED FOR CALCULATING THE AMOUNT OF CUT NECESSARY TO ACHIEVE DESIRED VOLUME OR GROWTH LEVELS

Growing Stock Only	Increment Only	Growing Stock and Increment
$Y_a = \frac{2(G_a)}{R}$	$V_n = V_o(1+i_t)^n - a\frac{(1+i_m)^n - 1}{i_m}$	$\text{Annual Cut} = \frac{V_m(P_m)+(V_t+(V_t+(G_t/2)))P_t}{n}$
Where: Y_a = growth or yield in an actual forest G_a = growing stock in an actual forest R = rotation in years a = age when volume is first measured Units are board feet	Where: V_n = desired future volume of growing stock V_o = present volume of growing stock i_t = compound rate of growth of merchantable stand cut only without ingrowth a = annual cut n = number of years included in estimate period Units are board feet	Where: V_m = volume of mature stands P_m = percent cut in mature stands (an arbitrary figure, developed on the basis of silvicultural and related considerations external to the method itself) V_t = volume of thrifty merchantable stands. G_t = increment of thrifty merchantable stands during cutting period (area of these stands times the periodic growth per acre) P_t = percent cut in thrifty merchantable stands n = cutting period in years Units are board feet

Source: (8)

C = total volume cut for budget period

V_o = volume at beginning of budget period

V_n = desired volume at end of budget period

n = number of years in budget period

i = increment period

The above formula is then applied to a forest of known size for each age class and area and the volume/area cut is determined.

Allowable Cut Effect

Schweitzer, Schallau, and Sassaman (21) relate an example of volume control coupled with a phenomenon called the "allowable cut effect" or ACE. They consider a forest of Douglass Fur 1000 acres in size. They assume a final harvest of 72,000 board feet per acre at age 90, $30 per thousand board feet for stumpage, and total planting costs of $30,000. They calculate an annual return of 5% will be returned on this stand. The formula used to calculate the annual allowable cut is:

$$\text{Annual allowable cut} = \frac{\text{Volume of mature timber}}{\text{length of rotation}} + \text{mean annual increment}.$$

By substituting in the numbers plus adding an additional 1000 acres of newly planted land, the increase in the annual allowable cut increases:

$$\frac{\text{72,000 board feet per acre}}{\text{90 years}} + \text{1000 acres} = \text{800,000 board feet}$$

By adding an additional 1000 acres of new stock to the land, return on investment would increase to 80 percent on the marginal investment by allowing an additional cut of 800,000 board feet per year with no new sawtimber added to the inventory. Walker's (29) critique of the ACE effect indicates that the larger the current inventory, the greater the economic incentive to produce more inventory exists. The above criticism is coupled with the fact that volume/area/ACE regulation has no built in mechanism to treat prices in any other way than to force them to be constant. This brings up the question of operation size. At which point does the timber holder become a price maker instead of a price taker.

Linear programming has also been introduced into volume regulation however, the economic implications of the constraints imposed on the objective function maximized have not been explored. Linear programming models have been introduced by F. H. Curtis (7) and T. A. Jones (17). The major benefit of the linear programming methods is the ability to include a large number of factors or constraints in the maximization process. Navon's (19) model, Timber RAM, is the current planning tool utilized by the U. S. Forest Service in the West and will be one of the major planning tools utilized in this study. Timber RAM means timber resource allocation method and its operation is discussed in Chapter IV.

Economic Models

The forest management plans developed using the pure economic approach are not as varied as the area and volume control types. The economic models are based primarily on evaluating the forest potential for production when facing a downward sloping demand curve. The result is different from the models mentioned previously because the owner faces the possibility of a price decrease for timber if he supplies a larger volume to the market.

Walker and Johnson (28) (15) have developed two models that assume downward sloping demand curves. Walker's model, ECHO, is discussed in detail in Chapter IV. Johnson's model, while similar to Walker's, has several mathematical differences. A discussion of these differences is beyond the scope of this study.

Similar Studies

In a study prepared by the Western Timber Association (32), the difference arising from the use of a negative sloping demand curve for timber demand and a totally elastic demand curve for timber is evaluated. The two models used to evaluate the management plans are basically the same as the ones used in this dissertation. The goals analyzed were:

1. Maximize the present value of the cash flows at a 6% discount rate.
   a. U. S. Forest Service acting as a monopolist.
   b. Maximizing net social benefits.
2. Demand projections.
   a. Static at 1975 level.
   b. Shifting outward at 2 percent per year.
3. Regenerated stand growth projections.
   a. Forest service yields.
   b. Doubled Forest Service yields to show impact of intensive management and small log utilization.

The results of the study are presented in Table VI. The results in every case indicate that to either maximize the present value of net social benefits or net cash flow under the ECHO plan, or utilizing a negatively sloped demand curve, yields larger harvest levels than any plan generated by Timber RAM. The major question, from the viewpoint of government, is the nations future lumber supply and the implications associated with the maximization process. Figures 3, 4, 5, 6, and 7 graphically indicate the results of each alternative listed above. In each illustration the smooth curved lines representing the monopolists harvest levels and the social optimum harvest levels were arrived at in the same manner utilized in this study by using the ECHO program. The broken lines representing the current Forest Service policy was achieved by Timber RAM, the same method used in this study. By matching the appropriate illustration with the appropriate planning assumption mentioned above, harvest levels for the planning period can be analyzed. In almost every case, the assumptions evaluated using the ECHO program indicated that harvest levels were much higher than the levels found with the Timber RAM program. These results obviously depend upon the credibility of the demand equations and the discount rates used in the management plans. The entire results of the study are heavily dependent upon the demand equation which is the critical assumption in the formulation of all the management plans developed using economic criteria. Another unique feature of the Western Timber Association's study is that it is the first evaluation of a Western forest using each management technique. The Western forest, (Stanislaw), is also characterized by a large amount of old growth timber which typically consists of a large amount of very old timber which is not growing and is in fact decreasing in volume per acre. This type of timber is characterized by large volumes per acre and is quite extensive in the West but is unique to the West. The old growth type of timber is not to be found in the South and East areas of the United States.

Johnson (15) evaluated six alternative situations in both recreation and timber production for a national forest on the Oregon coast. The method of analysis was similar to that utilized in the Western Timber

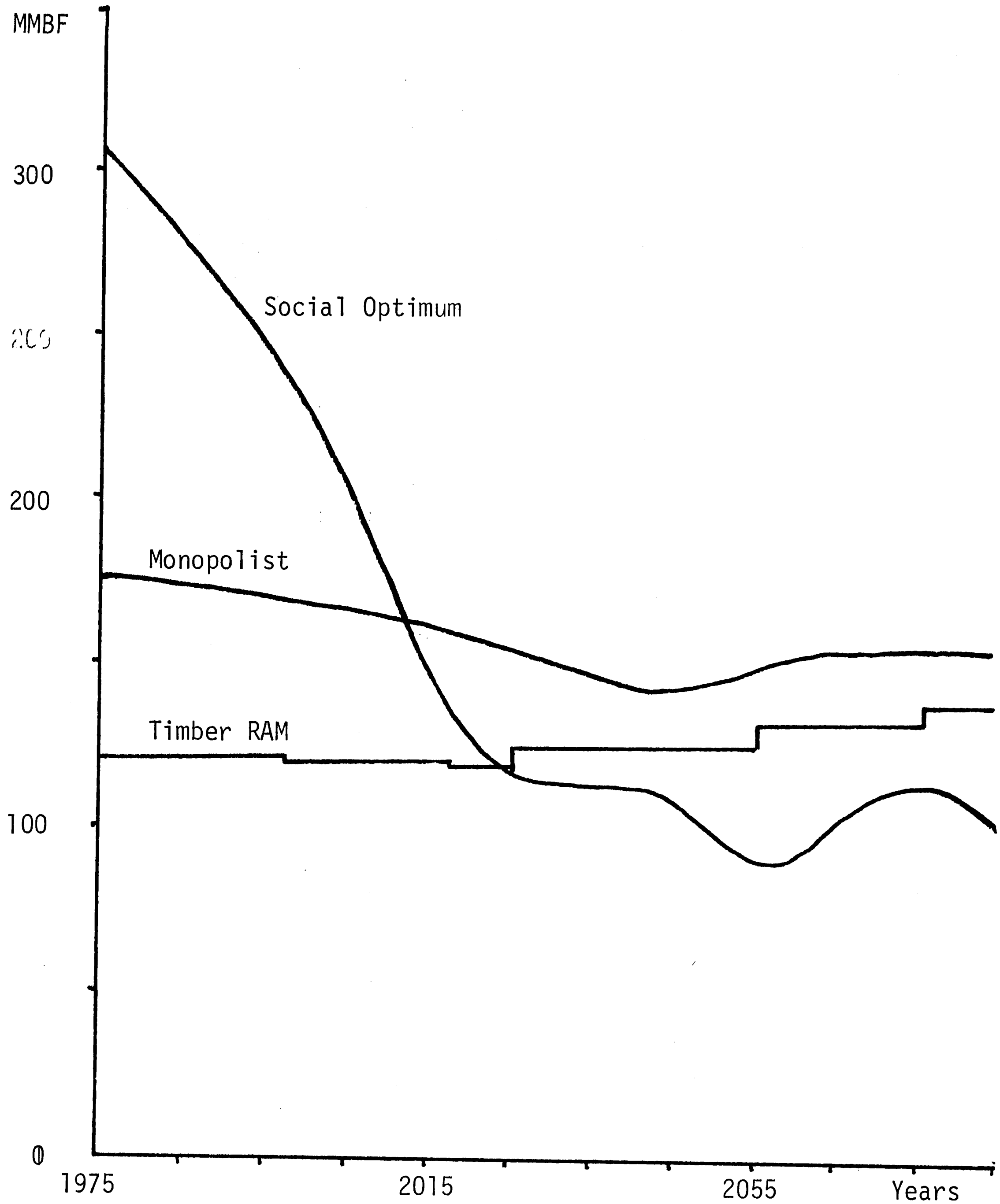


Figure 3. Comparison of Harvest Levels of the Approved Timber RAM Plan with the ECHO Plans Based on the Assumption that the Demand Curves Remain at the 1975 Level.

Source: (31)

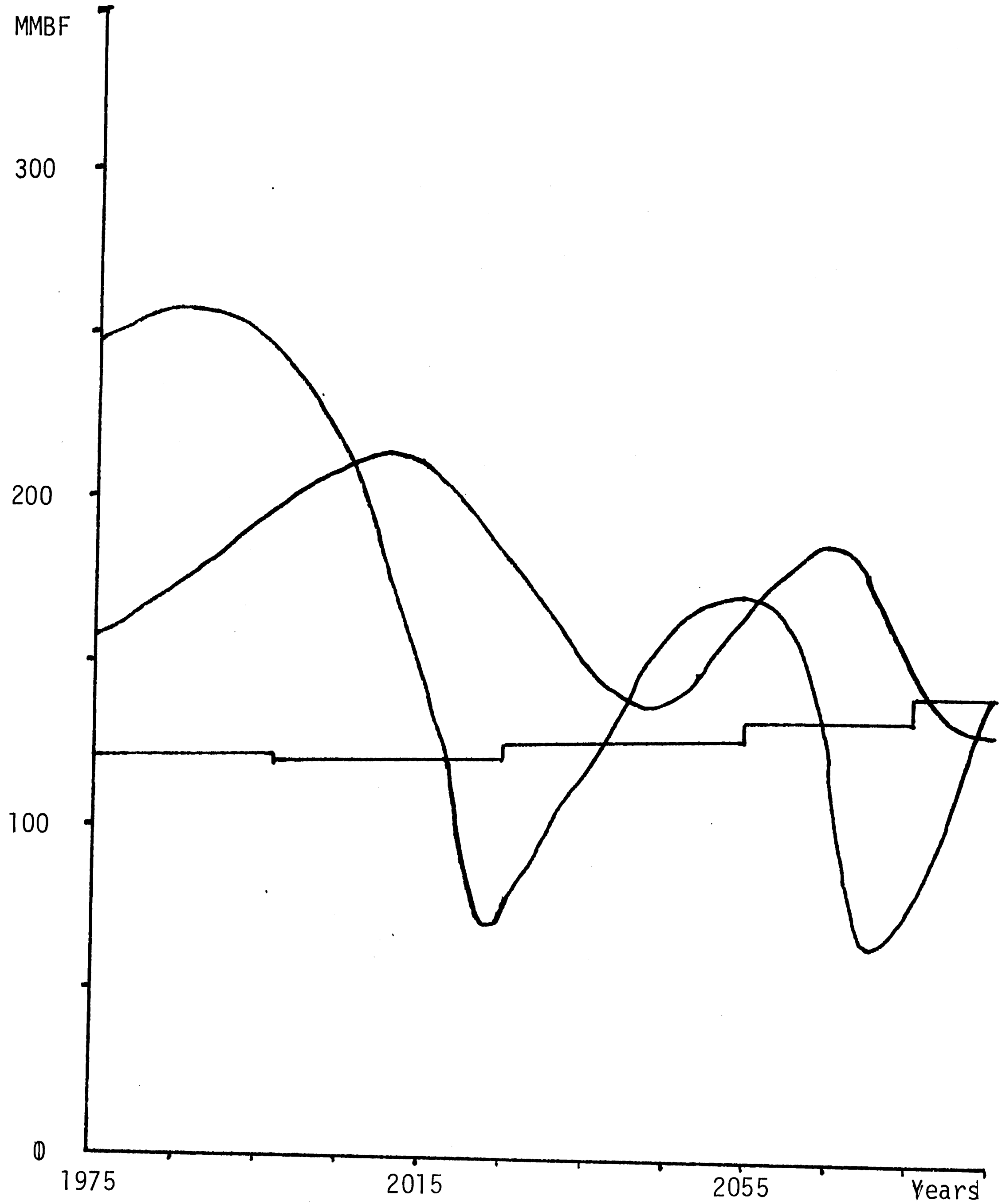


Figure 4. Comparison of Harvest Levels of the Social Optimum and Monopolist ECHO Plans with the Approved Timber RAM Plan when the 1975 Demand Curve is Assumed to Shift Outward at 2 Percent per Year.

Source: (31)

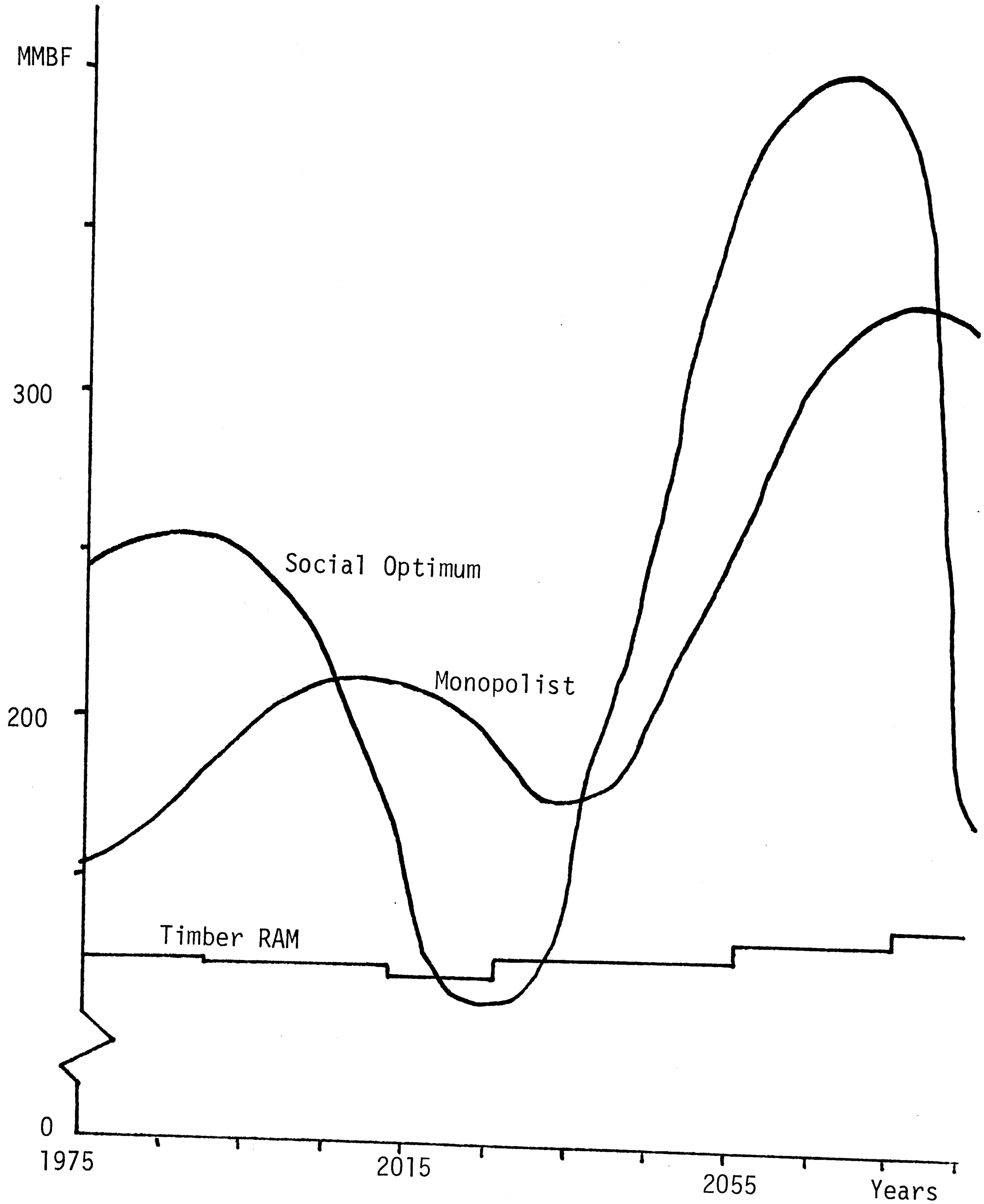


Figure 5. Comparison of Harvest Levels of the Social Optimum and Monopolist ECHO Plans with the Approved Timber RAM Plan when the 1975 Demand Curve is Assumed to Shift Outward at 2 Percent per Year and the Forest Service Plantation Yield Tables are Doubled to Test the Impact of more Intensive Management and Utilization.

Source: (31)

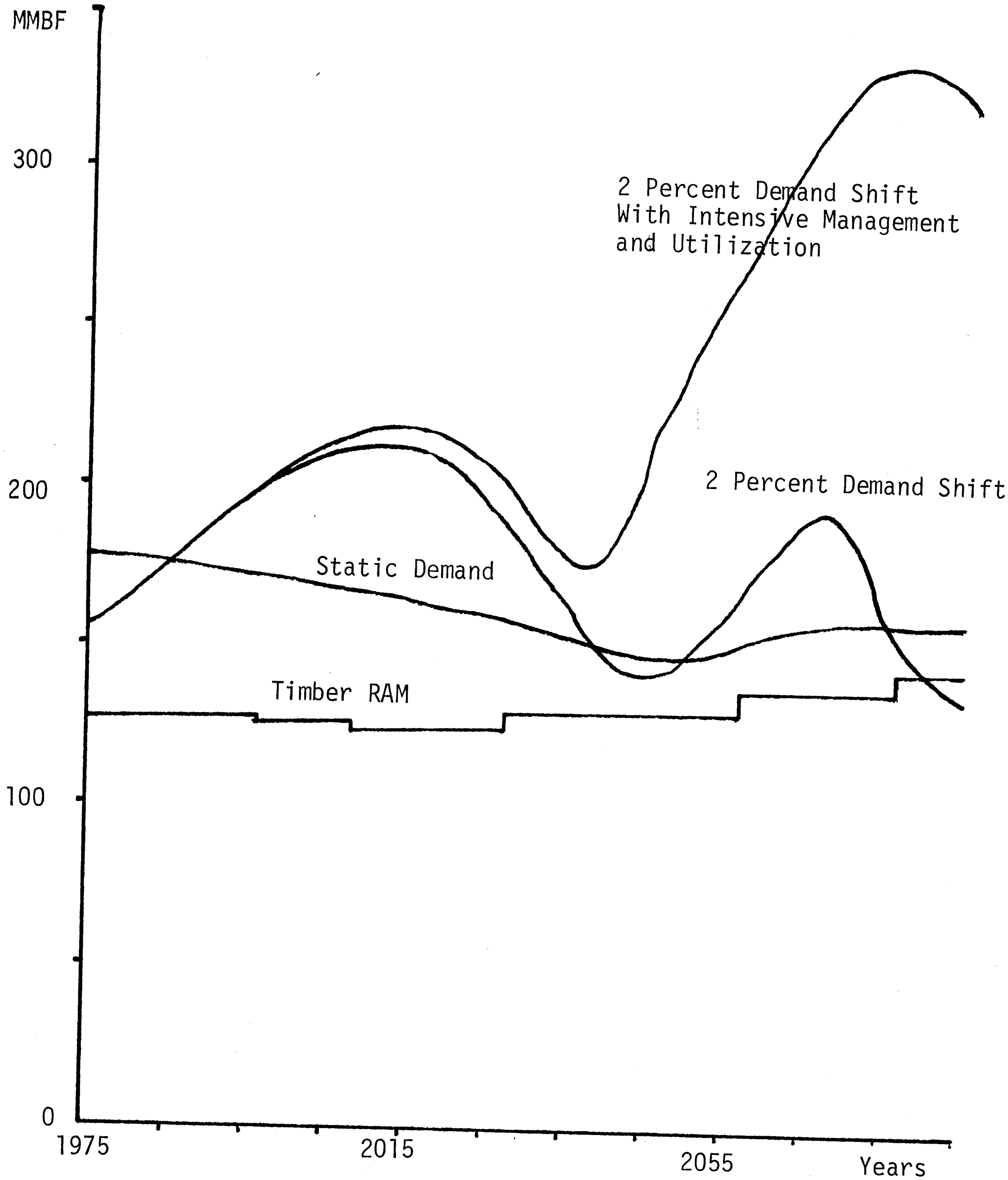


Figure 6. Comparison of the Approved Timber RAM Management Plan with the Three ECHO Plans Maximized for the Forest Service Acting as a Monopolist.

Source: (31)

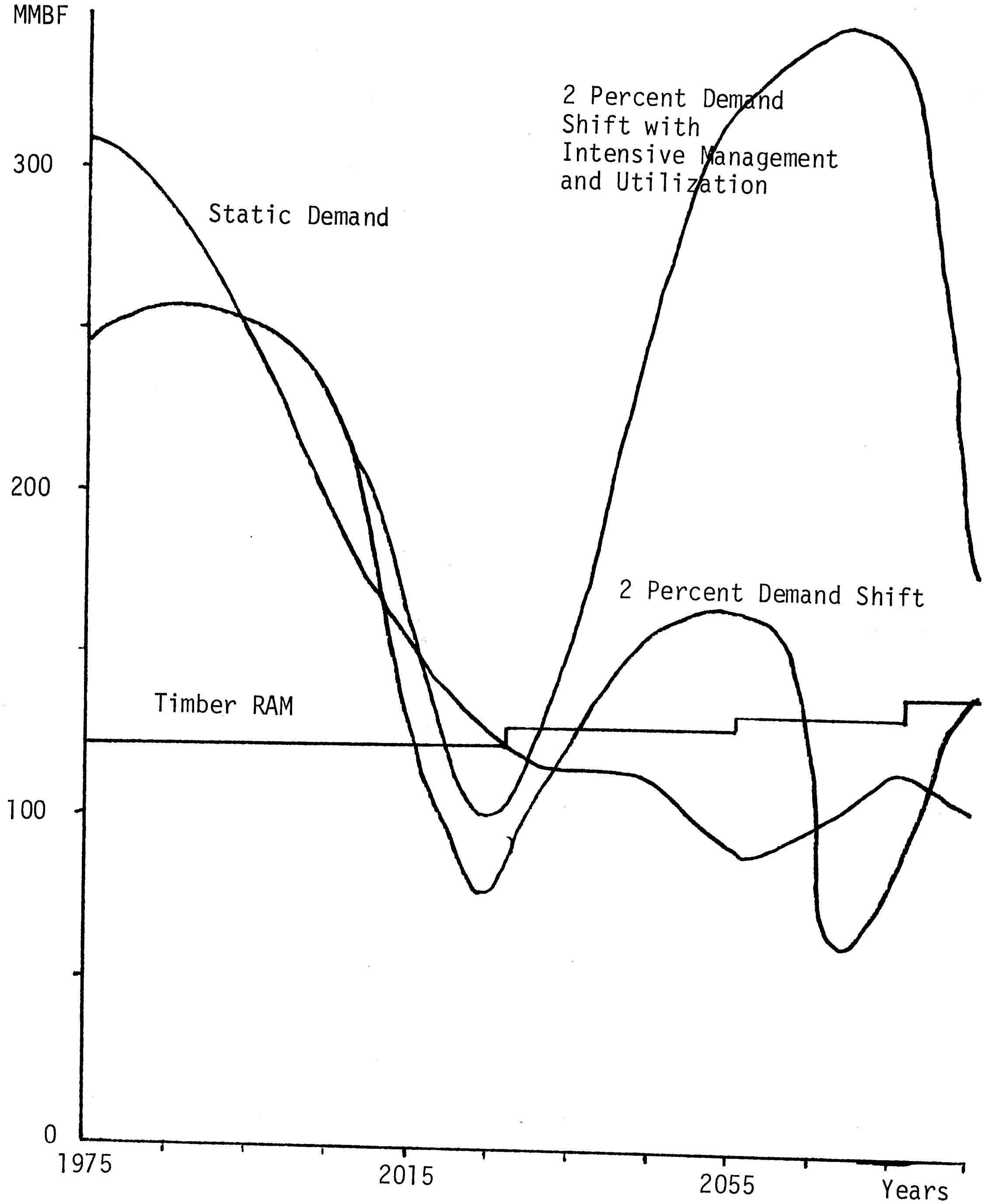


Figure 7. Comparison of the Approved Timber RAM Management Plan with the Three ECHO Plans Designed to Maximize Net Social Benefits.

Source: (31)

TABLE VI

SIX PERCENT PRESENT VALUES OF STANISLAUS NATIONAL FOREST MANAGEMENT PLANS

Basic Assumptions	U.S.F.S. $Million	Society $Million	Approved Timber RAM Plan $Million
Static Demand			
U.S. Forest Service	406	256	315
Net Social Benefits	600	708	418
Shifting Demand @ 2%			
U.S. Forest Service	880	795	529
Net Social Benefits	1123	1213	717
Shifting Demand @ 2% With Intensive Management and Utilization			
U.S. Forest Service	939	867	---
Net Social Benefits	1201	1301	---

Source: (31)

Association's survey (31), although more extensive in nature. Johnson utilized a technique similar to ECHO to evaluate alternative timber production levels for the different alternatives. In every situation evaluated by Johnson, future timber production or supply was lower than the supply forecasted by conventional methods that used present policy guidelines for a basis of prediction. Although Johnson's projection of future supply was lower, the maximization of the present value of net social benefits and cash flow was higher than conventional projections which indicates that the model predicted a higher price for timber in the future.

Beuter, Johnson and Scheurman (4) developed various alternative possibilities for the development of forest programs in Oregon. They divided the State of Oregon into ten local timber-dependent areas called timbersheds and for each area an answer was determined for each of the following questions:

1. Can the present annual harvest (based on the annual average for 1969-1973) be maintained to the year 2000 if public owners maintain their current allowable cuts and private owners continue to try to fill the gaps between the public harvest and the total?

2. What is the capability for timber harvest after the year 2000 if policies and actions among owner classes in number one above are continued until year 2000?

3. How would intensity of timber management change the results of the projection?

4. Assuming that the various owner classes are willing to change some of their policies and actions, what is the potential timber harvest over the next 100 years?

5. Given a rise of 47 percent in U. S. softwood consumption by the year 2000 compared to 1970, can Oregon continue to supply her relative share?

Results of the study were quite varied and interesting from question to question and timbershed to timbershed. The important facets of the study were the questions themselves in that they did portray reasonable questions concerning the future of Oregon's ability to supply timber. Other questions answered by the study were concerned with levels of future employment in Oregon forestry related industries, questions concerning timber-related taxes, and in-lieu payments. Johnson's study (15) used as its main analytical tool a model similar to ECHO, the model used in this dissertation. It is the only printed application of either model to relevant forest problems in management with consideration toward current and future price and demand criteria. Walker (29) has conceived a plan to merge ECHO and ITM (Interregional Timber Model) to make simulations of region wide use and production of timber. The U. S. Forest Service (25) plans to use Timber RAM in their planning decisions as a source for quantitative answers to the Resources Planning Act.

The two models mentioned are two very new and useful forest management tools available for future use. However, application of these two techniques has been limited to the forests of the Northwest United States. The application of these methods to provide quantitative answers to pertinent questions concerning a forest of an entirely different makeup have yet to be tested.

CHAPTER IV

DEVELOPMENT OF THE MODELS

Forest landowners are faced with two problems. They can either maximize volume produced or they can maximize the present value of the cash flow generated by the forest. Maximization of volume can be obtained by cutting all the volume in the first year. The maximization of cash flow can also be achieved by cutting in the first year depending on future prices. However, this solution to forest management problems for a given area violates the earlier assumption of sustained yield, even-flow harvests. The maximization of volume produced is accomplished under the assumption that prices will be constant regardless of volume produced. The maximization of the present value of cash flow is accomplished under the assumption of decreasing prices for increases in volume. Of the two cases outlined, the first, maximizing volume, implies a totally elastic demand curve and the second maximizeing the present value of cash flow, implies a less than totally elastic demand curve (Figure 8).

Other considerations in forest land management are harvest flow constraints which may be tied to environmental, political, or budgetary constraints. These constraints can limit the land owner's access to certain areas for certain periods of time, or limit the reproduction capability of the land due to a lack of regeneration funds or materials. This chapter contains a discussion of two models which can be used to analyze problems and propose solutions to timber management problems.

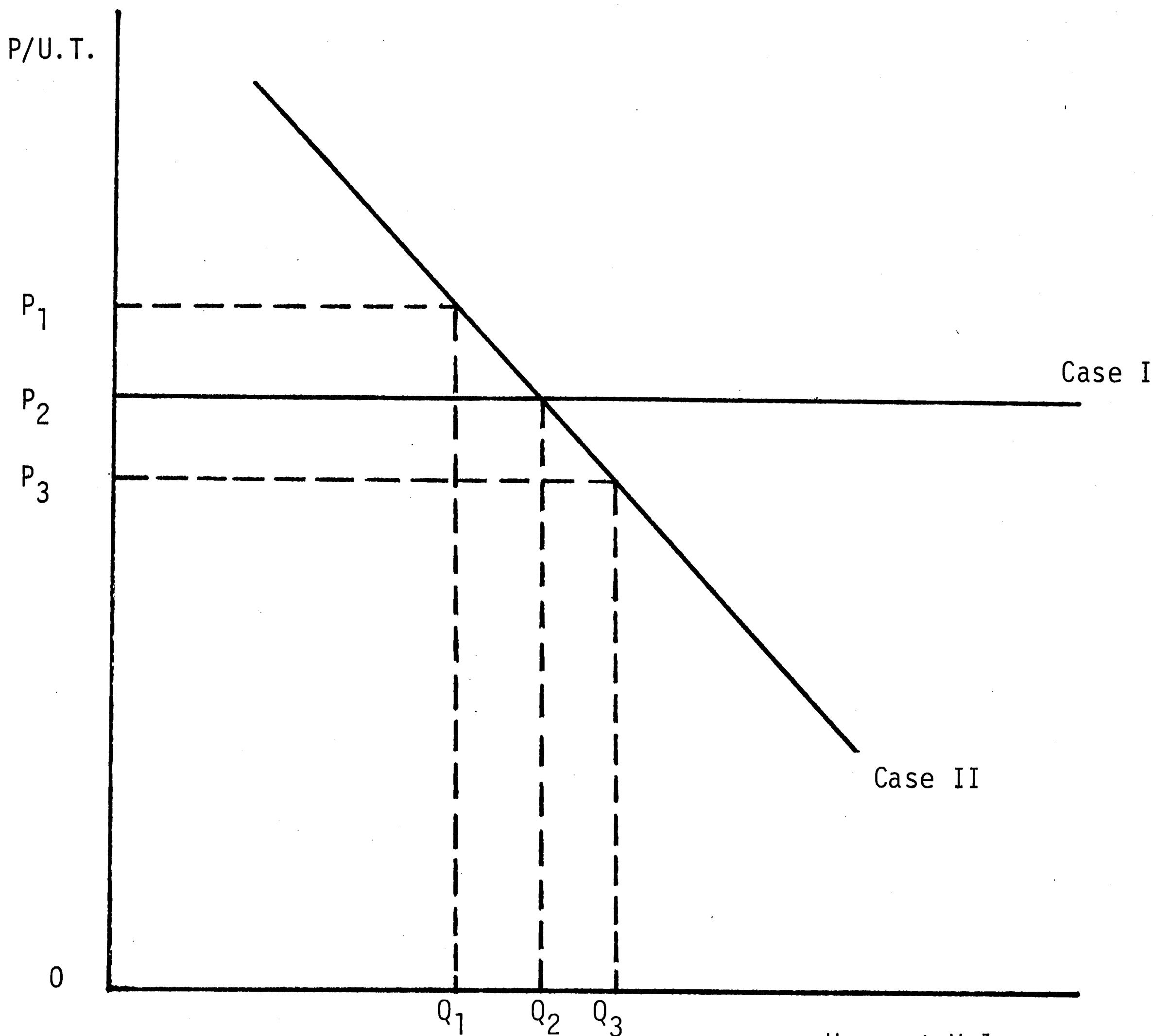


Figure 8. Case I Represents a Totally Elastic Demand Curve where Price P_2 is Offered for Volume Q_2 and Case II Represents a Negatively Sloped Demand Curve where P_1 is the Price for Quantity Q_1 and for the Greater Quantity Q_3 a Lower Price P_3 is Offered.

Timber RAM

Timber RAM is a linear programming model developed by Navon (19). Timber RAM was utilized on a West coast forest (24) and is the major planning tool utilized by the U.S. Forest Service to meet the requirements of the Resources Planning Act.

Timber RAM maximizes a linear objective function subject to a number of constraints. In Timber RAM, an activity refers to a complete set of actions that can occur on a particular land area during the planning horizon. An example of an activity would be a harvest removal of all the standing timber on a given acre with a 60 year rotation. Therefore, an activity is the set of harvesting sequences for the given land area (with the given age class and volume class) that will take place on that land area over the entire planning cycle. The planning horizon is the total time spanned by the model by adding the number of decades in the conversion period and the post-conversion period. The conversion period is the time taken to reduce the existing timber to the even-flow, sustained-yield level and the post-conversion period is the time taken to complete one rotation of the activities chosen in the final Timber RAM plan.

Mathematical Formulation

In the mathematical formulation and presentation, the assumption will be made that only one type-site of uniform productivity will be used and divided into a number of age classes and that the number of years between age classes equals the number of years between periods. Timber RAM can handle numerous type-sites, but to consider more than one would only complicate the mathematical formulation. Also, without regeneration harvest, acres will move sequentially into higher age classes over time, with the possibility of thinning or regeneration cutting in any period after the appearance of merchantable volume. This is basically an allowance in the model that permits the timber to actually grow until a profitable amount of timber can be harvested. After a regeneration harvest, regeneration occurs in the same period and the acres are assigned to a zero age class. The regeneration period can also be changed to allow any number of years for regeneration or the model can be altered to allow for a percentage survival in any given year. Timber RAM is also capable of handling multi-stage regeneration harvest such as overstory removal or shelterwood removal.

In Timber RAM, each age class that contains acres in the first period forms a management unit whose integrity is kept throughout the planning horizon. Each activity represents a possible management regime for a particular management unit, with it's associated inputs and outputs, over the planning horizon. A management regime is a combination of treatments such as two 5 year thinning cuts followed 5 years later by a harvest cut performed on a given area of land. Each regime has two parts 1) a sequence of regeneration harvests throughout the planning horizon and 2) an associated cultural treatment regime.

Using Linear Programming, Timber RAM solves for activities from each possible regeneration harvest sequence that can occur during the planning interval within each management unit. These activities are identified in terms of their regeneration harvest sequence number and the particular management unit to which they belong. Thus, $x_{\ell q}$ will represent acres of management unit ℓ assigned to a particular regeneration harvest sequence q. There must also be one constraint for each management unit to control the total number of acres that can be assigned to all regeneration harvest sequences.

The model is:

$$\text{MAX} \sum_{\ell=1}^{u} \sum_{q=1}^{R\ell} D_{\ell q} \; x_{\ell q} \qquad \text{I}$$

Subject to:

Acreage Constraints:

$$\sum_{q=1}^{R\ell} x_{\ell q} \leq A_{\ell} \quad \ell=1, \ldots u.$$

where

$x_{\ell q}$ = acres of management unit ℓ assigned to regeneration harvest sequence q.

$D_{\ell q}$ = discounted net revenue per acre of all harvests from management unit ℓ over the entire planning interval, if assigned to regeneration harvest sequence q.

A_{ℓ} = number of acres in management unit ℓ.

u = number of management units = number of age classes which contain acres in period one.

R_{ℓ} = number of possible regeneration harvest sequences over the planning interval for management unit ℓ.

Johnson and Scheurman (16) present an example in which the above equations are presented. Consider the problem of scheduling harvests for the next six periods from a forest that has two age classes, of ten acres each, aged four and eight periods. Further consider a minimum of two periods between regeneration harvests in that it takes two periods for a new stand to reach merchantability. To solve the problem, one must begin by finding the total number of activities for each possible sequence of regeneration harvests over the six periods for each age class. The formula that gives the number of activities, assuming that there is no age constraint on the maximum age that a stand can achieve before harvest and all existing stands are of merchantable age is:

$$U^* \sum_{\ell=1}^{N} t_\ell$$

where:

$$t_\ell = \begin{cases} 1 & \text{if } \ell \leq Z \\ t_{\ell-1} + t_{\ell-Z} & \text{if } \ell > Z \end{cases}$$

where: Z = minimum periods between regeneration harvests.

N = number of periods in the planning horizon.

U = number of age classes in period one which contains acres.

Table VII indicates that when the various values for ℓ and t_ℓ are substituted into the above summation, a value of 20 activities for the sample problem is calculated.

TABLE VII

VALUES FOR ℓ AND t_ℓ USED IN DETERMINING THE POSSIBLE NUMBER OF HARVESTING SEQUENCES FOR THE EXAMPLE PROBLEM

Period When First Harvest Occurs	Number of Possible Regeneration Harvest Sequences	ℓ	t_ℓ
6	1	1	1
5	1	2	1
4	2	3	2
3	3	4	3
2	5	5	5
1	8 Σ=20	6	8 Σ=20

Johnson and Scheurman (16)

It must be pointed out however, that these calculations assume no maximum age class restriction. The inclusion of a maximum age class restriction may decrease the number of activities needed depending upon the age limiations prescribed.

Table VIII indicates the harvest sequence which corresponds to Table VII calculations. In Table VIII each period equals ten years as is specified in Timber RAM. An example of the maximum age constraint would be if the timber was age 60 years in period one and a maximum age constraint was set at 100 years, then harvest sequence numbers 1, and 2 from Table VIII would be excluded from the possible activities generated. If harvest sequence 1 and 2 are allowed to remain, then the age 60 year timber would grow past the prespecified age of 100 years.

Timber RAM is also capable of specifying a minimum number or maximum number of harvest cuts. An example would be, again referring to Table VIII, if a maximum number of harvests were set at two. Then all activities that had more than two cuts specified would be eliminated. In Table VIII, harvest sequence numbers, 9, 13, 14, and 17 would be eliminated.

After the number of activities per age class have been found (20), substitution of the numbers into the equation find:

$$\text{MAX} \sum_{\ell=1}^{2} \sum_{q=1}^{20} D_{\ell q} X_{\ell q} \qquad \text{II}$$

subject to:

Acreage constraints (10 acres/age class)

$$\sum_{q=1}^{20} X_{1q} \leq 10 = \text{mgt. unit } 1$$

$$\sum_{q=1}^{20} X_{2q} \leq 10 = \text{mgt. unit } 2$$

TABLE VIII

POSSIBLE REGENERATION HARVESTED SEQUENCES OVER SIX PERIODS FOR AN AGE CLASS THAT CONTAINS MERCHANTABLE VOLUME IN PERIOD ONE AND WHERE THERE MUST BE AT LEAST TWO PERIODS BETWEEN REGENERATION HARVEST. WHERE EACH H REPRESENTS A POSSIBLE REGENERATION HARVEST.

Harvest Sequence Number	Period Number 1	2	3	4	5	6
1						H
2					H	
3				H		H
4				H		
5			H		H	
6			H			H
7			H			
8		H		H		
9		H		H		H
10		H			H	
11		H				H
12		H				
13	H		H		H	
14	H		H			H
15	H		H			
16	H			H		
17	H			H		H
18	H				H	
19	H					H
20	H					
Age	60	70	80	90	100	110

Timber RAM would take the above specifications and maximize II. The resulting maximization would give the harvesting sequences and yields which would maximize the discounted cash flow from the timber lands.

Inclusion of Harvest Flow Constraints

There are various types of harvest flow constraints that are used in forest operations of which three are: 1) maximum percent fluctuation in harvest from period to period 2) maximum percent fluctuations in harvest around the overall average and 3) no decrease in harvest from period to period. (non-declining yield). An example of a constraint of the maximum percent fluctuations in harvest from period to period when included in the model becomes:

$$\text{MAX} \sum_{\ell=1}^{U} \sum_{q=1}^{Re} D_{\ell q} \; X_{\ell q} \qquad \text{III}$$

subject to: 1. Acreage Constraints

$$\sum_{q=1}^{Re} X_{\ell q} \leq A_{\ell} \quad \ell=1, \ldots, U$$

2. Harvest Flow constraints

$$(1-\alpha)\, h_j - h_{j+1} \leq 0 \quad j=1, \ldots, N-1$$

$$(1-\beta)\, h_j - h_{j+1} \geq 0 \quad j+1, \ldots, N-1$$

where:

$$h_j = \sum_{\ell=1}^{U} \sum_{q=1}^{Re} Y_{\ell q j} \; X_{\ell q} = \text{total harvest}$$

Where: $Y_{\ell qj}$ = harvest per acre of management unit 1 in period q under management regime j.

α,β = permitted fluctuations in harvest from period to period ($\alpha,\beta \geq 0$).

In Timber RAM, there are three ways to specify the above constraints, and convert them into a lower and upper bound constraints.

Harvest Control and Regulation Constraints

The first control that can be specified in Timber RAM is the arbitrary control. The harvest level of each period is restricted to a range of values specified by fixed upper and lower bounds; for example: 100 and 70 million board feet or 2500, and 2000 acres.

In sequential control, a second type of control, each periodic harvest level is restricted to a range of values around the preceeding periodic harvest level. The upper and lower bounds of this range are expressed as a percentage of the preceeding periodic harvest level: for example, given a harvest level of 100 million board feet, .25 and 0.10 specify the range of 125 million and 90 million board feet for the next periodic harvest. The first periodic harvest level is restricted to a range around a specified "current level" to provide a means of insuring a smooth transition into the Timber RAM plan.

The final control available is the conventional control. The conventional control limits the periodic harvest to a range of values around their average. The upper and lower bounds of the range are specified as percentages of their average. The first periodic harvest can in addition be restricted to a range around a specified "current level" to insure a smooth transition into the Timber RAM plan. The upper and lower bounds of the range are also specified as percentages by of the "current level". Figures 9, 10, and 11 illustrate the three harvest flow constraints and their limiting capabilities in the model.

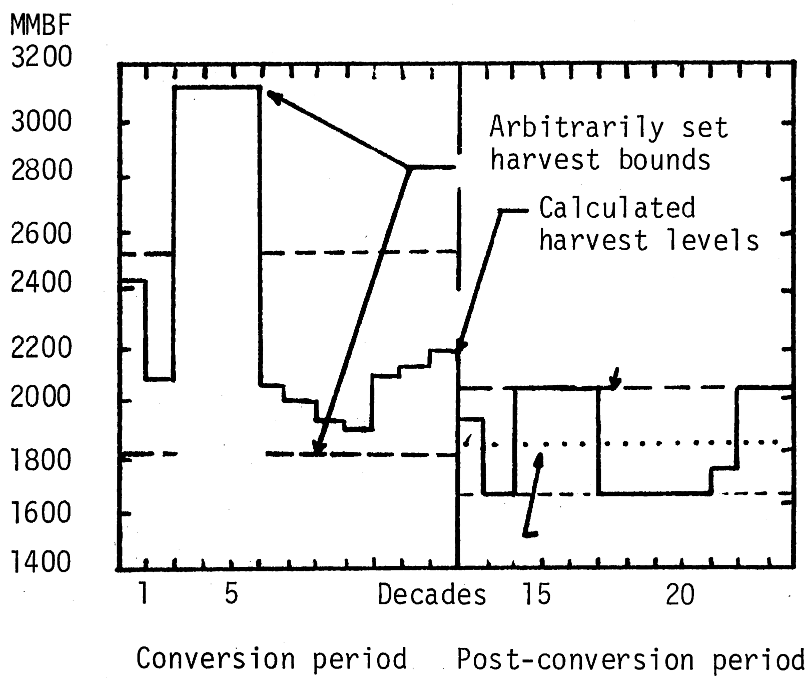


Figure 9. Timber RAM Arbitary Control. The user specifies the exact volume ranges within which he wants to maintain periodic harvest levels during the conversion period. In the problem illustrated, the user set the lower bound at 1,800 MMBF and the upper bound at 2,500, except for decades 3-5 where he set the minimum harvest level at 3.100 MMBF. Regulation was insured by specifying an allowable tolerance of ± 10 percent around the post-conversion average. The user can set the bounds and allowable percentage variations differently for each decade.

Source: (19)

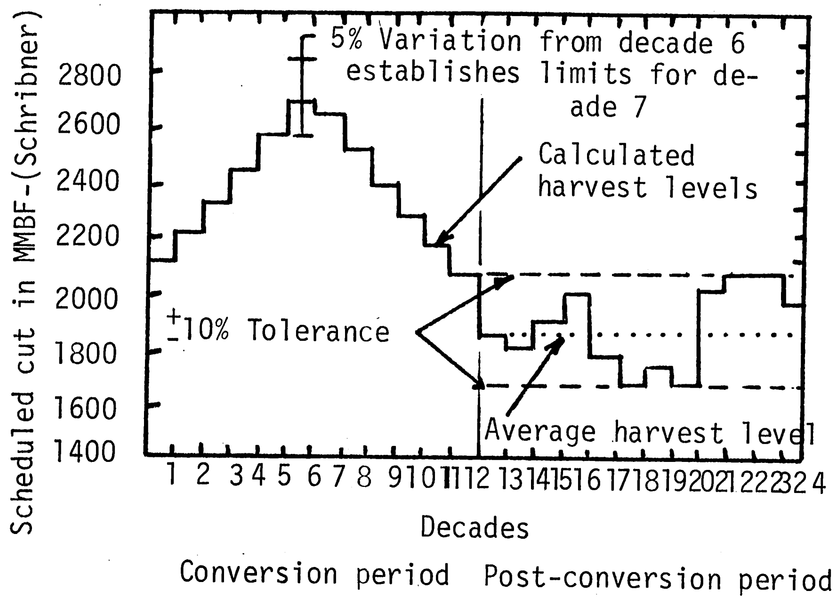


Figure 10. Timber RAM Sequential Control. The user constrains the level of each periodic harvest during the conversion period to an allowable percentage variation around the level calculated for the preceding decade. In the problem in illustrated, the user chose ± 5 percent as the allowable variation between decades Forest regulation was insured by also allowing only a ± 10 percent variation for post-conversion harvests around their average. The user can set the allowable tolerance for each decade independently.

Source: (19)

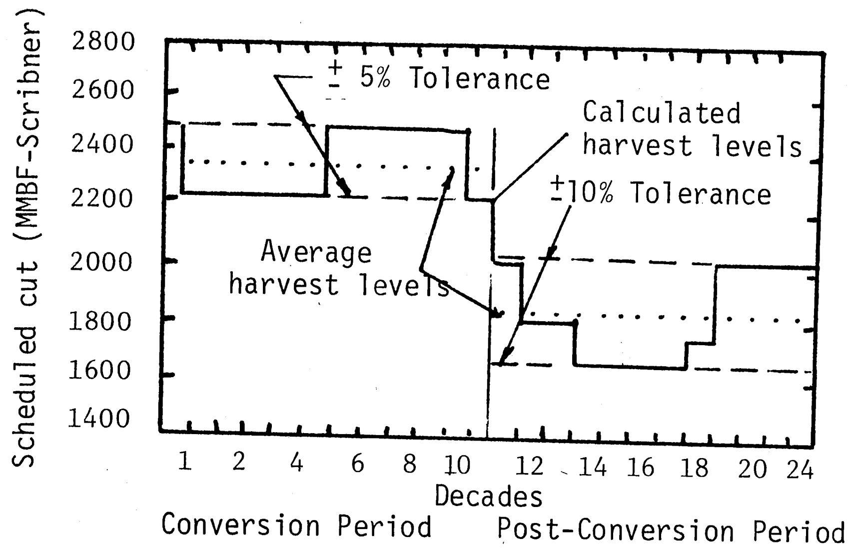


Figure 11. Timber RAM Conventional Control. The user constrains periodic harvest levels to a percentage variation around their average during the conversion period. In the problem illustrated, the user chose ± 5 percent as the allowable variation. To insure regulation, he specified that post-conversion periodic harvests be within ± 10 percent of their average. Thus, the user controls the degree of evenflow and regulation simply by setting the tolerances for each decade.

Source: (19)

Other constraints that may be introduced into the Timber RAM model are area and accessibility constraints and periodic constraints. These two along with the harvest control and regulation constraints provide for a wide range of alternative solutions based on the specifications of each.

Timber RAM Objectives

Timber RAM plans may be based on three types of objective functions. Timber RAM can:

1. Maximize volumes.
2. Maximize net revenues.
3. Minimize costs.

Each of these objectives can be incorporated into six alternative planning horizons, and seven different interest rates for revenues and costs for a total of up to 174 alternative objectives for a single Timber RAM problem.

Planning Alternatives

Changing the objective, constraints, or activities defines a new planning alternative for which a different combination of activities will normally be found. By changing the objective of maximizing the total discounted net revenue collected over eight periods to four periods for example, an entirely new set of activities and thus a new solution or new Timber RAM plan will be found.

Additional planning alternatives can be defined and the corresponding Timber RAM plans obtained by making one or more combinations of changes in the specification of the objective, the constraints, or the activities. Changes in the objective, could be specified by:

1. Varying the number of decades over which the objective function is defined.

2. Changing the index of performance (maximize volume harvested instead of discounted net revenue).

3. Varying the discount rate of the index of performance.

Changes in or deletion of the constraints could also generate new Timber RAM plans by:

1. Exploring changes in current or tenative goals.

2. Evaluating alternative multiple-use management policies, even-flow sustained yield, the size of stream side zones, and of scenic areas and protected wildlife habitats.

3. Evaluating accelerated road construction or tree improvement programs.

Changes in activities can be specified by adding or deleting activities to evaluate:

1. Special treatments for sensitive areas.

2. Different rotation ages.

3. New types of logging.

4. Various levels of management intensity including fertilization and the introduction of genetically improved stock.

Operation and Generation of Timber RAM Plans

The steps required for the operation and generation of Timber RAM plans are illustrated in Figure 12. Each step requires the preparation of an input deck and making a computer run.

The objectives, constraints, and all data necessary to define activities for every timber class are entered in a specific order. The

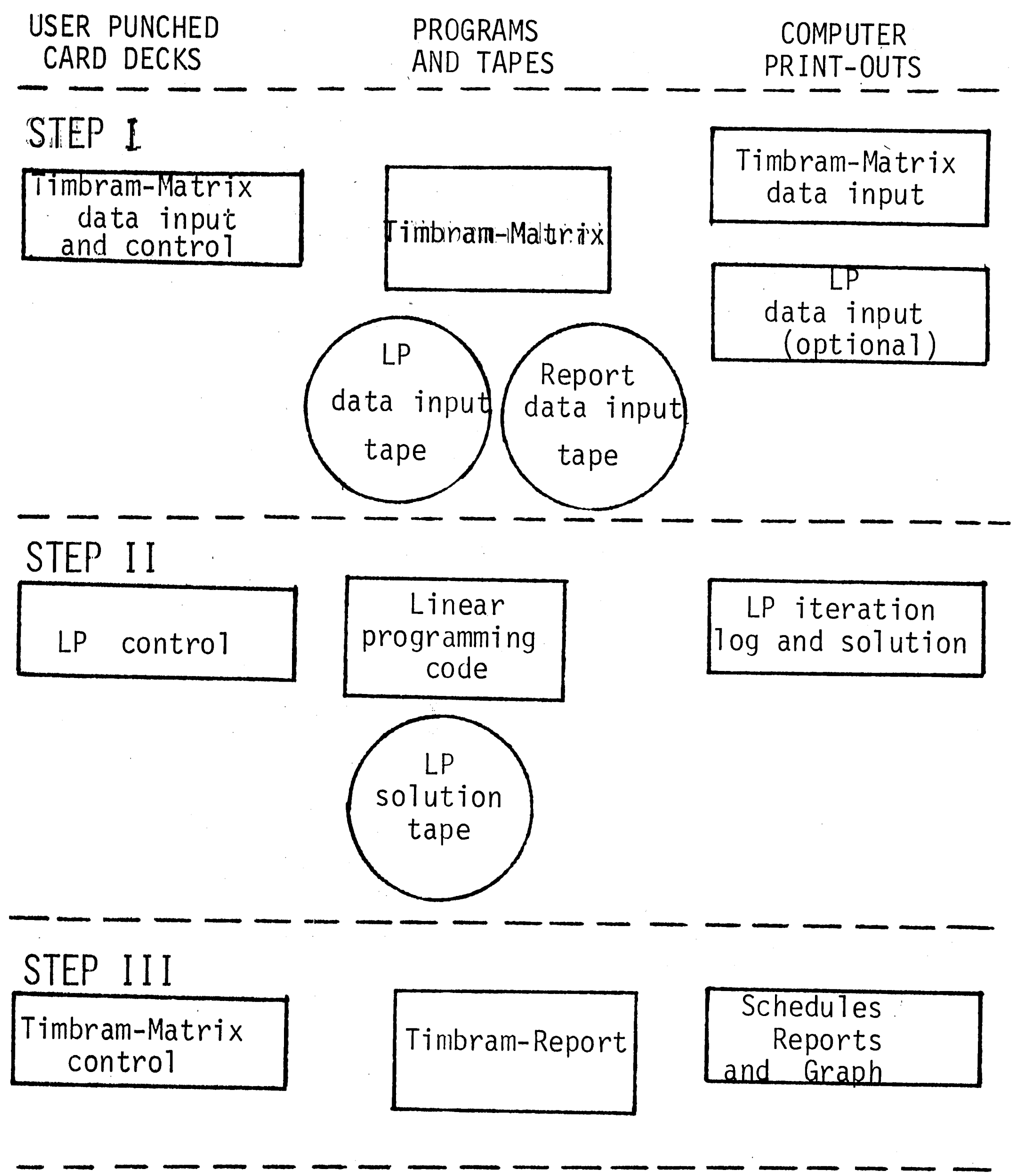


Figure 12. Flow Chart of Timber RAM.

Source: (19)

program Timber RAM Matrix is then run to produce the Linear Program (LP) Data Input Tape used in Step II and the report input tape used in Step III. The data printed on these tapes can be checked by inspecting the Timram-Matrix Input computer printout. Using this procedure, the planner can eliminate errors in input before the program enters the solution phase.

The next step is finding a combination of activities with the linear programming algorithm MPSX. The L.P. control deck consists of only a few cards and the control language is available in the MPSX user's manual. It is also possible to solve alternative Timber RAM problems by changing the right hand side values in the MPSX control cards which would save considerable time and money.

The final step requires the generation and interpretation of the Timber RAM report output. Appendix B contains an example of the Timber RAM output. The output consists of a timber harvest schedule, which lists the harvests by decades and type of cut. The problem schedule lists the revenues, costs, and volumes associated with each cut by decade. The harvest report lists a summary of acres cut, periodic cuts, and total cuts by period, and an economic report which lists the revenues, costs, and net revenues associated with each period.

As pointed out in Western Timber Association (32), and Navon (19), Timber RAM and other forest management linear programming models suffer from proportionality of linearity. The implication is that the total inputs and outputs of each activity is directly proportional to the number of acres managed with the activity. The linearity also is present on the cost and revenue side which leads to the assumption of a completely elastic demand curve for timber. A proof of this can be obtained with Timber RAM by lifting all constraints in the first period and as a result, Timber RAM would indicate that all financially mature timber should be harvested in the first period. If the study area were very large, a step such as this would, with almost certainty, drive down the stumpage price. Walker (27) makes the point that in Timber RAM, every constraint must be specified by the user. On the other hand, the forest manager should be able to provide the input with his knowledge of forest operations and of his labor's capabilities. In fact, Navon (19) feels that this type of input requirement leads to overall better knowledge of the forest by the forest manager.

ECHO

Timber RAM is based on a totally elastic demand curve for timber. ECHO, (Economic Harvest Optimization) is based on a negatively sloped demand curve. Timber RAM is based on a single price for any given amount of timber, therefore, any seller of timber has no influence upon the price offered. That is, the seller of timber is a price taker. ECHO is based on the negatively sloped demand curve implying that for different quantities demanded by the buyers, a different price will be offered. The result of a downward sloping demand curve is the necessity of maximizing a quadratic function. The reason for this is that even though a demand curve is usually visualized as a linear function, in reality, it usually is shaped more or less as case II in Figure 13.

Mathematical Derivation

Walker (28) presented his model in an economic/mathematical form as follows:

$$V_t\ (MR_t - MC_t)\ (1 + i) = V_{t+1}\ (MR_{t+1} - MC_{t+1}) \qquad \text{I}$$

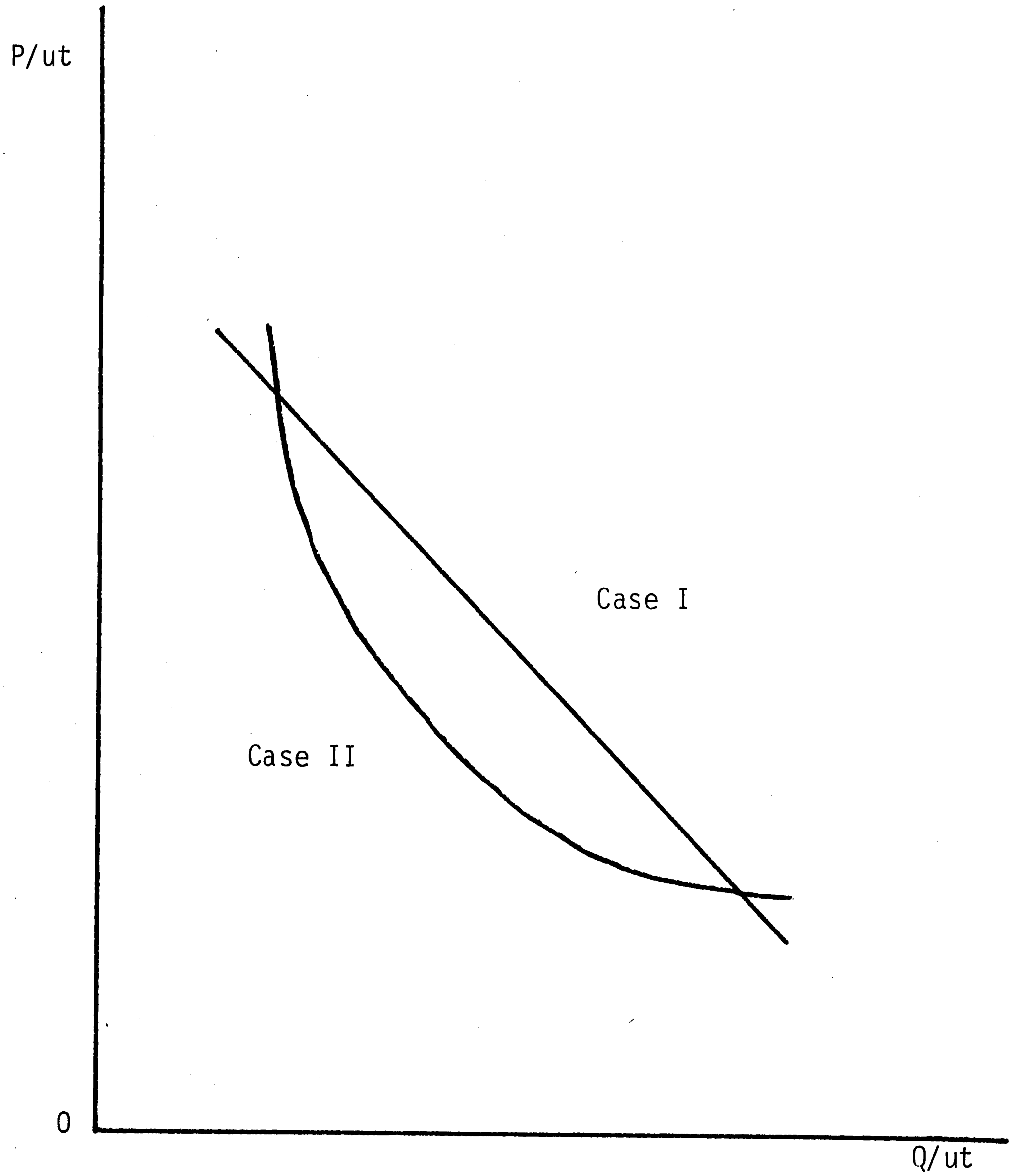


Figure 13. A Downward Sloping Linear and Quadratic Demand Function

Where: V_t = the volume per acre of the last (youngest) age class harvested at time t.

V_{t+1} = the volume per acre of the first (oldest) age class harvested at time t=1.

MR_t = marginal revenue of the last unit of wood harvested at time t.

MR_{t+1} = the change in total revenue at time t+1 if a unit of wood of the first (oldest) age class is not harvested in time t+1.

MC_t = marginal cost of the last unit of wood harvested in time t.

MC_{t+1} = the change in total cost at time t+1 if a unit of wood of the first (oldest) age class is not harvested in t+1.

i = the rate of interest for equating net cash flows at time t and t+1. (Walker, 1971, p.6)

Equation I is not of the form actually used in the program. The algebraic equality used in the solution process is:

$$\frac{V_t(MR_t - MC_t)\ (1+i)}{V_{t+1}} + MC_{t+1} = MR_{t+1} \qquad \text{II}$$

Equation II is used in the searching process of the program and a review of that process follows.

Johnson and Scherman (16) present Walker's model in a different notation which makes the model clearer. The assumptions underlying the mathematical presentation are:

1. The seller faces a downward sloping demand curve. (This is a questionable assumption because the size the seller must be in order to actually face a downward sloping demand curve is statistically unknown).

2. The age of the harvest or whether the harvest comes from a regeneration harvest or thinning does not affect the net revenue received per unit of timber, and that the cost is a linear function of volume cut.

3. Only one cultural regime is considered for each management unit. (This assumption precludes overstory removal).

Under these assumptions, equation I could be written in mathematical form as:

$$\text{MAX} \sum_{j=1}^{N} (C_{1j}h_j - C_{2j}h_j^2) \qquad \text{III}$$

Subject to: Acreage constraints

$$\sum_{j=1}^{N} X_{ij} = A_i \quad i = -M, \ldots, 0 \qquad \text{IV}$$

where:

$$h_j = \sum_{i=-M}^{j-Z} V_{ij}\, x_{ij} = \text{total harvest in period } j.$$

and: C_{1j}, C_{2j} = coefficients used to define the discounted net return from harvesting h_j units of timber in period j.

N = number of periods in planning interval,

Z = minimum number of periods between regeneration harvests,

A_i = number of acres present in period one that was regenerated in the ith period, i = -M, . . . , 0. with each A_i being a given constant at the beginning of the planning interval,

V_{ij} = volume per acre regeneration harvested in period j on acres that were regenerated in period i.

M = number of periods before period one in which the oldest age class in period one was regenerated.

Equation IV says nothing more than harvest acres must equal the acres available.

ECHO in Economic Terms

A form of equation III more familar in an economic sense is:

$$\text{MAX} \sum_{j=1}^{N} \frac{(C'_{1j} - C'_{2j}\, h_j)h_j - C_{3j}h_j}{\gamma^j} \qquad \text{V}$$

where: $C'_{1j} - C'_{2j}h_j$ = ordinary demand equation for timber in time period j,

C_{3j} = direct cost per unit of timber harvested,

γ^j = appropriate discount rate for year j.

By interpreting the $C_{3j}h_j$ as the schedule of costs incurred for different harvest levels and using the relevant portion of it as a marginal cost or supply curve, it is possible to equate supply and demand through time. Simply equating supply and demand through time however, does not achieve profit maximization when demand is less than perfectly elastic.

Figure 14 shows demand, D_1 , as a perfectly elastic demand curve. If MC_1 is the marginal cost (supply), then the firm would offer an amount Q_1 at price P_1. Any additional amount of Q placed on the market would not be purchased as it would require a higher price and given the totally elastic demand curve, consumers would not be willing to pay the price. If, however, the firms' offering of timber does in fact affect the price offered, then the firm would be facing a downward sloping demand curve. Figure 14 shows D_2 as the downward sloping demand curve faced by the producer. MR_2 is the marginal revenue for D_2. If the firm is a profit maximizer, it will equate MC_2 (supply) with MR_2 and offer Q_2 units at price P_2. This is referred to as monopolistic pricing. By using this policy over time, the firm would maximize its discounted cash flow over time. This can be presented by summing the discounted value of $\int_0^{Q_2} MR_2 - MC_2$ over all periods.

On the other hand, by assuming a firm will produce where MC = Demand, forces the firm to engage in competitive pricing. Figure 15 again

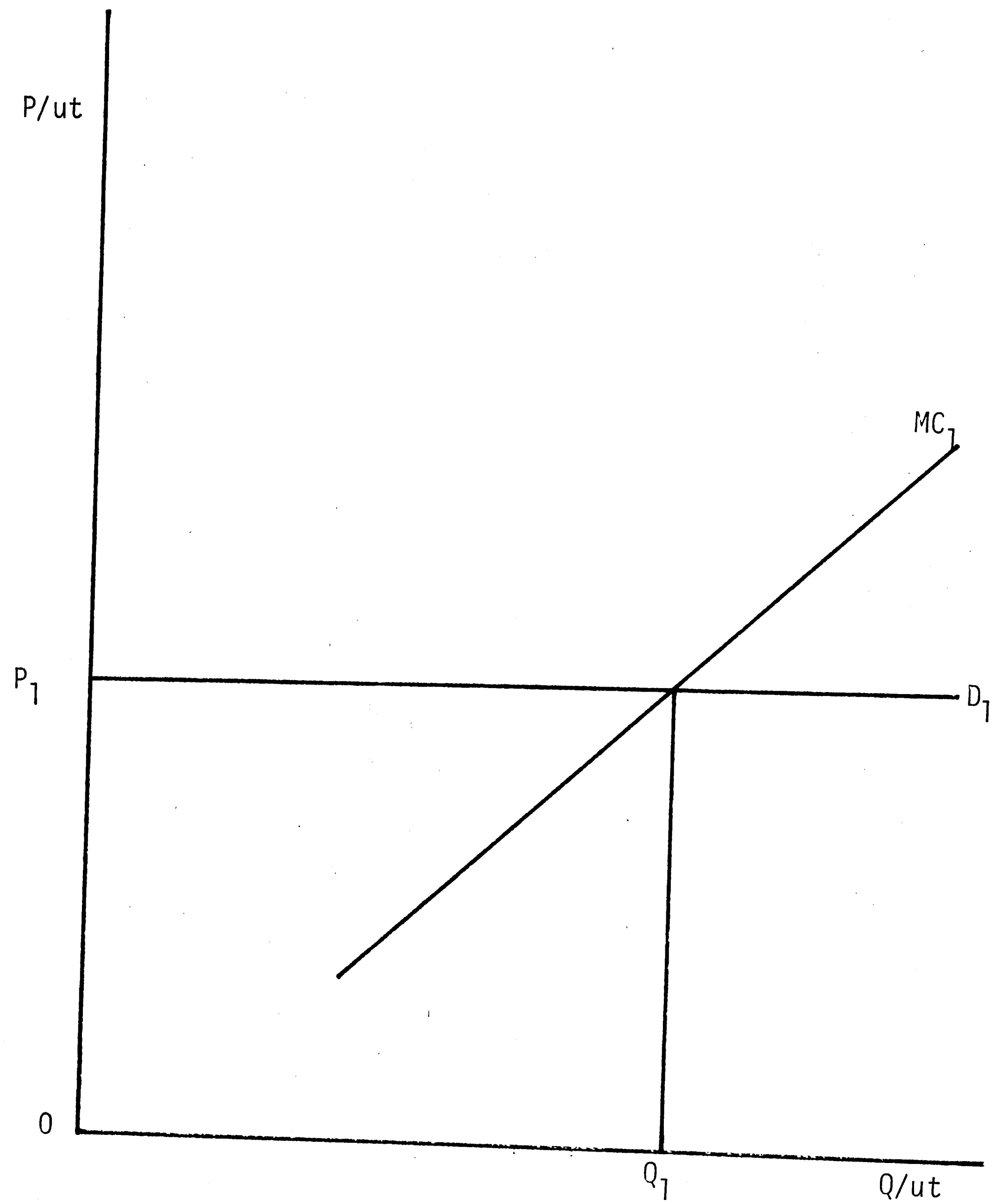


Figure 14. Quantity to Produce While Facing a Perfectly Elastic Demand Curve.

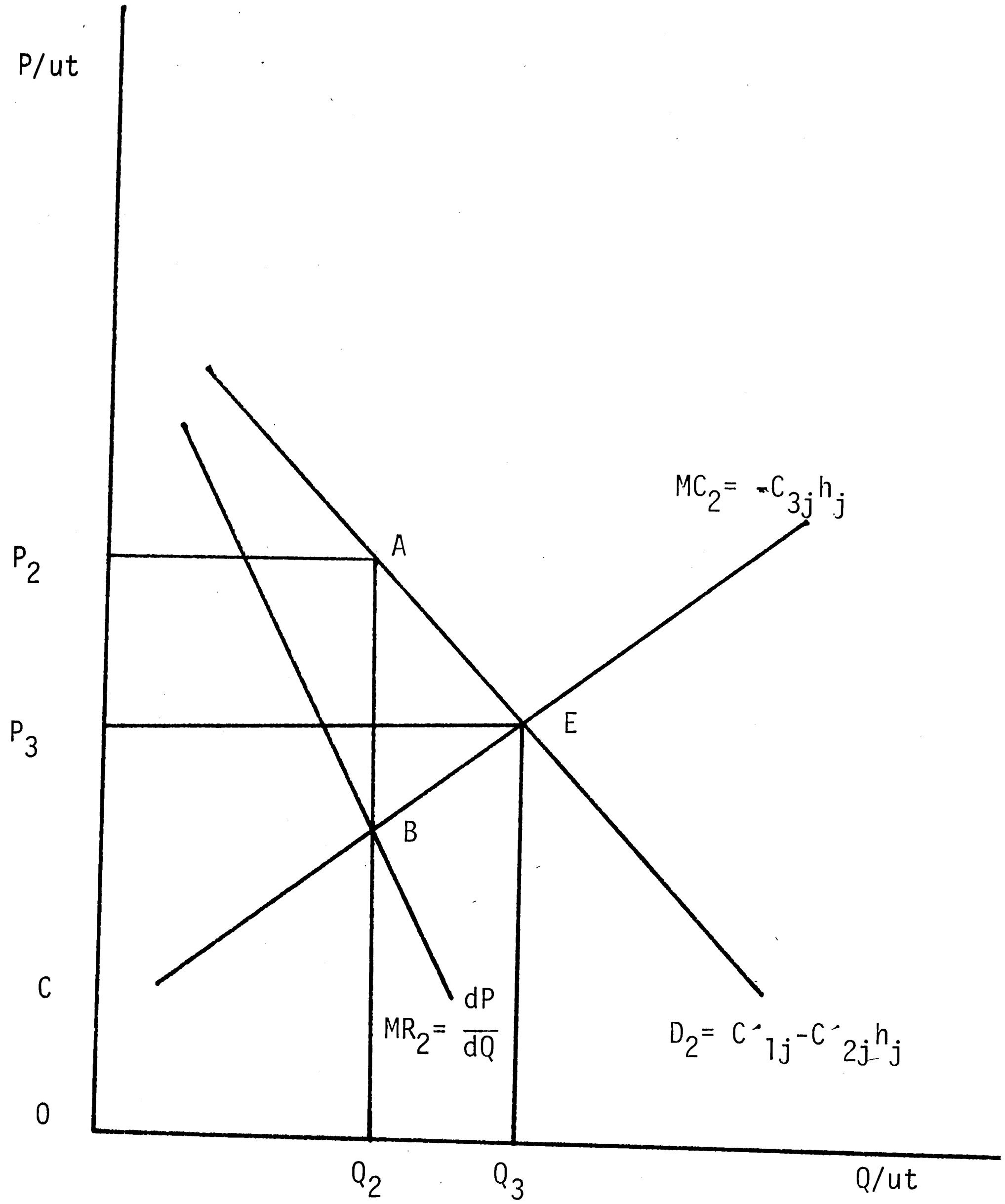


Figure 15. Quantity Produced Under a Negatively Sloped Demand Curve.

indicates that if this policy is pursued, the firm would offer Q_3 units at price P_3. Using this policy, it becomes evident that the firm will make less money than when operating under the monopolistic strategy. Under competitive pricing, profits fall from P_2 ABC (monopolistic) to P_3 EC (11).

As Walker (28) points out, it is possible, by using the competitive pricing scheme, it becomes possible to find the present net social benefits (PNB) by finding the discounted value of $\int_0^{Q_2} P_2\text{-}MC_2$ over all periods.

The ECHO model has the ability to maximize discounted cash flow for producers facing more than one demand curve. If a firm faces more than one individual demand curve, the market demand that the firm faces is found by summing horizontally all individual demand curves faced by the firm. Figure 16 shows the resulting market demand that a firm faces by combining several individual demand curves. D_1 and D_2 are individual demand curves faced by the firm and the market demand curve, $D_1 + D_2$, is found by horizontally summing D_1 and D_2.

Combining the demand equations enter in the model, allows maximizing under either monopolistic conditions or competitive conditions.

Rewriting equation III in LaGrangian form gives:

$$\text{MAX} \sum_{j=1}^{N} (C_{1j}h_j - C_{2j}h^2{}_j) - \sum_{k=-M}^{0} \lambda_i \left(\sum_{j=1}^{N} x_{ij} - A_i\right)$$

The LaGrangian multiplier portion is required for nothing more than finding the correct number of acres to harvest in time period i under management regime j. Using the Kuhn-Tucker theorem, necessary and sufficient conditions for maximization are:

$$\text{a.} \quad \sum_{j=1}^{N} x_{ij} - A_i = 0 \qquad i = M, \ldots, 0$$

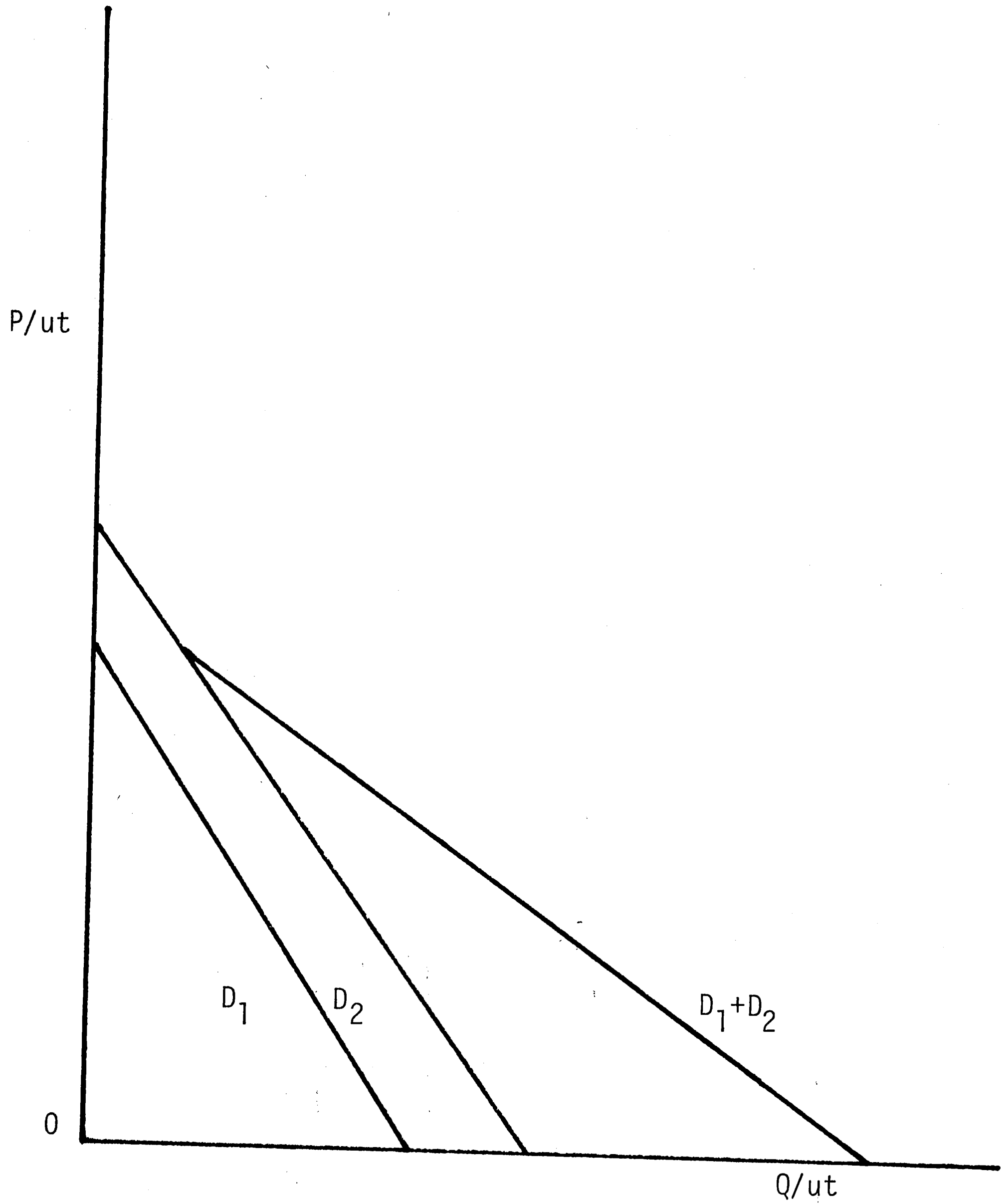


Figure 16. Summation of Individual Demand Curves to Obtain Market Demand $D_1 + D_2$.

which states that acres used = acres available;

b. $(C_{1j} - C_{2j}h_j)\ V_{ij} - \lambda_i - u_{ij} = 0$;
which implies that Mr - MC = 0;

c. $x_{ij} \geq 0 \qquad u_{ij} \leq 0$
which implies that b=0;

d. $x_{ij} \cdot u_{ij} = 0$;
which is the condition for maximum

(conditions b–d hold for $i = -M, \ldots\ldots, j-Z.$ and $j = 1, \ldots\ldots, N.$)

where: $u_{ij} = \frac{\partial \phi}{\partial x_{ij}} = (C_{1j} - 2\ C_{2j}h_j)V_{ij} - \lambda_i$

$\phi = (x,\lambda)$ the LaGrangion function (Johnson and Scheurman(16))

When the maximum λ_i is found for each age class i, it can be interpreted as the shadow price associated with an additional acre of that age class. The primary difference between this concept and the linear programming concept is that each age class is kept as a contiguous unit throughout the planning period in the L.P. approach. In the quadratic approach, the age classes are not held by this restriction and they can be changed from time period to time period. This is further represented by the fact that in the linear programming solution, C_{1j} is the associated marginal revenue and $C_{1j} - C_{2j}h_j$ is the marginal revenue associated with the quadratic form. This means that in the first case, volume is not included as it is in the second case where the amount of volume sold affects the price.

Utilizing the Kuhn-Tucker conditions previously given, it follows that:

$$(C_{1j} - 2C_{2j}h_j)(V_{ij}) = (C_{1j+1} - 2C_{2j+1}h_{j+1})\ (V_{ij+1}) = \lambda_i$$

(or)

$$\frac{[(C'_{1j+1} - 2C'_{2j+1}h_{j+1}) - C_{3j+1}]\ \ V_{ij+1}}{[(C'_{1j} - 2C'_{2j}h_j) - C_{3j}]\ V_{ij}} = \gamma$$

This is just another presentation of equation I where:

$MR_t = (C'_{1j} - 2C'_{2j}h_j)$

$MR_{t+1} = (C'_{1j+1} - 2C'_{2j+1}h_{j+1})$

$MC_{t+1} = C_{3j+1}$

$V_t = V_{ij}$

$V_{t+1} = V_{ij+1}$

$(1+i) = \gamma$ Johnson and Scheurman (16).

This concludes the basic mathematical presentation of the model; however, the addition of financial maturity and land holding costs as well as inclusion of commercial thinnings and harvest flow constraints are possible.

Operating the ECHO Model

The amount of input required to operate the ECHO model is less than that required by Timber RAM. Three basic inputs required are:

1. A stand yield equation or stand volume tables.
2. Demand and marginal revenue functions.
3. A marginal cost function.

In additional to the above, problem control parameters must be specified. These parameters are designed in such a manner that an extreme amount of flexibility is inherent in the model. Table IX denotes the parameters and their use in the model.

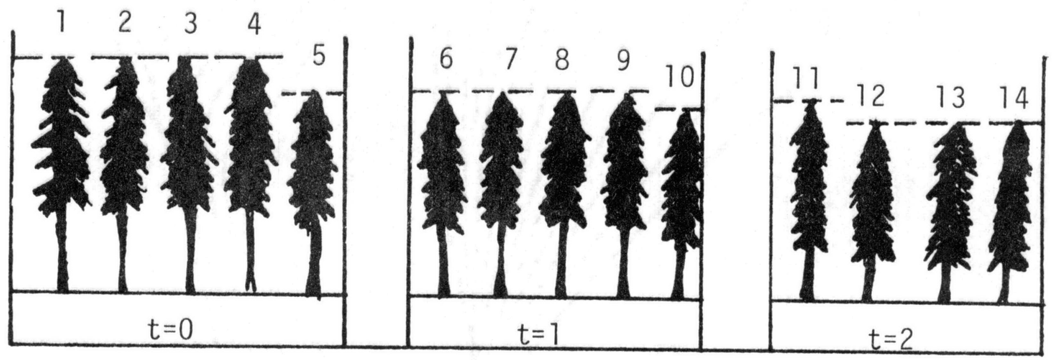
The program uses an iterative search technique to find the necessary value which will solve the basic equation (Equation I) within the tolerances by the specified parameters. Figure 17 can be used to illustrate this technique. As an example, consider that the sequence

TABLE IX

PROGRAM CONTROL PARAMETERS FOR ECHO

Input	Value	Use
Initial Harvest Level	800,000	First trial harvest level for t = 0
Initial Harvest Step	50,000	Change specified in t=0 harvest level for subsequent iterations until optimum harvest has been bracketed
Equilibrium harvest level tolerances	1.0	Required precision in units of harvest for program to recognize that cycling is occurring and that a long-run equilibrium has been reached
Inventory acres tolerance between successive iterations that bracket optimum harvest levels	1.0	Sum of acres left in last age class harvest under lower harvest level and the acres used in the last age class harvested under higher harvest level
Minimum iteration step	.5	Minimum difference between first time period harvest levels for each iteration series
Long-run equilibrium checkpoint	300	First time period for computer to check for cycling to see if a long-run equilibrium has been reached. If it has, the iterations will stop and the present value report will be generated
Increments to long-run equilibrium checkpoint	20	Added to checkpoint if test indicates that long-run equilibrium has not been reached

Source: (28)



$$V_t\ (MR_t - MC_t) = \frac{V_{t+1}\ (MR_{t+1} - MC_{t+1})}{(1+i)} \qquad \text{I}$$

Figure 17. Optimal Harvest Calculation. Equation I focuses on the mathematical relationship that exists between the last tree harvested at each point in time and the first tree harvested at the next point in time.

Source: (28)

presented holds for the equation. If tree 6 is harvested in time period 0, then the amount of revenue added by tree 6 to time period 0 will be less than the discounted value that tree 6 contributed to time period 1. This process is completed for each time period involved in the iteration process.

Another problem that occurs in the sequence is that at some time in the future, the equation on the upper harvest level just exhausts an age class thereby forcing the lower level harvest to use a different age class for its calculation. At this time the harvest level must be reduced for the equality to hold. This is necessary because the change in volume per acre from the higher age class to the lower age class is significant enough to cause a divergence in the formula.

After the program has reached a long-run equilibrium the iterations cease and the reports and summaries are printed. Appendix C contains an example of the ECHO output. The iteration summary lists each iteration in each time period from time period 0 and each time period where the harvest levels are reduced. The harvest calculation report lists the amount of harvest from each age class for each iteration. The next two pages of output present the harvest levels, prices, allocations of harvest levels, costs, and net revenues for price discrimination and no price discrimination respectively. The final report generated presents the stand structure at time t=0 and the stand structure when the long-run equilibrium is reached.

CHAPTER V

ALTERNATE FOREST MANAGEMENT SITUATIONS

Many alternative goals must receive attention when managing a forest. In this chapter several forest management strategies are developed to show the diverse results obtained when a profit maximization scheme is compared with a non-profit maximizing scheme. These situations show the versatility of each model used in the analysis and the relative ease with which one can adjust management plans once the necessary data has been obtained. As an example, to alter the original land area available in the study requires changing as little as one number in a specific age class. Each strategy developed is vital to forest management plans in that the problems encountered in each situation are highly realistic and are observed frequently in forest management planning. The results of each situation are presented two ways; the first presents the results in tabular form and the second in illustration form.

The plans developed by the Timber RAM plan are based on the previous 10 year harvest level which was approximately 137 MCCF. This level, when divided by 10 years, yields an annual cut of 13,700 CCF harvested per year which is approximately the current harvest level that the Forest Service allows to be harvested in the district.

Regular Yield

The regular yield strategy examines the present value of the cash flow from the forest assuming the yield from each acre would not vary over the planning period. This is a plausible strategy because the availability and in some instances the desirability of introducing genetically improved stock will not be present. The regular yield situation takes the forest as it currently is and projects cuttings, growth, and income into the future. Four different discount rates are used which provides for diversity in evaluation investment opportunities. In this strategy as well as all others, a 60 year rotation age is utilized with the Timber RAM model. This age is utilized for three reasons. First, 60 years appears to be the age when loblolly enters or is near the border between stage II and stage III of the neo-classical production function, therefore; it can be labled a mature or over-mature tree in an economic sense. Secondly, consultation with the area foresters indicates that this age tree is the usual age group being cut and most probably will continue to be cut in the future. The third and final reason is age 60 or older loblolly pine would come very close to satisfying the constraint imposed by the Organic Act of 1897 which specifies that only mature or over-mature trees may be cut. Therefore, age 60 loblolly pine was selected as the standard age to use in the Timber RAM model. It should also be noted here, that the ECHO model is free to search for an age that will maximize the discounted cash flow, consequently, specification of a harvest age for the ECHO model is unnecessary.

Improved Yield

The improved yield strategies point out the changes expected when genetically improved stock is planted in favor of the regular stock. The improved genetic stock would enable a larger amount of wood to be harvested from a given acre. The increase in volume available from the genetically improved stock was set to be 25 percent greater than the regular yield. This situation is useful for evaluating the increase in supply from a given land area if all stock were genetically improved.

Recreation Development

Frequently, forest managers must determine the impact of new recreational facilities being developed in a forest. The problem developed is one of estimating the opportunity cost of installing a recreational center by witholding 200 acres of 40 year age class timber from production. Two hundred acres is approximately the size of the two existing recreation centers in the Tiak District. The analysis illustrated estimates the opportunity cost of an additonalinstallation. The opportunity cost was calculated both for the regular yield equation and the improved yield equation.

Increased Costs

Timber harvesting is more costly each year. This analysis shows the impact of higher costs for each unit harvested. These costs could be attributed to higher wages, fuel costs, etc. The increased cost figure utilized was an additional $5.00 per unit harvested using both the regular yield equation and the genetically improved yield equation.

Increased Recreation and Increased Costs

The potential presence of both more recreation areas and increased costs indicates the versatility needed to effectively plan complete forest managment programs. The analysis estimates the opportunity cost of a new 200 acre recreational development coupled with the anticipation of a \$5.00 per unit increase in harvesting costs. This strategy is evaluated with both the regular yield equation and the genetically improved yield equation.

Marginal Revenue Equal to Demand

This analysis utilizes the regular yield equation to estimate the difference in present value of net benefits to the public under a monopolistic and a perfectly competitive management situation. The theoretical framework for this analysis is presented in Chapter III under the discussion of ECHO. Losses in benefits to the public resulting from monoplistic management were estimated. This particular framework could be utilized in conjunction with all other strategies however, this was not done. The impact of making marginal revenue equal to demand was analyzed at 6, 8, 10, and 12 percent discount rates.

Additional Timber RAM Situations

Several additional simulation runs were performed using the Timber RAM data. These runs were designed to determine the impact of various levels of management intensity on the forest. As stated earlier, the harvest level during the previous 10 years was 137 MCCF and this is the harvest level currently allowed. Additional runs were made at 300, 400, 500, and 600 MCCF to estimate the maximum value of production the forest could produce.

Two additional rotation ages were utilized to test whether or not a younger rotation on the district would result in the same harvest levels and cash flow. Rotation ages of 20 and 40 years were used to test this hypothesis.

A final analysis involved withdrawing acres from production to determine the minimum acreage required to produce 137 MCG. Four withdrawals were made; eliminating portions of the 40 year age class, the entire 40 year age class, the 60 and 70 year age classes, and the 50, 60, and 70 year age classes. This analysis simulates a situation that may result when a forest fire destroys a large amount of growing timber.

The following sections of this chapter indicate how the data was standardized for entry into each model. The standardization allows for comparison of each model on each situation listed above.

Yield Per Acre

Establishing yield equations for specific areas is a complete research project in itself and is beyond the scope of this dissertation. Yield data from old-field loblolly pine plantations established by Burkhart (5) were utilized in the construction of the yield equation utilized in this study. Burkhart's formula for predicting yield in cubic volume was:

$$\log_{10} = B_0 + B_1(1/A) + B_3(N/100) + B_4(A)(\log_{10} N)$$

where: Y = cubic-foot volume per acre

H = average height of the dominants and codominants in feet

A = total stand age in years

N = number of trees per acre (1-inch dbh class and above)

The model was used to predict cubic foot volume for stands with a site index base age of 25 years. Various yields, such as board feet and dry weight, were predicted with the equations. The model which estimates cubic foot volume will be the one utilized in this study. Burkhart also presented a formula for converting site index of base age

25 years to base age 50 years. The conversion has the form:

$$SI_{50} = (SI_{25}) * 1.31$$

The above equation was utilized for converting the site index of 70, base age 25 years, to a site index with a base age of 50 years. As an example, by applying the formula:

$$SI_{50} = (SI_{25}) * 1.31$$

$$SI_{50} = (70) * 1.31$$

$$SI_{50} = 91.70$$

Therefore, a site index of 70 with a base age of 25 years is approximately equal to a site index of 91.7 with a base age of 50. The site index of 91.7 is sufficiently close to a site index of 90 to not cause any significant effect in yields per acre. Further, site index numbers are usually rounded to the nearest ten. Table X indicates the conversion results from application of the site index reduction formula.

TABLE X

CONVERSION RESULTS FROM SI_{25} TO SI_{50} USING

$SI_{50} = (SI_{25}) * 1.31$

SI_{25}	SI_{50}	Rounded SI_{50}
50	65.5	70
60	78.6	80
70	91.7	90

In another data adjustment, the acres in the initial site index distribution (Table IV) were transformed to a single standard number of acres so that a single yield equation could be utilized. Burkhart's (5) yield tables were utilized to develop multipliers for estimating equivalent acreages with a site index 90. Table XI indicates the percentages used and the subsequent redisignation of total acres available at a base of site index 90. The multipliers were determined by dividing the yield at the actual site index by the yield at site index 90. For example, if the yield per acre on land with a site index of 90 is 6000 CCF, then the yield from an acre of land with a site index of 80 will be .674 x 6000 or 4044 CCF per acre. This means that 67.4 percent of an acre with site index 90 will yield the same amount as one full acre of site index 80. Dividing the adjusted acres computed in Table XI by the actual acres indicates that the adjusted acreage is 94.8 percent of the actual acreage.

TABLE XI

ADJUSTMENT OF ACREAGES TO SITE INDEX
TO FIND TOTAL ADJUSTED ACRES
BASE AGE = 50

Site Index	Real Acres	Adjustment Factor	Adjusted Acres
70	200	.455	91.000
80	8022	.674	5406.828
90	13041	1.000	13041.000
100	3490	1.326	4627.740
110	500	1.545	772.5
			Total = 23,939.068

$$\frac{23,939}{25,253} = .948$$

The adjustment factor, .948, was then applied to the adjusted age class distribution table, Table III . Table XII contains the results of the transformation.

TABLE XII

ADJUSTED AGE CLASS DATA

Age	Real Acres	Adjusted Acres	Rounded Acres
0	2217	2101.716	2102
10	2224	2108.352	2108
20	7681	7281.588	7282
30	4034	3824.382	3824
40	2481	2351.988	2352
50	1835	1739.580	1740
60	4524	4288.752	4289
70	257	243.636	244
Adjustment Factor = .948			Total = 23.941

The number of acres per age class in the column headed Rounded Acres in Table XII represent the adjusted acres in the forest with a base site index of 90 at base age 50.

With age, stocking, and site index standardized, a cubic equation was fitted to the data presented by Burkhart (5). This equation estimates the wood yield in cubic feet per acre of wood and bark to a 3-inch top diameter, outside bark, international 1/4 inch rule. The yield equation formulated was:

$$Y = -24.27 + 4.711\ A - .06372\ A^2 + .000229\ A^3$$
$$(-4.296)\quad (11.029)\quad (-6.999)\quad (4.00)$$
$$R^2 = .97$$

where: Y = one hundred cubic feet per acre

A = age in years

Appendix B contains the information needed for the development of the equation.

The broken line in Figure 18 illustrates the basic yield equations utilized in this study.

Genetically Improved Yield Equation

A genetically improved yield equation was formulated for the data for simulations requiring genetically improved stock. The genetic improvement assumed for the study was 1.25 times that of the regular yield. In evaluating the equation for the genetically improved yield equation, the volume per acre was multiplied by 1.25 and a new ordinary least squares procedure was run to obtain a prediction equation for the improved yields. It should be noted that the yields and intervals used in each model were identical except for rounding in the programs. The genetically improved yield equation was:

$$Y = -30.33 - 5.889\ A - .0796\ A^2 + .000286\ A^3$$
$$(-4.296)\quad (11.029)\quad (-6.999)\quad (4.003)$$
$$R^2 = .97$$

where: Y = one hundred cubic feet per acre

A = age in years

The improved yield equation is also illustrated in Figure 18.

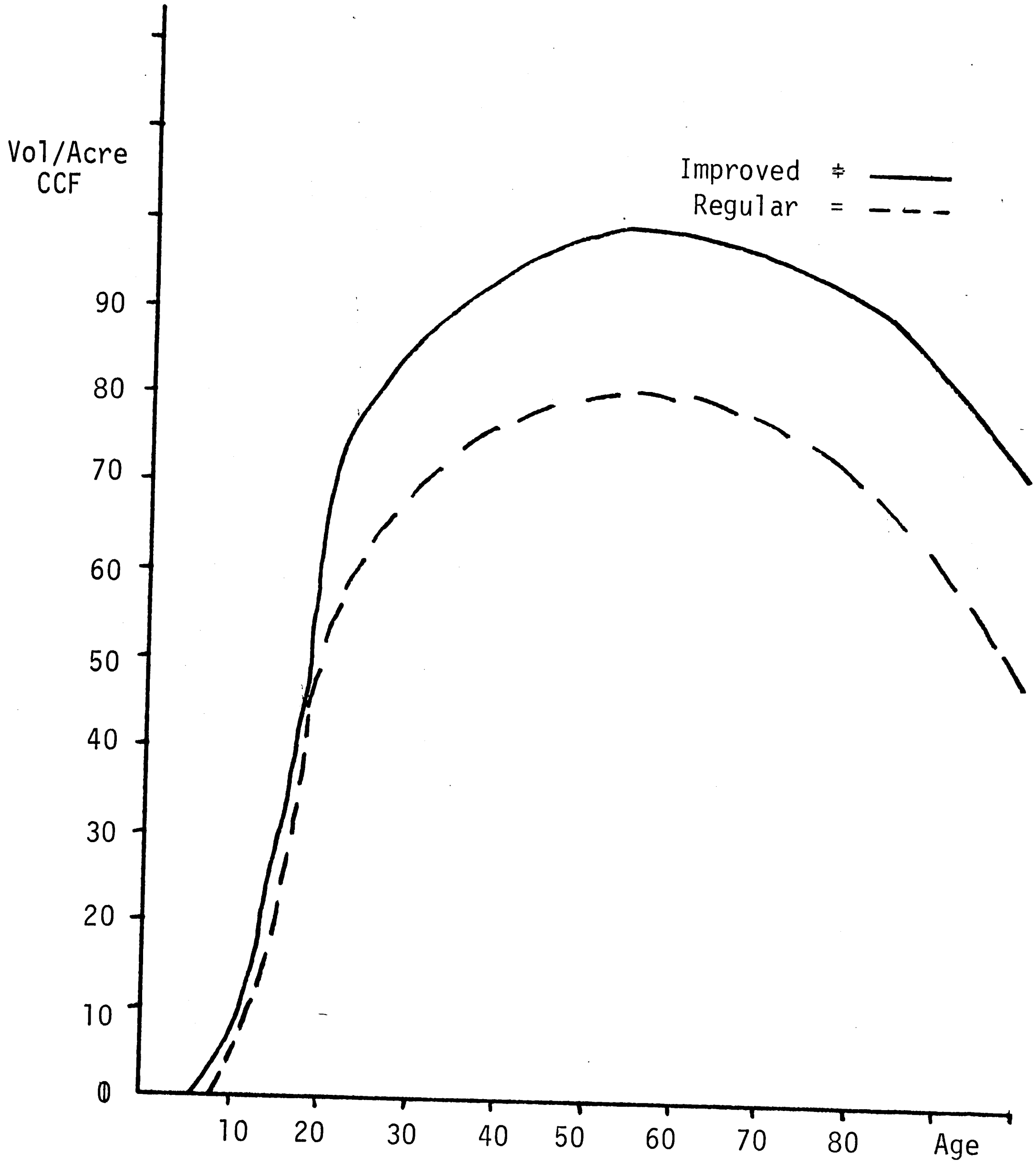


Figure 18. Yield Equations for Loblolly Pine Used in ECHO

Cost of Timber Management

There are several costs when reforestation or aforestation takes place. For the purposes of this study, costs for reforestation procedures are used. The costs involved in overall timber management are divided into fixed and variable.

Fixed costs in forest management account for items such as taxes, insurance, fire insurance, and management costs. Taxes were estimated at 80 cents per acre by visiting with tax paying citizens in the area. Other tax considerations such as capital gains treatment are beyond the scope of this study. Local insurance and fire insurance amount to $1.00 per acre per year for the area. This totals to $1.80 per acre per year for the fixed cost of forest ownership.

Regeneration Costs

Sundra and Lowry (22) present a table of regeneration costs for several methods of site preparation and regeneration. These data are perhaps the newest and most reliable data obtainable. The costs for one method are summarized in Table XIII. Because the approach is similar to techniques used in Oklahoma, these costs will be used throughout this study. To promote comparability, the regeneration costs given in Table XIII are used for all management plans analyzed.

The average regeneration cost per acre will be computed by summing the average site preparation cost and machine planting cost. The estimated regeneration cost per acre was $54.11. In Timber RAM, this figure is included in the total cost per acre category along with the harvesting costs since the timber will be replanted in the same decade as it is harvested. In the ECHO model, the regeneration cost is entered separately from the harvesting costs.

TABLE XIII

COSTS OF REGENERATION MEASURES IN THE INTERIOR WEST GULF COASTAL PLAIN

Practice	Number of Reporting Sources	Costs Per Acre	
Mechanical Site Preparation			
Shearing	7	27.40	
Piling	5	19.73	
Shearing and Piling	5	45.49	
Chopping	6	20.64	
Chrushing	1	27.00	
Flat Disking	2	18.37	
Bedding	3	11.75	
Average			24.34
Planting (includes seedlings)			
Machine	13	27.13	
Hand	9	32.40	
Average			24.33
Average Total			54.11

Source. (22)

Harvesting Costs

Included in harvesting expenses are the per acre costs associated with taking a volume of wood from the acre. In functional form, the equation could be represented as $C = f(V)$ where C is cost per acre and V is the volume of wood per acre. The harvesting costs will be typical of the area and were obtained from data obtained from the U.S. Forest Service. Appendix D contains the data utilized.

Prices and Demand

Price data employed in the study was obtained from the four most recent U.S. Forest Service sales in the area. All prices in the sales were reduced to price per CCF for consistancy. A listing of sales and prices received presented in Table XIV. An ordinary least squares regression was fitted and the results are:

$$Y = 20281.341 - 339.372\ P$$
$$(3.26) \qquad (-2.73)$$
$$R^2 = .788$$

This equation is graphed in Figure 19. The demand equation is suspect because of a lack of observations. However, the data utilized was considered the only relevant data available.

TABLE XIV

U. S. FOREST SERVICE SALE INFORMATION
ON THE TIAK DISTRICT*

Date	CCF	Bid	Price/CCF	Price/MBF
12/29/75	2780.6	133,911.14	48.16	62.54
04/11/75	6422.2	263.780.00	41.07	53.34
10/22/75	4359.0	225,880.01	51.81	67.28
10/02/75	150.7	8,680.00	57.60	74.81

*Appendix E contains the original Tiak sales data.

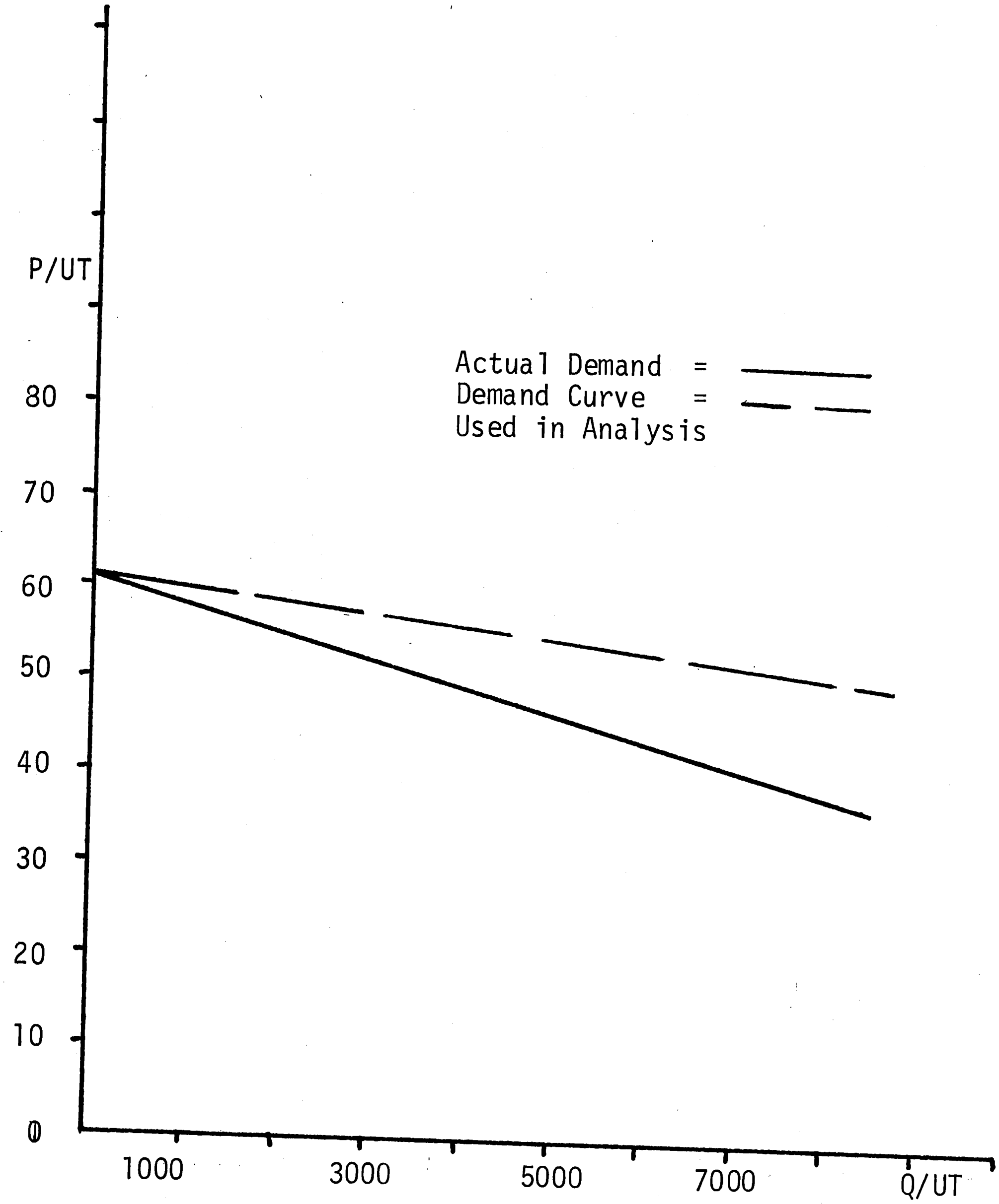


Figure 19. Illustration of the Demand Equations Utilized in the ECHO Solution Process.

The demand equation was inserted in the ECHO model and ran to ascertain whether or not a feasible solution was attainable. The demand equation presented above proved to be unsatisfactory as it produced values that assymotically approached the harvest level. This occurs when the potential supply of timber from the district is so much greater than the demand indicated by the regression demand curve, that harvest levels capable of achieving profit maximization for the area are incapable of being reached. This situation results in a constraint which prohibits profit maximization. Sensitivity runs were made utilizing various elasticities of demand until a satisfactory demand curve was found that would allow the solution process to continue. The demand equation for this study obtained from the sensitivity runs was:

$$Y = 360{,}000 - 6000.00P$$

where: Y = one hundred cubic feet

P = price

The 360,000 CCF level is within the production capability of the forest. The procedure utilized for obtaining the demand curve for this study is naive. However, conceptualization and preparation of a regional demand curve for the area is beyond the scope of this study.

CHAPTER VI

RESULTS AND CONCLUSIONS

The results are presented in three sections. The first contains results obtained using ECHO for various forest resource situations. The second presents Timber RAM results for those same resource situations plus several additional situations. The final section compares the results of using the Timber RAM and ECHO models.

ECHO Results

Analysis of a Required Recreational Increase Using ECHO

The analysis assumed the use of an additional 200 acre recreational site within the forest. Table XV presents the opportunity costs of implementing a new recreational area in terms of timber production only. It does not include the cost of construction or maintenance of the recreational area.

Table XXIV indicates for example, that if a 6 percent discount rate is used, a decrease of $111,952.00 from the present value of the cash flow will result. This results in an overall decrease of approximately .39 percent. The dollar decrease in this analysis when compared with the total value appears to be an insignificant amount. This indicates to the forest manager that the opportunity cost of establishing a recreational area of 200 acres in size on the district would be slight. The opportunity cost should be analyzed carefully however, because the decrease in the maximized present value of net cash flows will be felt immediately. This results because the discount factors used in the discounting procedure decrease rapidly after the first few years. As a result, harvest levels must be analyzed before a decision can be made.

TABLE XV

DIFFERENCES IN THE MAXIMIZED PRESENT VALUE OF NET CASH FLOWS USING REGULAR YIELDS OBTAINED BY WITHDRAWING 200 ACRES OF 40 YEAR AGE CLASS TIMBER FROM THE TIAK DISTRICT TO SIMULATE AN INCREASE IN RECREATIONAL AREA AND COMPARING THE RESULTS WITH THE MAXIMIZED PRESENT VALUE OF NET CASH FLOWS WITH NO CONSTRAINTS USING THE ECHO MODEL WITH DISCOUNT RATES OF 6, 8, 10, AND 12 PERCENT

STRATEGY	DISCOUNT RATES			
	6%	8%	10%	12%
Regular	28159520	22294304	18600368	16051269
Rec.↑ Reg. Yield	28047568	22226928	18551424	16015664
Difference	111952	67376	48944	35605
Percent Decrease	.39%	.30%	.26%	.22%

Figures 20 through 23 show the harvest levels over time comparing the harvest levels associated with the recreational increase and the harvest levels found when no constaints are placed on the forest. These four figures, with their respective discount rates indicate that the loss of timber revenue will occur in approximately the first twenty five years of the planning period. Therefore, serious consideration should be given to the management plans which indicate that there will be a small decrease in revenue. If the decision was made to go ahead with the new recreational area in this case, the resulting decrease

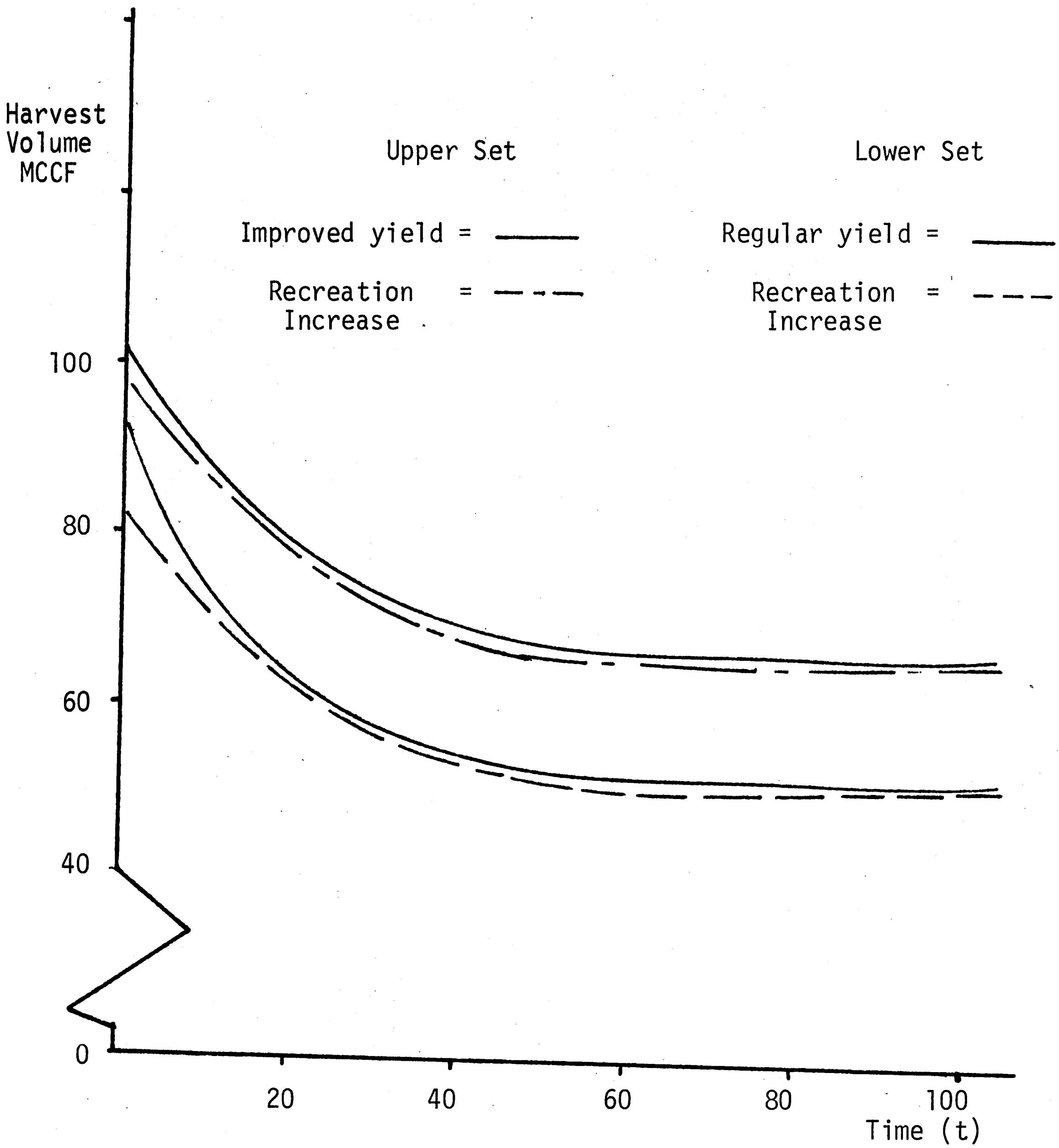


Figure 20. Harvest Levels Over Time Comparing an Increase of 200 Acres in Recreational Area and no Increase with Regular Yields at a 6 Percent Discount Rate.

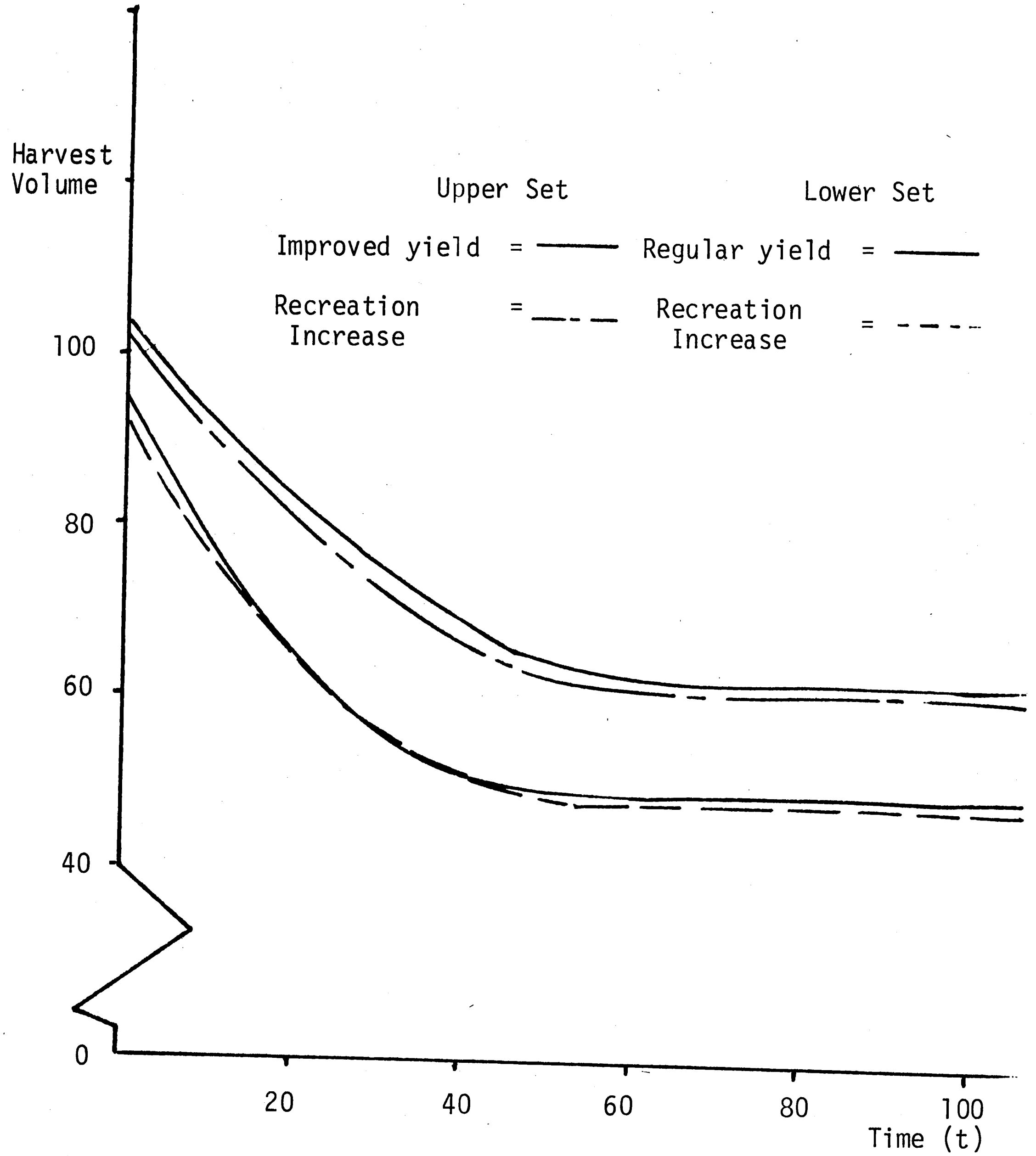


Figure 21. Harvest Levels Over Time Comparing an Increase of 200 Acres in Recreational Area and no Increase with Regular and Improved Yields at an 8 Percent Discount Rate.

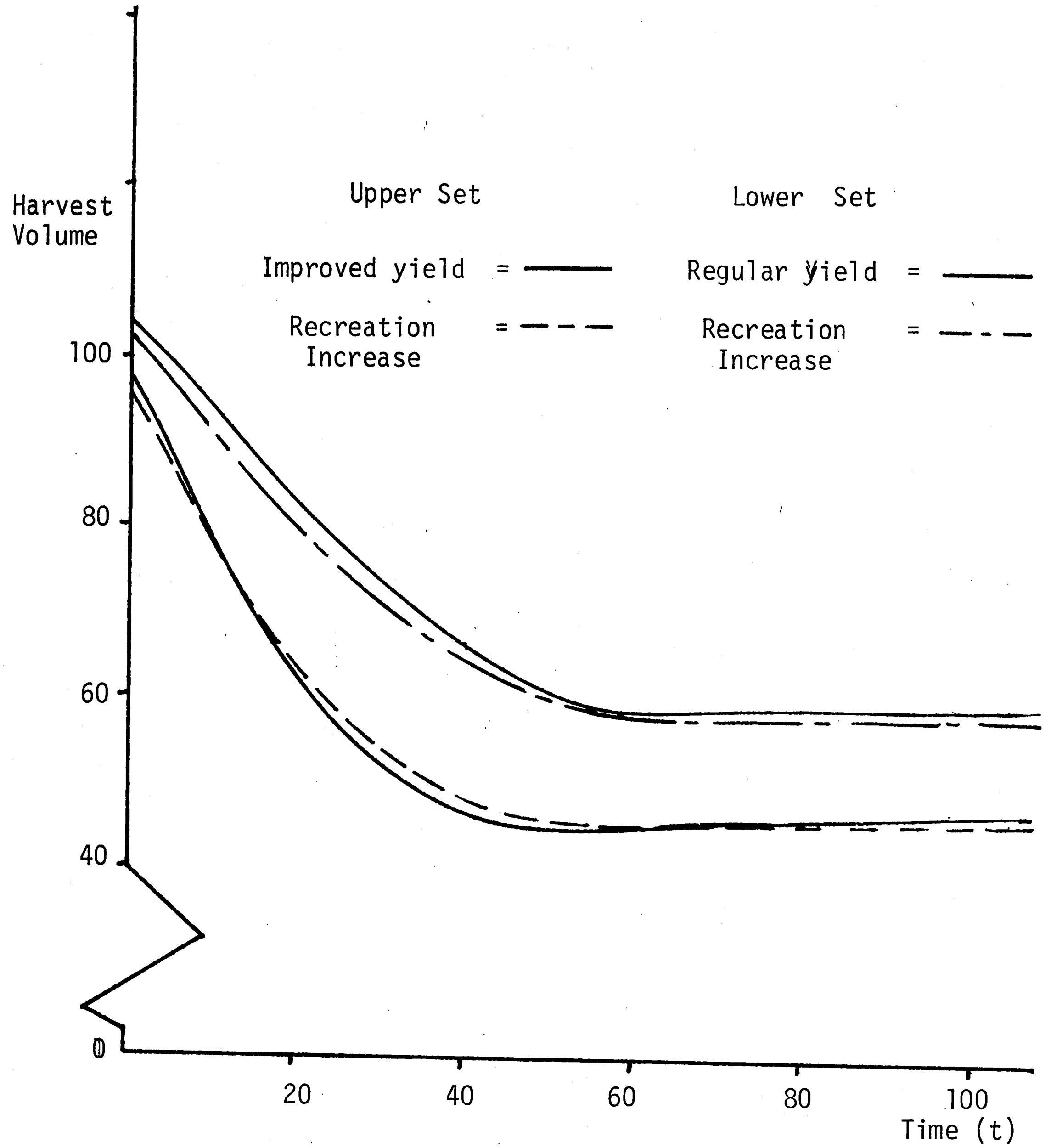


Figure 22. Harvest Levels Over Time Comparing an Increase of 200 Acres in Recreational Area and no Increase with Regular and Improved Yields at a 10 Percent Discount Rate.

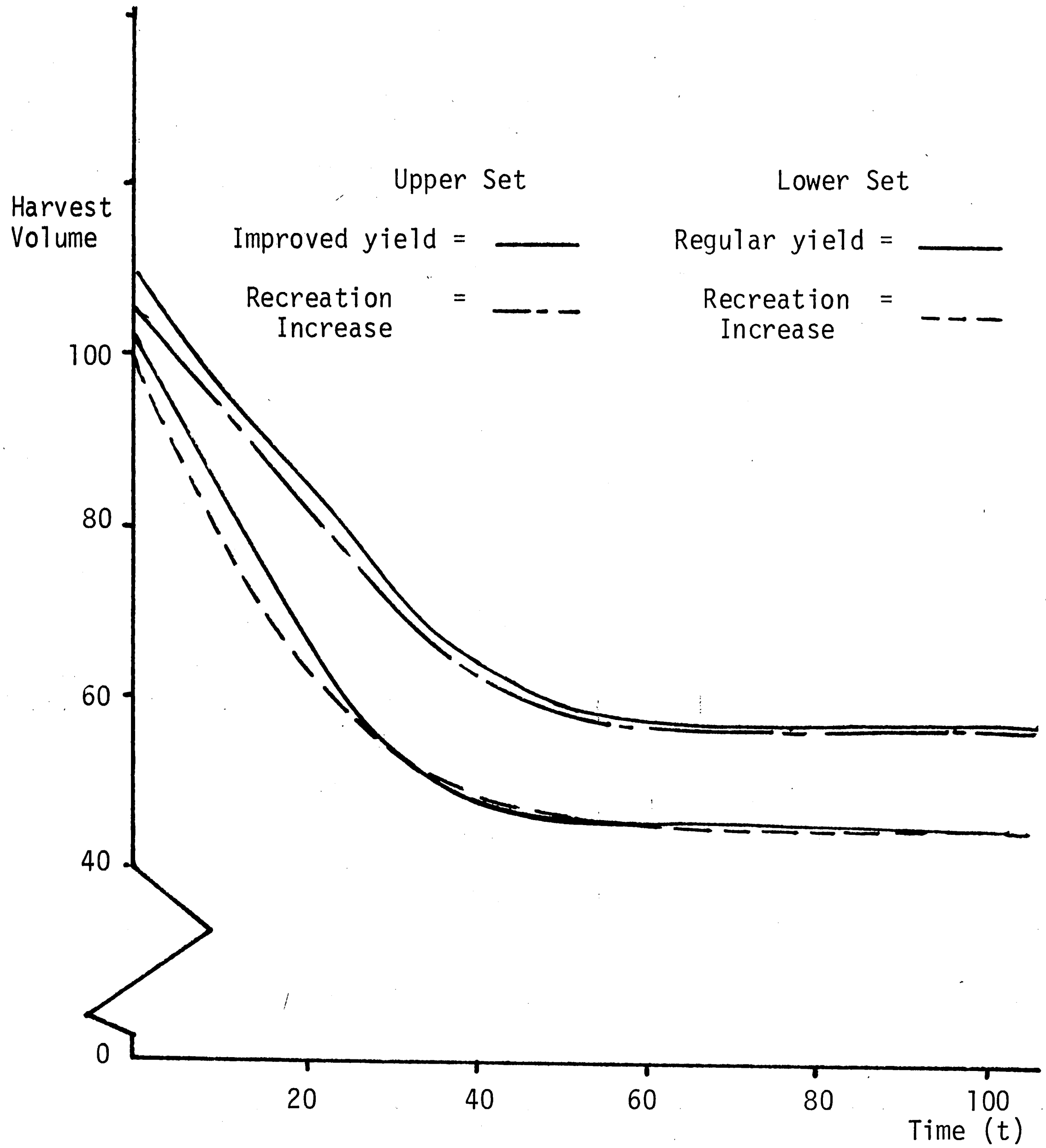


Figure 23. Harvest Levels Over Time Comparing an Increase of 200 Acres in Recreational Area and no Increase with Regular and Improved Yields at a 12 Percent Discount Rate.

in harvest levels indicated in Figures 20 through 23 may be large enough to decrease the input to the mill.

The upper set of curves in Figures 20 through 23 reflect the harvest levels obtained when the genetically improved yield equation was entered in the model. As expected, the harvest levels in every case are higher than the harvest levels obtained through the use of the regular yield equation. The improved yield results show that the harvest levels obtained when withdrawing the 200 acres are consistently lower than the harvest levels obtained with no constraints placed on the forest. This differs from the regular yield equation results in that the regular yield harvest levels eventually converge. The shape of the harvest level curves found by the ECHO process indicate that current harvesting policies for the forest and below a profit maximizing level. The ECHO model adjusts the harvest level to maximize profits and carries the forest to a long run harvest equilibrium. Table XVI indicates the present value results from the improved yield case.

Table XXVI shows that for an increase in the recreational area by withdrawing 200 acres of 40 year age class timber results in an opportunity cost of $75,136 or a reduction of .25% from the maximum discounted net cash flow using the improved yield equations. The same analysis presented for the regular yield equation holds true for the improved yield equation however, it appears that the immediate effect of a decrease in harvest level is not quite as significant as the regular yield results. This is a result of the utilization of the improved yield equation.

TABLE XVI

DIFFERENCES IN THE MAXIMIZED PRESENT VALUE OF NET CASH FLOW OBTAINED BY WITHDRAWING 200 ACRES OF 40 YEAR AGE CLASS TIMBER TO SIMULATE AN INCREASE IN RECREATIONAL AREA ON THE TIAK DISTRICT AND COMPARING THE RESULTS WITH THE MAXIMIZED PRESENT VALUE OF NET CASH FLOW WITH NO CONSTRAINTS USING THE ECHO MODEL WITH DISCOUNT RATES OF 6, 8, 10, AND 12 PERCENT WITH IMPROVED YIELDS

STRATEGY	DISCOUNT RATES			
	6%	8%	10%	12%
Improved	30549904	23772784	19579920	16726348
Rec.↑ Imp. Yield	30474768	23734224	19555024	16711052
Difference	75136	38560	24896	15296
% Difference	.25%	.16%	.13%	.09%

<u>Analysis of a Cost Increase Using ECHO</u>

This analysis assumed a \$5.00 increase in unit harvesting cost. The \$5.00 amount was chosen arbitrarily and amounts to a 20% increase in the harvesting costs. Table XVII contains the results obtained when an increase of \$5.00 per unit harvesting cost was compared with no cost increase.

The six percent column indicates a \$5.00 per unit increase in harvesting costs, with no corresponding changes in the product prices received, will result in a 23.119 percent decrease in the present value of the cash flow. This is a dollar decrease of \$6,510,208.00 over a period of 100 years. The corresponding harvest levels as seen in Figure 24 through 27 indicate that this loss occurs early in the planning period. This is a result of the added cost to harvest the same level without the increase in cost would result in the marginal cost of harvesting at the higher level being greater than the marginal revenue obtained at the higher level. This means that the higher unit harvesting cost shifts the marginal cost curve upward as the marginal revenue curve remains constant. Forest managers anticipating cost increases should plan carefully as increased costs may reduce harvest levels which in turn may reduce raw material input to the mills.

TABLE XVII

DIFFERENCES IN THE MAXIMIZED PRESENT VALUE OF NET CASH FLOWS FROM REGULAR YIELDS OBTAINED BY INCREASING HARVESTING COSTS $5.00 PER UNIT AND COMPARING THE RESULTS WITH THE MAXIMIZED PRESENT VALUE OF NET CASH FLOWS WITH NO CHANGE IN THE HARVESTING COSTS USING THE ECHO MODEL AND DISCOUNT RATES OF 6, 8, 10, and 12 PERCENT

STRATEGY	DISCOUNT RATES			
	6%	8%	10%	12%
Regular	28159520	22294304	18600368	16051269
Cost↑ Reg Yield	21649312	16934704	14006228	12000372
Difference	6510208	5359600	4594140	4050897
Percent Difference	23.119%	24.040%	24.699%	25.237%

The improved yield present value results are listed in Table XVIII. The six percent column indicates a $5.00 per unit increase in harvesting costs, with no corresponding changes in the product prices received, will result in a 27.87 percent decrease in the present value of the cash flows found using the improved yield equation. This is a dollar decrease of $7,597,184.00 over a period of 100 years. The percentage

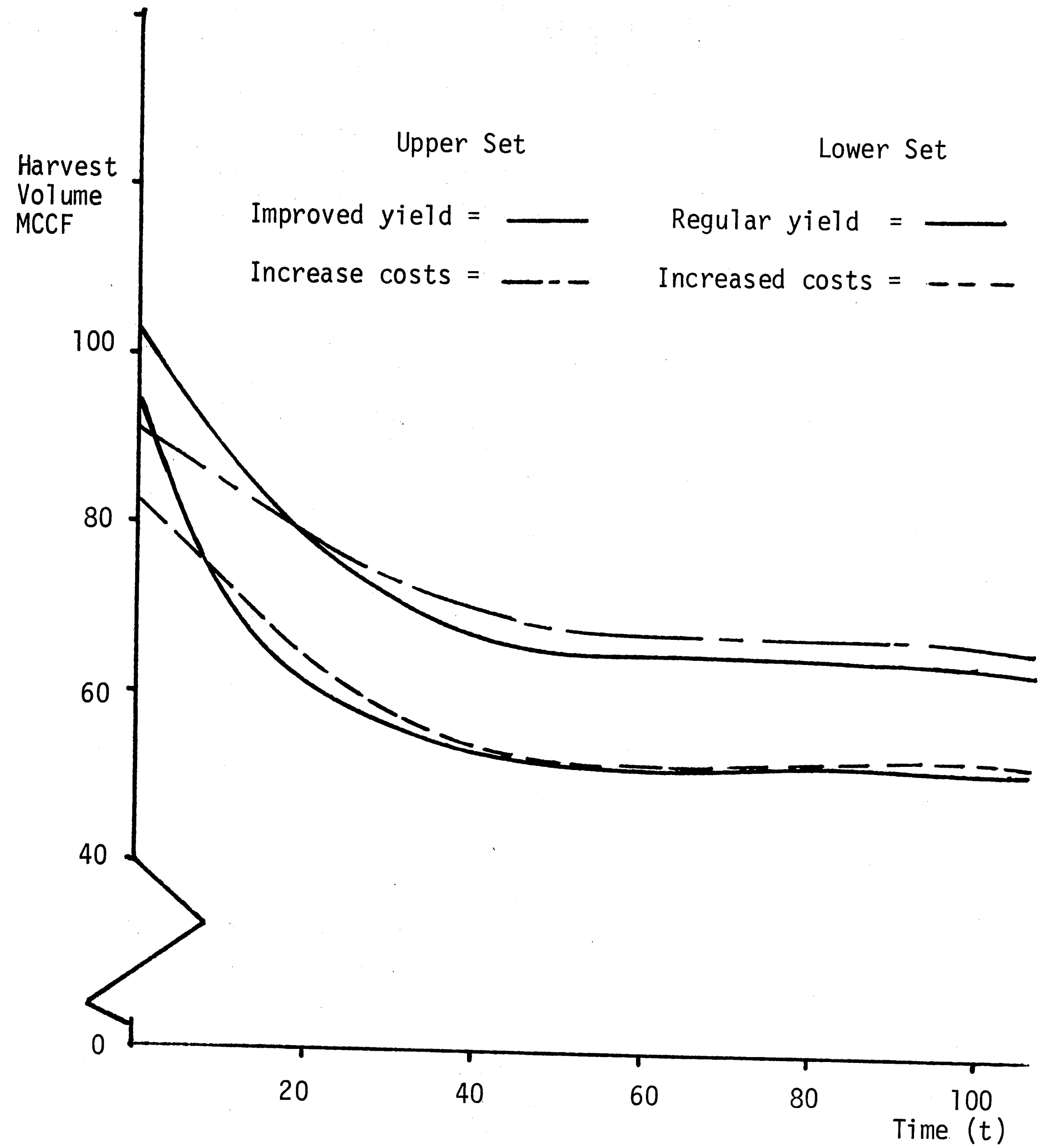


Figure 24. Harvest Levels Over Time Comparing an Increase of $5.00 per Unit Harvesting Cost and no Increase with Regular and Improved Yields at a 6 Percent Discount Rate.

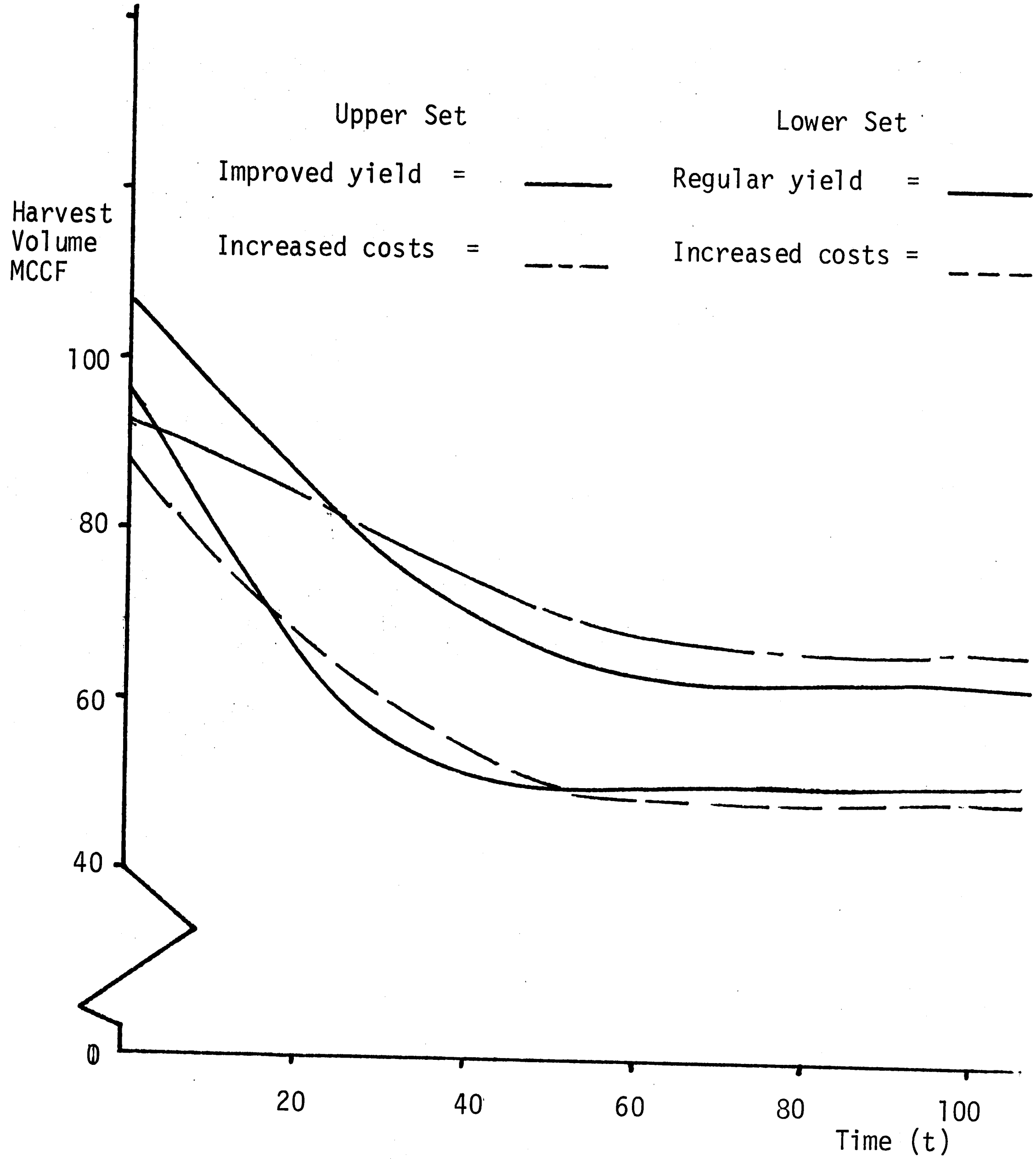


Figure 25. Harvest Levels Over Time Comparing an Increase of $5.00 per Unit Harvesting Cost and no Increase with Regular and Improved Yields at an 8 Percent Discount Rate.

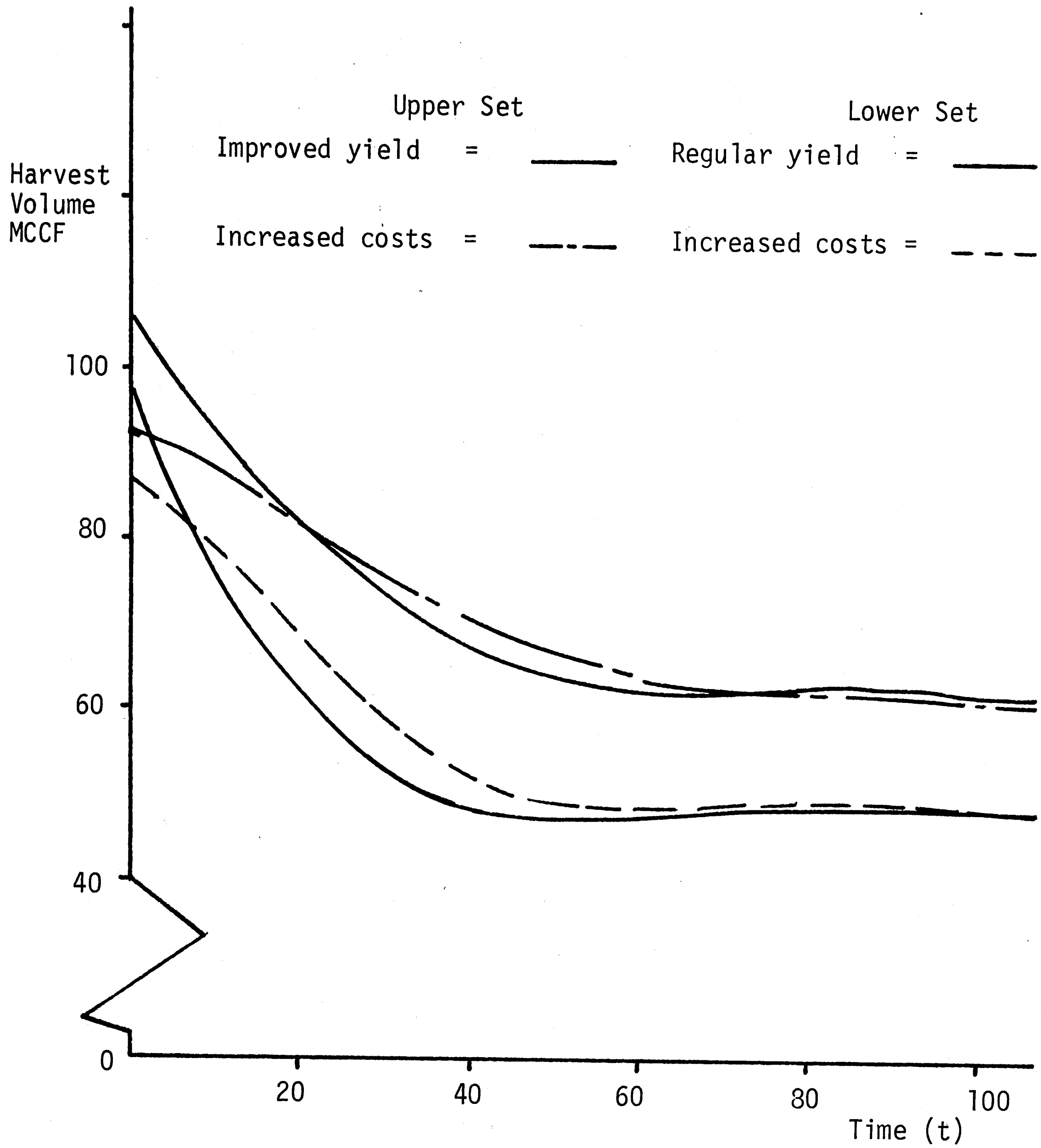


Figure 26. Harvest Levels Over Time Comparing an Increase of $5.00 per Unit Harvesting Cost and no Increase with Regular and Improved Yields at a 10 Percent Discount Rate.

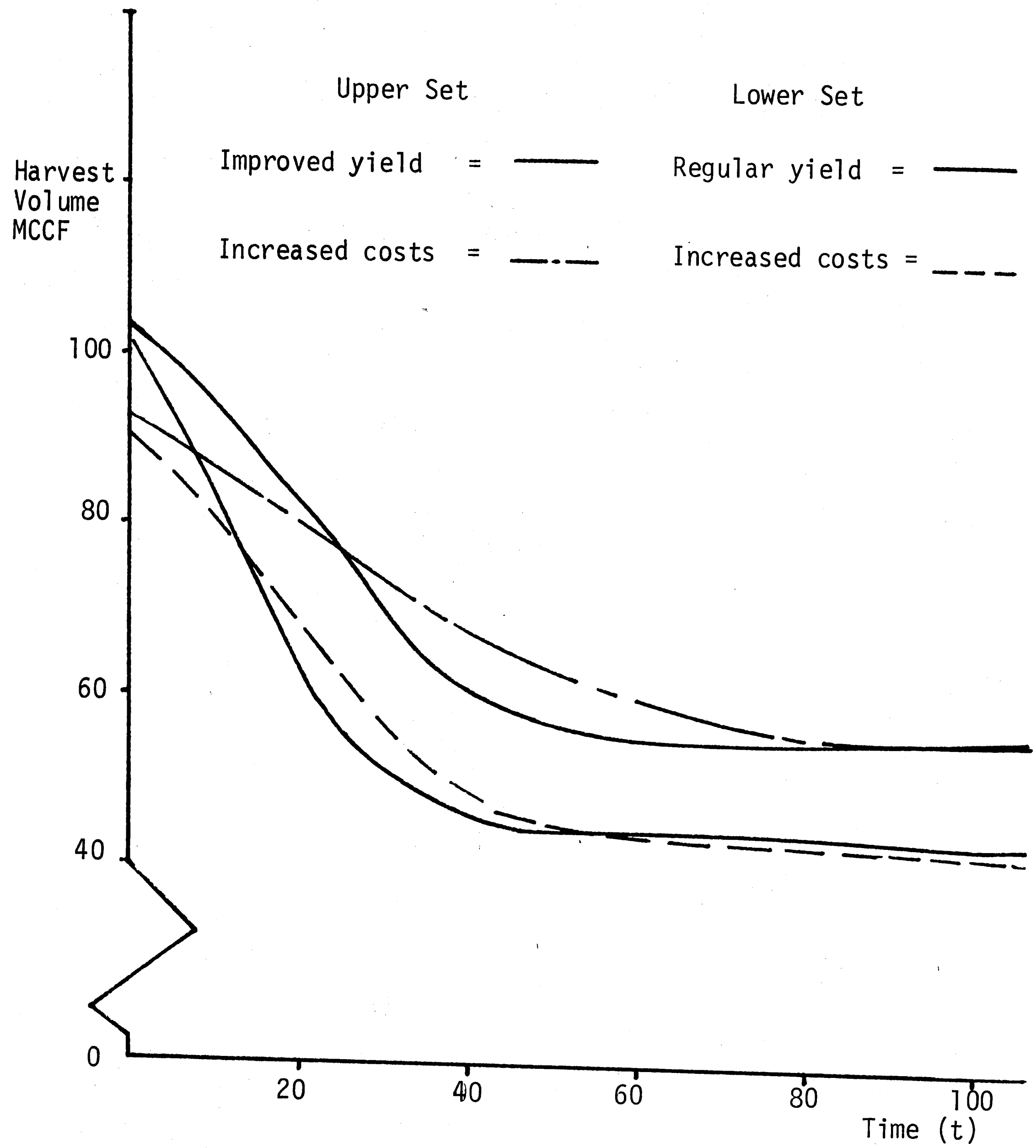


Figure 27. Harvest Levels Over Time Comparing an Increase of $5.00 per Unit Harvesting Cost and no Increase with Regular and Improved Yields at a 12 Percent Discount Rate.

differences are almost identical to the regular yield equations and the differences in harvest levels are again similar to the results obtained from the regular yield equation. Figures 24 though 27 indicate however, that the harvest levels at the beginning of the planning period are somewhat lower than the regular yield results.

TABLE XVIII

DIFFERENCES IN THE MAXIMIZED PRESENT VALUE OF NET CASH FLOWS OBTAINED BY INCREASING HARVESTING COSTS BY $5.00 PER UNIT AND COMPARING THE RESULTS WITH THE MAXIMIZED PERCENT VALUE OF NET CASH FLOWS WITH NO CHANGE IN THE HARVESTING COSTS USING THE ECHO MODEL WITH DISCOUNT RATES OF 6, 8, 10, AND 12 PERCENT AND IMPROVED YIELDS

STRATEGY	DISCOUNT RATES			
	6%	8%	10%	12%
Improved	30549904	23772784	19579920	16726348
Cost↑ I	22952720	17684704	14473690	12312113
Difference	7597184	6088080	5106230	4414235
Percent Difference	27.87%	27.61%	27.08%	26.39%

Analysis of a Recreation Average Increase Combined with Harvest Cost Increase Using ECHO

This particular analysis combines the previous two situations into one. The results as presented in Table XIX indicate that if both the 200 acre increase in recreational area and a $5.00 per unit increase in harvesting costs is included in the planning process, reductions in the present value of cash flow ranges from 23.345 percent to 25.331 percent for the varying discount rates.

TABLE XIX

DIFFERENCES IN THE MAXIMIZED PRESENT VALUE OF NET CASH FLOWS OBTAINED BY WITHDRAWING 200 ACRES OF 40 YEAR AGE CLASS TIMBER AND COMBINING A $5.00 PER UNIT HARVESTING COST ON THE TIAK DISTRICT AND COMPARING THE RESULTS WITH THE MAXIMIZED PRESENT VALUE OF NET CASH FLOWS WITH NOT CONSTRAINTS USING THE ECHO MODEL WITH DISCOUNT RATES OF 6, 8, 10, AND 12 PERCENT WITH REGULAR YIELDS

STRATEGY	DISCOUNT RATES			
	6%	8%	10%	12%
Regular	28159520	22294304	18600368	16051269
Rec ↑ Cost ↑	21585552	16897584	13981735	11985265
Differences	(6573968)	(5396720)	(4618633)	(4066004)
% Differences	23.345%	24.207%	24.831%	25.331%

Figures 28 through 31 illustrate the change in harvest levels for the four discount rates. Harvest levels drop considerably at year 0 in the planning period and converge with the no constraint situation at about year 20. Again, the initial harvest level drop must be weighted carefully as the immediate input of resources to the mill may be affected. The improved yield results are presented in Table XX.

Reductions in the present value of cash flows for the improved yield situation ranges from a reduction of 24.964 percent at a six percent discount rate to 26.414 percent at the 12 percent discount rate. Figures 28 through 31 include the harvest levels found using the improved yield equation. Harvest level differences are more pronounced than for the regular yield situation. The difference can be attributed to higher volumes per acre with the improved yield equation.

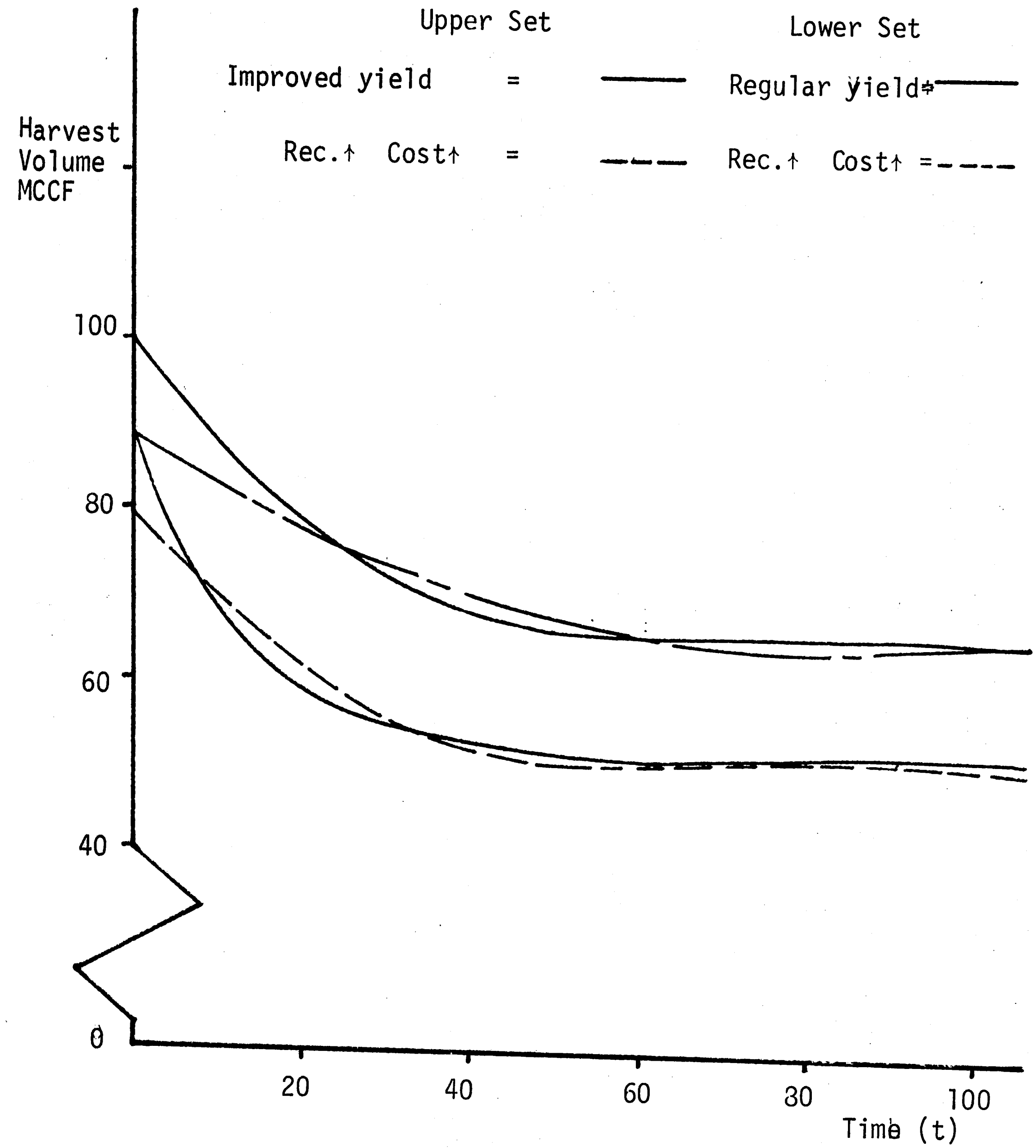


Figure 28. Harvest Levels Over Time Comparing an Increase of 200 Acres in Recreational Area and a $5.00 Increase in per Unit Harvesting Costs and no Increase with Regular and Improved Yields at a 6 Percent Discount Rate.

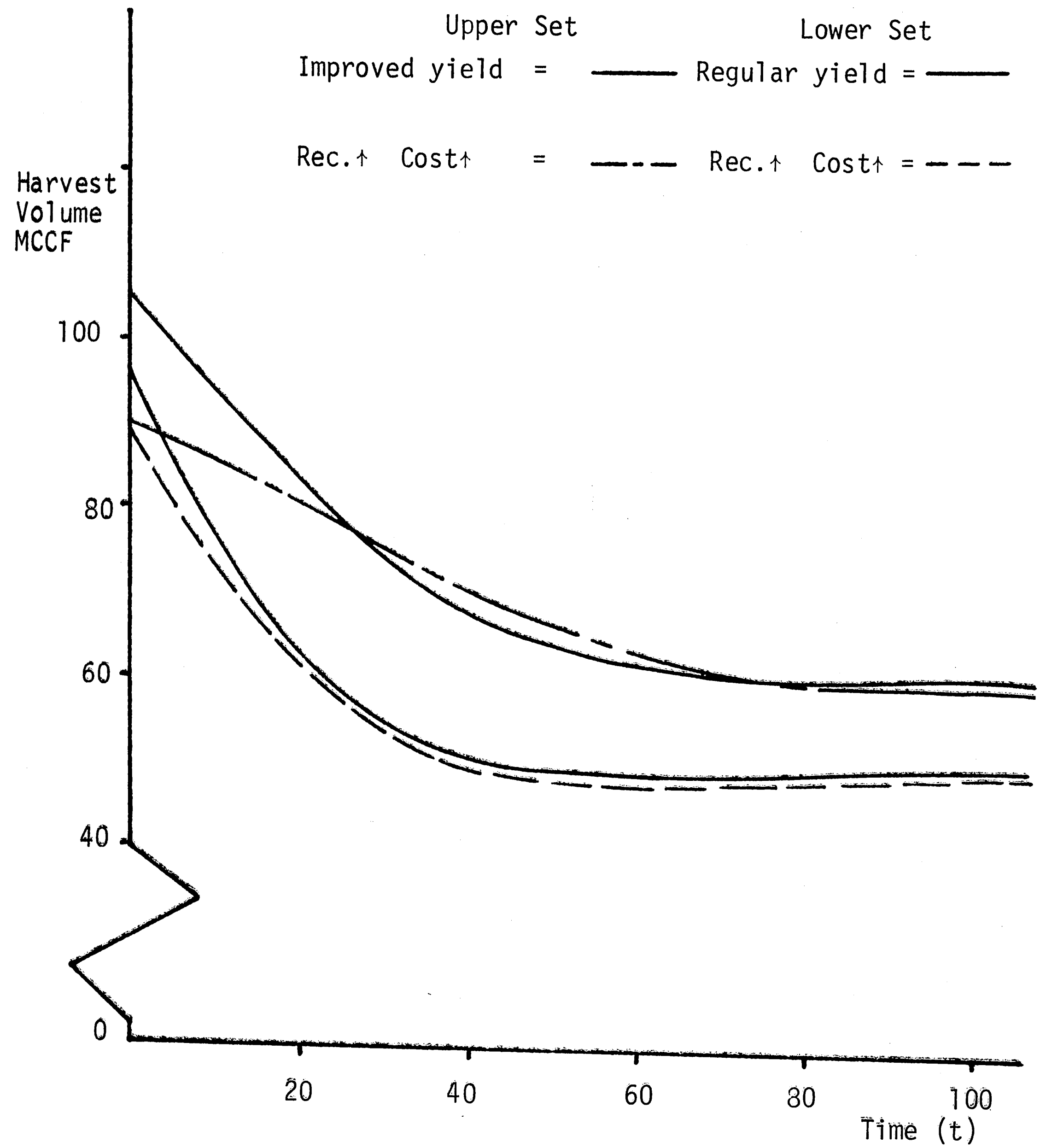


Figure 29. Harvest Levels Over Time Comparing an Increase of 200 Acres in Recreational Area with a $5.00 Increase in per Unit Harvesting Costs and no Increase with Regular and Improved Yields at a 8 Percent Discount Rate.

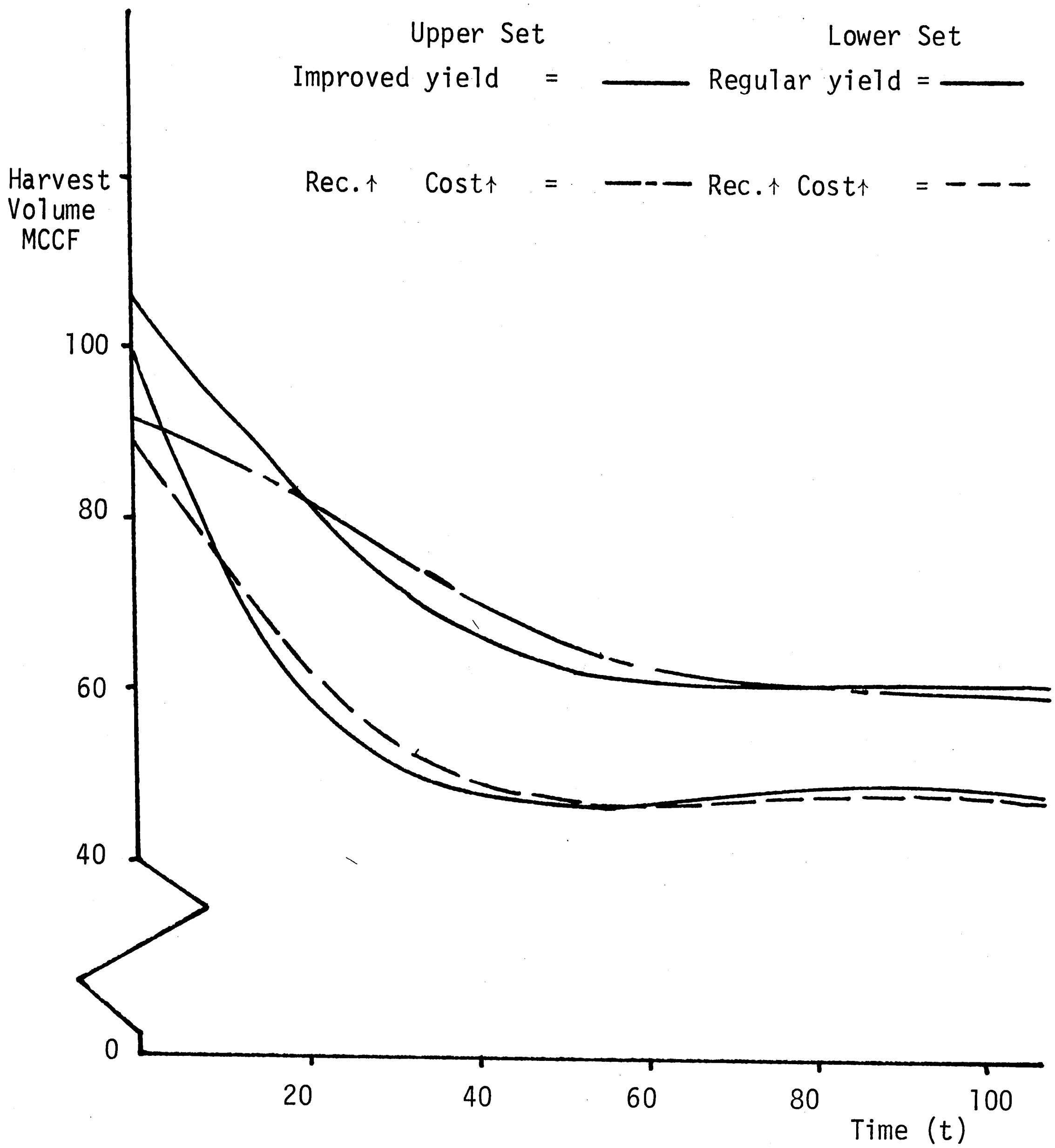


Figure 30. Harvest Levels Over Time Comparing an Increase of 200 Acres in Recreational Area and a $5.00 Increase in per Unit Harvesting Costs and no Increase with Regular and Improved Yields at a 10 Percent Discount Rate.

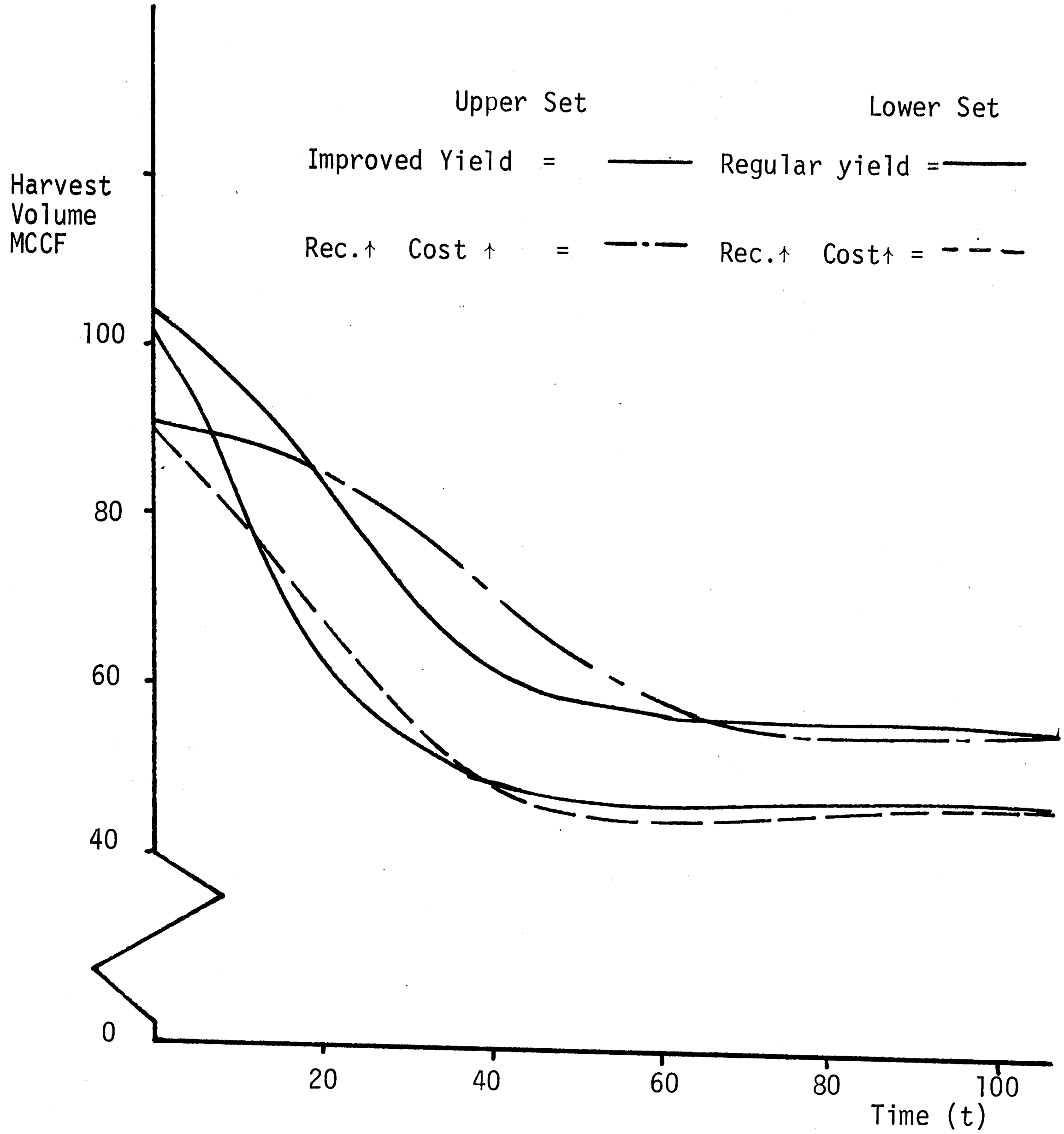


Figure 31. Harvest Levels Over Time Comparing an Increase of 200 Acres in Recreational Area and a $5.00 Increase in per unit Harvesting Costs and no Increase with Regular and Improved Yields at a 12 Percent Discount Rate.

TABLE XX

DIFFERENCES IN THE MAXIMIZED PRESENT VALUE OF NET CASH FLOW OBTAINED BY WITHDRAWING 200 ACRES OF 40 YEAR AGE CLASS TIMBER AND COMBINING A $5.00 PER UNIT HARVESTING COST ON THE TIAK DISTRICT AND COMPARING THE RESULTS WITH THE MAXIMIZED PRESENT VALUE OF NET CASH FLOW WITH NO CONSTRAINTS USING THE ECHO MODEL WITH DISCOUNT RATES OF 6, 8, 10, AND 12 PERCENT WITH IMPROVED YIELDS

STRATEGY	DISCOUNT RATES			
	6%	8%	10%	12%
Improved	30549904	23772784	19579920	16726348
Rec↑ Cost↑	22923280	17670656	14466507	12308276
Difference	(7626624)	(6102128)	(5113413)	(4418072)
% Difference	24.964%	25.669%	26.116%	26.414%

This concludes the step by step presentation of results obtained from managing the Tiak district as if it were a business proposition.

ECHO Marginal Revenue Equal to Demand

Theoretical background for this analysis was presented in Chapter IV. Briefly, the difference between the present value of cash flows calculated where marginal revenue equals marginal cost (monopolistic) and the present value of cash flows when price equals marginal cost (perfect competition) is the quantity to be determined. Table XXI indicates that profits are smaller for the perfectly competitive firm over a period of time.

The quantities in the difference column represent the added amount that the public pays or looses when monopolistic conditions exist. This loss occurrs in the manner of higher prices to the consumer and lower supplies of goods to the market. Figures 32 through 34 represent harvest levels, cash flows, and prices when marginal revenue was set equal to marginal cost in comparison with price being set equal to marginal cost at an 8 percent discount rate. Figure 32 illustrates the harvest levels found in the two situations. The harvest levels for the monopolistic practice are lower than for the competitive situation. The long run equilibrium harvest level for the monopoly case levels out at a lower harvest than the competitive case also. This even-flow period would begin around the 60th year and continue. This agrees with economic theory that relates to lower production levels when monoploy is higher during the first 25 years of planning period and falls below the competitive period after the 25th year. In Figure 34, the expected prices for the monoploy are higher than the competitive prices except initially in year 0-2 and year 19-23. Overall, the results from this section indicate that if there was monopolistic management of the study area, harvest levels would be lower, and prices would be higher over the long run.

TABLE XXI

A COMPARISON OF MAXIMIZED PRESENT VALUES OF CASH FLOW BY FIRST ASSUMING PERFECT COMPETITION AND SECONDLY ASSUMING MONOPOLY USING THE ECHO MODEL AS THE METHOD OF ANALYSIS

Int. Rate	Perfect Comp.	Monopoly	Difference	% Diff.
6%	27,227,344	28,159,520	932,176	3.3%
8%	20,827,296	22,294,304	1,467,008	6.6%
10%	15,837,392	18,600,396	1,762,976	9.5%
12%	14,027,387	16,051,269	2,023,882	12.6%

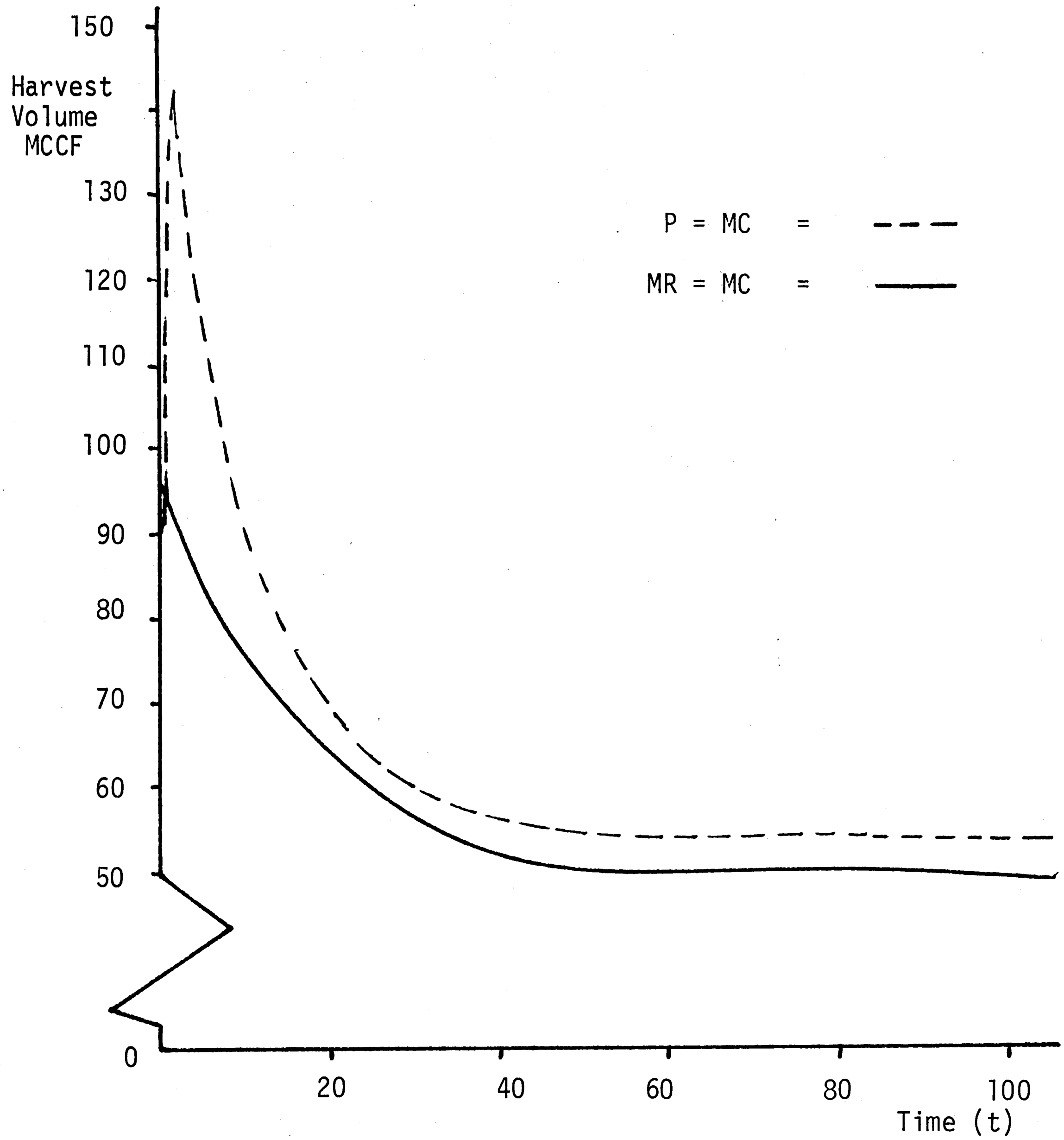


Figure 32. Regular Yield Harvest Levels at an 8 Percent Discount Illustrating the Difference Between P = MC and MR = MC.

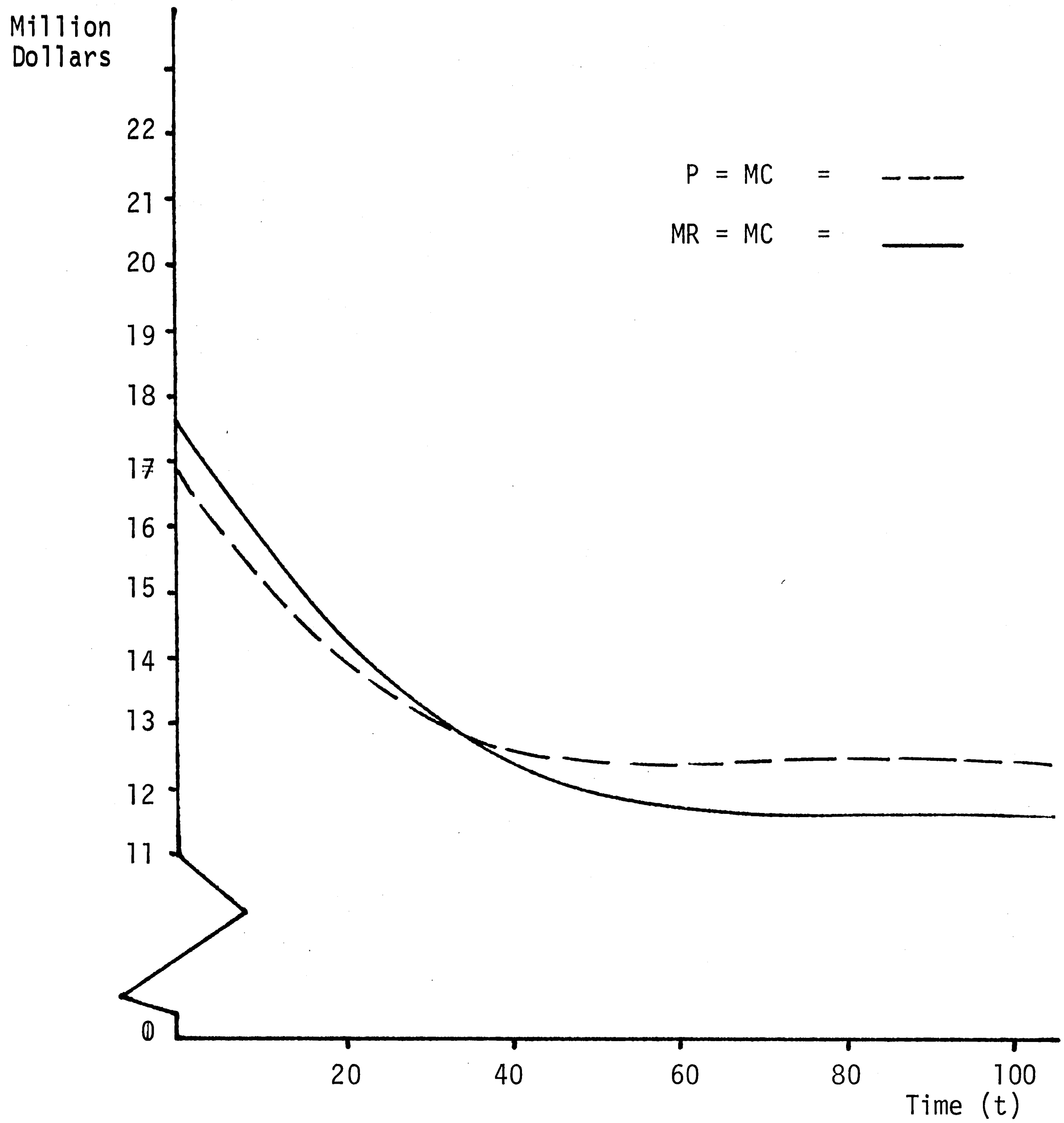


Figure 33. Differences in Net Cash Flows when P = MC and MR = MC.

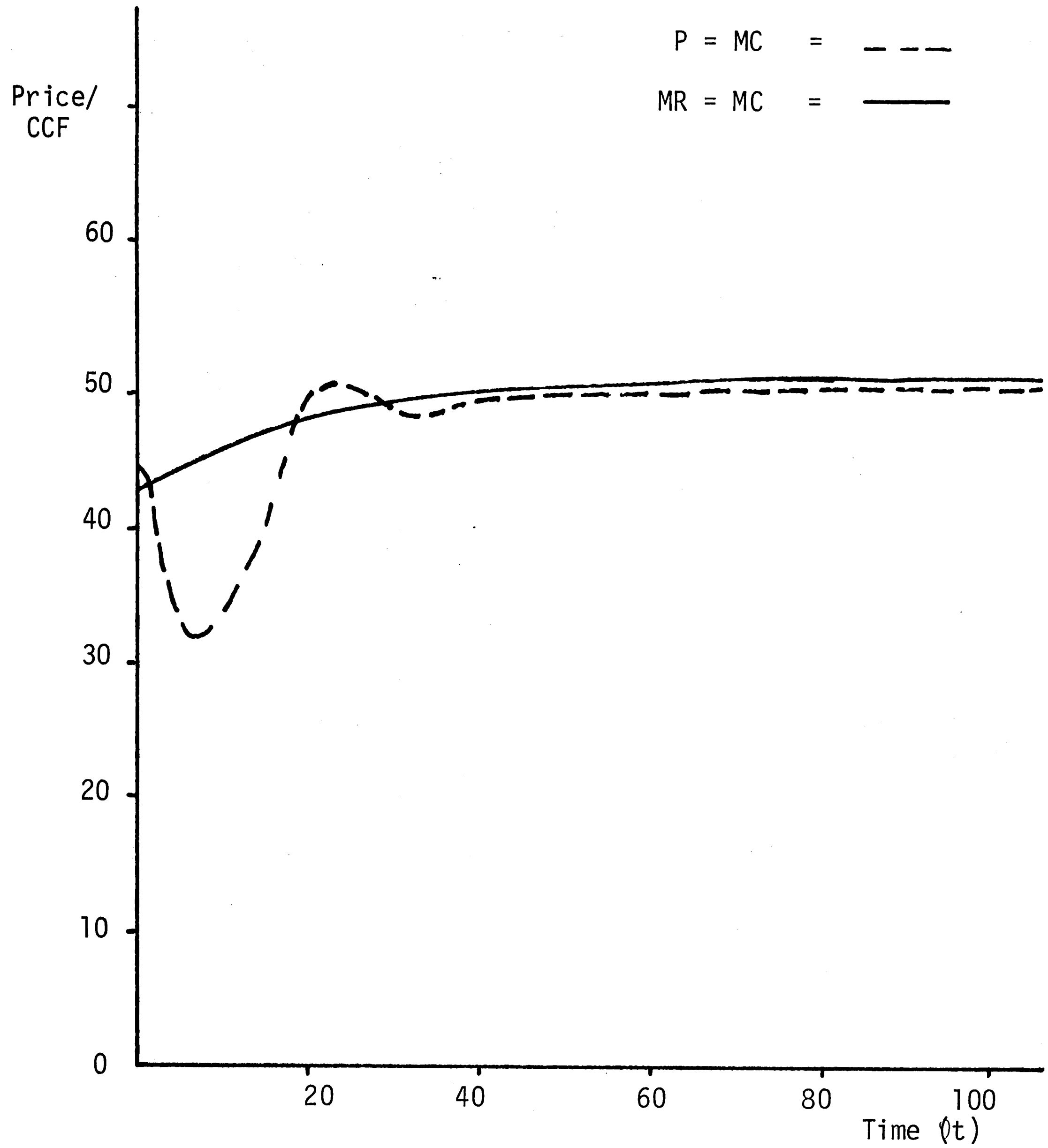


Figure 34. Comparison of Price Flows Between p = MC and MR = MC Plans.

Timber RAM Results

Analysis of a Recreational Increase of 200 Acres Using Timber RAM

This section begins the presentation of the results obtained using the Timber RAM model. The first situation to be analyzed is the opportunity cost associated with a 200 aαre increase in reαreational facilities on the TIAK district. Table XXII lists the results, differences, and percentage differences obtained when the Timber RAM program was run with the regular yield equation with the incorporation of a 200 acre recreational area in age class 40. The 137 CCF initial harvest was used in this situation.

TABLE XXII

DIFFERENCES IN THE MAXIMIZED PRESENT VALUE OF NET CASH FLOWS OBTAINED BY WITHDRAWING 200 ACRES OF 40 YEAR AGE CLASS TIMBER TO SIMULATE AN INCREASE IN RECREATIONAL AREA ON THE TIAK DISTRICT AND COMPARING THE RESULTS WITH THE MAXIMIZED PRESENT VALUE OF NET CASH FLOWS WITH NO CONSTRAINTS USING THE TIMBER RAM MODEL WITH DISCOUNT RATES OF·6, 8, 10, AND 12 PERCENT AND REGULAR YIELDS

STRATEGY	DISCOUNT RATES			
	6%	8%	10%	12%
Regular	8313900	6054230	4719270	3828310
Rec+ Reg. Yield	8312690	6053670	4710000	3828170
Differences	1290	560	270	140
% Differences	-------	-------	-------	-------

Opportunity costs calculated by the Timber RAM model ranged from $1,290.00 for the 6 percent discount rate to $140.00 for the 12 percent discount rate. Timber RAM is inefficient in incorporating small acreage changes for the purpose of evaluating the opportunity cost of withdrawing small acreages from timber production. This is a serious handicap and severly limits the model as an effective planning tool for these purposes. The results obtained from running the Timber RAM program with the improved yields show no changes in the present values when the 200 acre recreational area was witheld. The maximized present value of the cash flow for the improved yield situation at a 6 percent discount rate was $8,528,460.00. This is an increase of $214,560.00 over the amount obtained from the regular yields.

Analysis of a $5.00 Dollar Per Unit Increase In Harvesting Cost Using Timber RAM

Table XXIII shows the results obtained when a $5.00 per unit increase in harvesting costs was included in the model.

The percentage decrease for each interest rate is the same. This is a result of the linearity restriction inherent in linear programming. The percentage decrease in each case was 19.252 percent. The improved yield results are not presented in tabular form as the percentage decreases were the same.

Illustration of the harvest levels in the increased per unit cost situation are not presented as the harvest levels will stay the same regardless of the costs. The linear program initially finds the harvest level that will maximize the present value of the cash flow and these levels will not change. The inclusion of an additional cost is subtracted at the end of the analysis and has no effect on the harvest levels.

TABLE XXIII

DIFFERENCES IN THE MAXIMIZED PRESENT VALUE OF NET CASH FLOWS OBTAINED BY INCREASING PER UNIT HARVESTING COSTS BY $5.00 AND COMPARING THE RESULTS WITH THE MAXIMIZED PRESENT VALUE OF NET CASH FLOWS WITH NO CONSTRAINTS USING THE TIMBER RAM MODEL WITH DISCOUNT RATES OF 6, 8, 10, AND 12 PERCENT REGULAR YIELDS

STRATEGY	DISCOUNT RATES			
	6%	8%	10%	12%
Regular	8313900	6054230	4710270	3828310
Cost↑ Reg. Yield	6713290	4888570	3803340	3091150
Difference	(1600610)	(1165660)	(906930)	(737160)
Percent Difference	19.252%	19.252%	19.252%	19.252%

Analysis of an Increase in Recreational Area Combined with a $5.00 Increase in Per Unit Harvesting Using Timber RAM

When Timber RAM is confronted with a 200 acre increase in recreational area and a $5.00 per unit increase in harvesting costs the results are the same as found in the previous two sections. Table XXIV illustrates the results.

By comparing the difference row in Table XXIV with the sum of the difference rows of Table XXIII and Table XXII one can see that the sums are almost identical. The dollar amount lost by considering a 200 acre increase in recreational area and an increase of $5.00 in per unit harvesting amounts to $1,601,610.00.

TABLE XXIV

DIFFERENCES IN THE MAXIMIZED PRESENT VALUE OF NET CASH FLOWS OBTAINED BY INCREASING THE RECREATIONAL AREA BY 200 ACRES AND COMBINING A $5.00 INCREASE IN PER UNIT HARVESTING COSTS AND COMPARING THE RESULTS WITH THE MAXIMIZED PRESENT VALUE OF NET CASH FLOWS WITH NO CONSTRAINTS USING THE TIMBER RAM MODEL WITH DISCOUNT RATES OF 6, 8, 10, AND 12 PERCENT REGULAR YIELDS

STRATEGY	DISCOUNT RATES			
	6%	8%	10%	12%
Regular	8313900	6054230	4710270	3828310
Cost↑ Rec↑ Reg. Yield	6712290	4888100	3803100	3091929
Difference	1601610	1166130	907170	737290
Percent Difference	19.26%	19.26%	19.26%	19.26%

Analysis of the Results Obtained from the Additional Timber RAM Situations

The computer runs of the Timber RAM model on the data were adjusted so that the results would be based on the current district management practices in the TIAK district. The level of previous harvests was set at 137 MCCF because of reasons listed in Chapter V. Additional runs were made at the 300, 400, and 600 MCCF level to ascertain whether or not the Timber RAM plans could approach the results obtained in the profit maximizing (ECHO) model. The results of the runs are listed in Table XXV.

With 300 MCCF as the beginning harvest level, the Timber RAM program indicated that the forest was capable of meeting that harvest level. The longrange sustained yield found was 292.46 MCCF/decade. The average of postconversion periodic harvest was 300.41 MCCF/decade. The difference can be attributed to lower harvests in the 60 year conversion period. The lower harvest levels are averaged with the postconversion levels to obtain the longrange sustained yield average.

TABLE XXV

RESULTS OBTAINED FROM THE TIMBER RAM MODEL WHEN BEGINNING HARVEST LEVELS WERE ADJUSTED UPWARD FROM THE 137 MCCF LEVEL

MCCF VOLUME	LONGRANGE SUSTAINED YIELD AVG.	AVG. OF POSTCONVERSION PERIODIC HARVEST
137	213.98 MCCF/decade	210.98 MCCF/decade
300	292.46 MCCF/decade	300.41 MCCF/decade
400	307.24 MCCF/decade	309.41 MCCF/decade
600	Unable to meet harvest level.	

With 400 MCCF as the beginning harvest level, the Timber RAM program obtained a feasible solution also. The solution obtained for this situation is probably close to the limits of the forest to produce at the yield levels, rotation age, and age groups given the program. The longrange sustained yield average was 307.24 MCCF/decade and the average of postconversion periodic harvests was 309.41 MCCF/decade. These harvest levels are only slightly higher than those obtained with 300 MCCF as the beginning level. This would indicate that at the 400 MCCF level, the program is finding the most feasible solution at the lower bounds of the sequential limits set.

With the 600 MCCF level as the beginning harvest, no feasible solution could be found indicating that the 600 MCCF level was too high to be reached by the forest while keeping within the specified bounds.

Figure 35 illustrates the harvest volumes for the three harvest levels that had feasible solutions. Harvest levels for the 300 and 400 MCCF levels are for the most part very close together and converge with the 137 MCCF level at about year 30 in the planning period. Figure 36 compares the three harvest levels with the harvest level obtained with the ECHO plan. None of the three harvest levels approach the ECHO harvest level at any time. This can be attributed to the 60 year rotation age built into the Timber RAM situation while the ECHO program is free to search for the optimal rotation age.

Table XXVI shows the difference in the present values of net cash flow calculated for the values of different harvest levels.

TABLE XXVI

PRESENT VALUE OF CASH FLOWS GENERATED BY THE TIMBER RAM PROGRAM USING 137, 300, 400, AND 600 MCCF AS THE BEGINNING HARVEST LEVEL

SOURCE	INTEREST RATE	YIELD	HARVEST LEVEL	P.V. CASH FLOW
ECHO	8%	Regular	Unbounded MCCF units	$22,294,304
Timber RAM	8%	Regular	137	6,054,230
Timber RAM	8%	Regular	300	11,044,660
Timber RAM	8%	Regular	400	11,167,320
Timber RAM	8%	Regular	600	Infeasible

The present values of cash flows generated by each harvest level are in the fifth column of Table XXVI. The largest value calculated was when the beginning level was 400 MCCF/decade with the Timber RAM

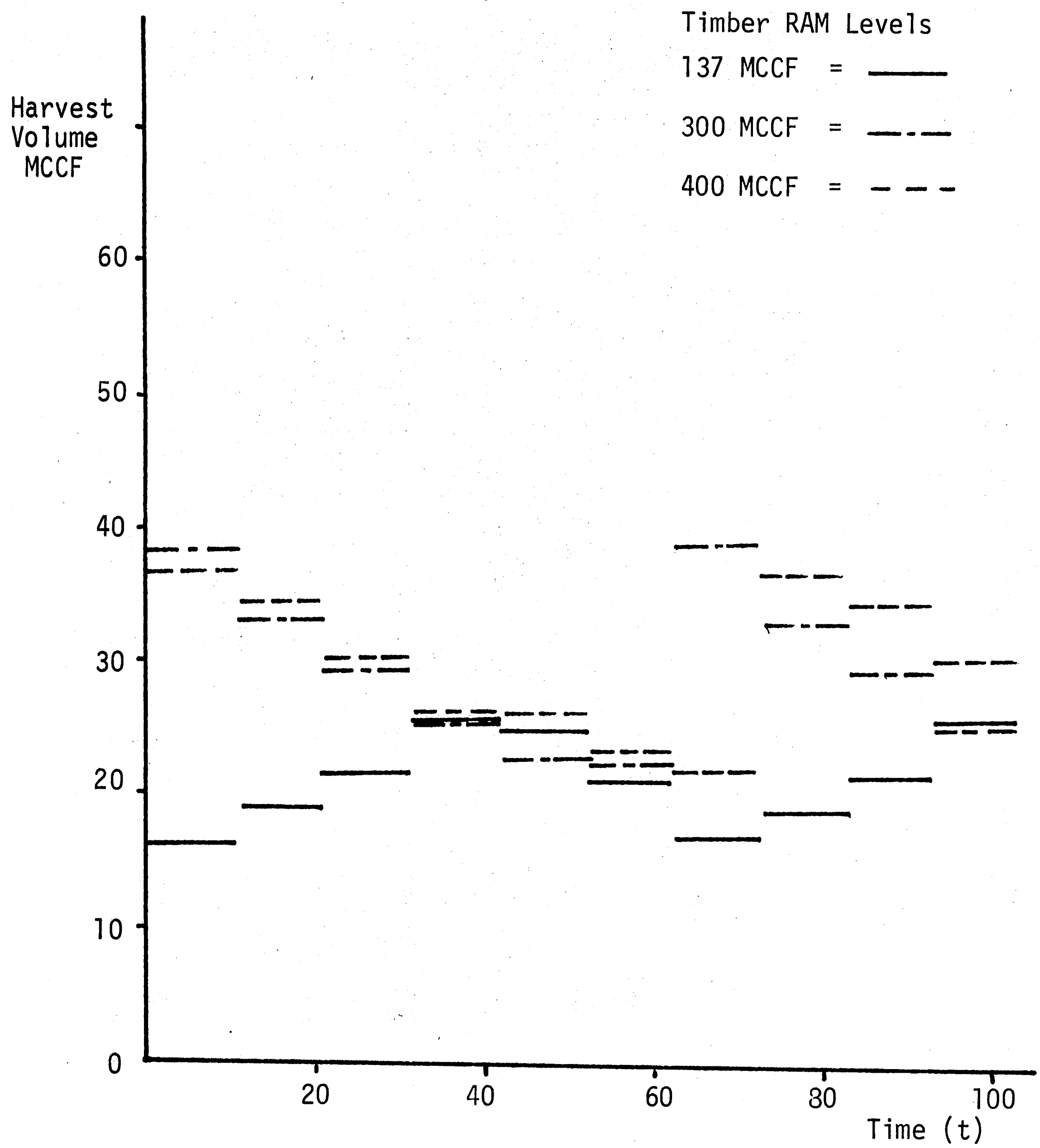


Figure 35. Timber RAM Harvest Levels for Different Initial Values of 137, 300, and 400 MCCF/Decade.

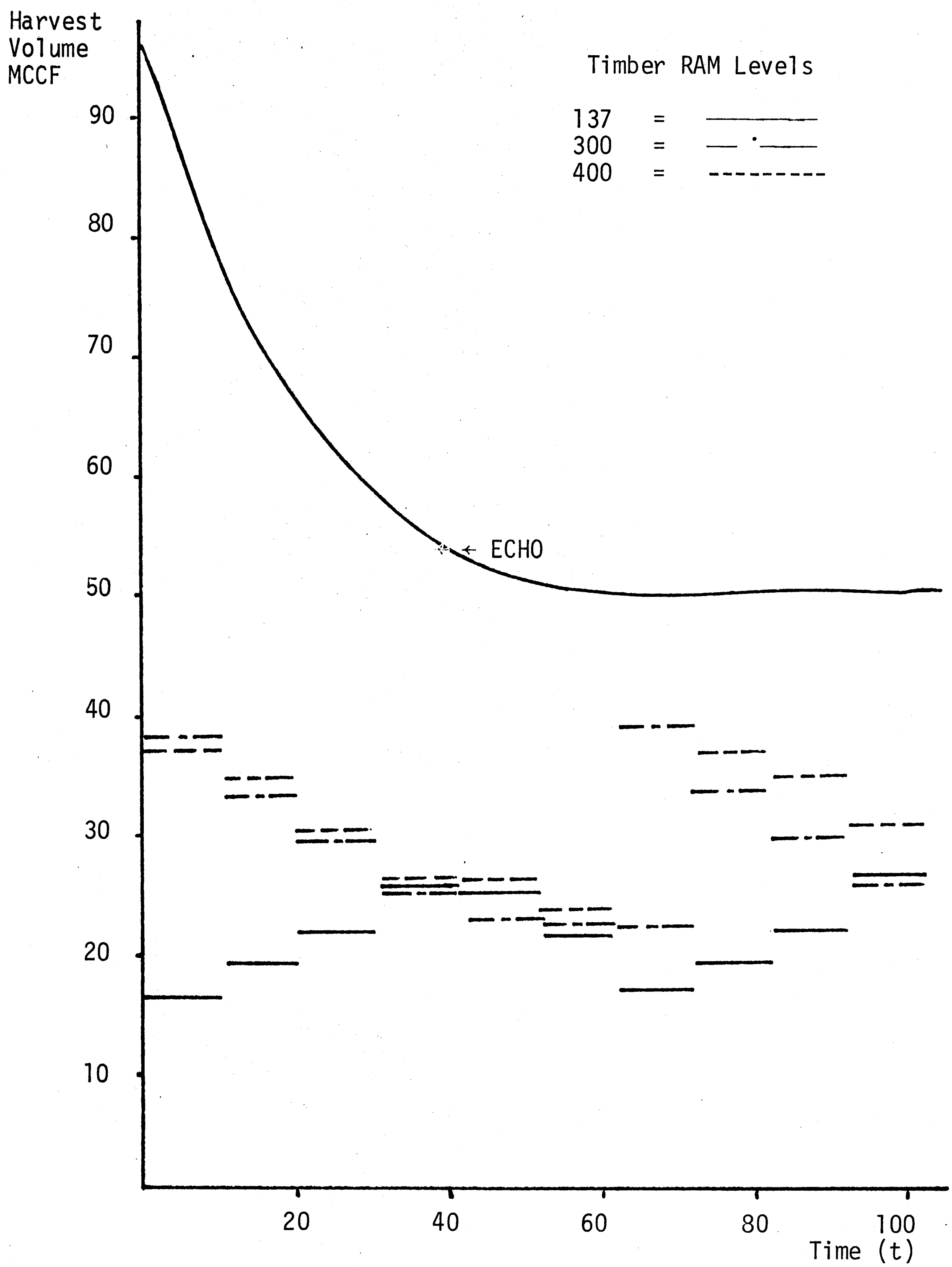


Figure 36. Comparison of Different Initial Timber RAM Harvest Levels with the Corresponding ECHO Harvest Level.

program. This value however, is approximately one-half that of the value obtained by the ECHO program which is listed at the top of the column. This again, is attributable to the fact that ECHO can search for a minimum rotation age that will allow for profit maximization.

Additional simulation was conducted on alternative rotation ages of 20 and 40 years. The Timber RAM plan indicated that both the 20 and 40 year rotation would produce virtually the same results as the 60 year age rotation. This indicates that a rotation age of 20 years on the forest is not out of the question because almost identical present values were calculated.

Simulation was also conducted on the district by removing acreages from the various age classes and then determining the effect on harvest levels and present values of cash flows. Table XXVII indicates the results of these situations.

TABLE XXVII

INCREASED TIMBER RAM RECREATIONAL AREAS

AGE CLASS REMOVED	NUMBER ACRES REMOVED	TOTAL ACRES LEFT	HARVEST LEVEL CHANGE	P.V. OF CASH FLOW	INT. RATE	YIELD EQUATION
40	1000	22,941	slight	6,137,570	8%	Regular
40	2000	21,941	slight	6,119,070	8%	Regular
60,70	4533	21,589	slight	5,028,390	8%	Regular
50,60,70	6368	17,668	slight	5,983,060	8%	Regular

This situation simulated withdrawing large amounts of acreage from production for recreational purposes. Portions of the 40 year age class were removed along with all of the 50, 60, and 70 year age class. It was simulated with an 8% discount rate using regular yields. The results indicate that approximately the same results found with all acres available could be found with the entire 50, 60, and 70 year age class removed. This can be attributed to the fact that the harvest levels set for the forest are not as large as the forest is capable of producing.

Analysis of Timber RAM and ECHO

The comparison of the two algorithms utilize the situations as discussed in the previous two sections. However, the analysis is limited to one discount rate, 8 percent.

Analysis of a Recreation Increase

A 200 acre increase in area utilized for recreational purposes is the situation considered first. Under the ECHO plan at an 8 percent discount rate, the present value of the net cash flows is $22,266,928 where the Timber RAM plan gives present value of $6,053,670. A total difference between the two values results in a sum of $16,216,258. These results indicate that the ECHO plan yields roughly 3.5 times as much revenue as the Timber RAM plan. The ECHO plan also harvests roughly 3.5 times as much timber from the same area as the Timber RAM plan does. The reasons for the vast differences are rotation age and allowable cut. These constraints limit the availability of timber in two ways. The first rigidly constrains the cut to small tolerances around a specified level (allowable cut). The second, rotation age, severly limits harvesting in two ways, 1) the first being that you must wait for the timber to grow into the specified age group and 2) if you have an abundance of timber in the specified age group, you will be limited by the allowable cut constraint. This allows the trees to become older and the annual average yield per acre to decrease.

Analysis of a Cost Increase

With an increase in cost of $5.00 per unit harvested, the ECHO plan generated a present value of $16,934,704 compared with a present value of $4,888,570 from the Timber RAM plan. The difference between the two plans was $12,946,134. Here again, rotation age and allowable cut enter into the results by allowing the ECHO results to be much larger. In this case however, the difference between the two plans decrease from the previous situation. This is a result of the initial drop in harvest levels of the ECHO plan to bring the difference equation to equality. The cost increase altered the marginal cost side of the equation upward which caused a decrease in harvest levels. The implication of this is that if a firm were maximizing profit using the ECHO model as a planning tool, they would be much more sensitive to cost changes than a similar firm using Timber RAM as a planning tool.

Analysis of a Recreational Increase and Cost Increase

The situation is the recreational increase combined with an increase of $5.00 per unit harvesting cost. The ECHO plan generated a present value of $16,897,584 compared with a value of $4,888,100 from the Timber RAM plan. A total difference of $12,099,484 or roughly 3.5 times the amount of revenue and 3.5 times the amount of timber harvested. The results here are basically a combination of the previous two sub-sections. The implications are that if the study area was being managed with the ECHO plan, the results obtained would be considerably more variable than the results obtained with Timber RAM as an operational tool.

Cash Flow, Harvest Levels, and Prices of Each Model

This section examines the differences between the results generated by each plan. Figures 37 through 39 illustrate the difference between harvest levels, cash flows and prices paid for the regular yield equation at an 8 percent discount rate. Figures 40 through 42 illustrate the same features for the improved yield equation at an 8 percent discount rate.

The graphical analysis demonstrates the extreme differences between the two plans. The ECHO plan does seek and find a much higher level of timber resource use than the Timber RAM plan. Figures 37 and 40 indicate the differences in the two levels. These differences are attributed to the fact that Timber RAM plans are constrained by harvest levels and maximum rotation ages. The ECHO plan is free to adjust the forest via harvest levels and rotation ages until a profit maximizing even-flow equilibrium is reached.

Figures 38 and 41 indicate the cash flows obtained from each model. The cash flow diagram indicates the dollar value forthcoming with respect to the year on the horizontal axis. The differences in these two illustrations accentuate the constraints encountered by the Timber RAM plan. If harvest levels are suppressed to a certain level with prices constant as they are in Timber RAM, situations such as those depicted will arise.

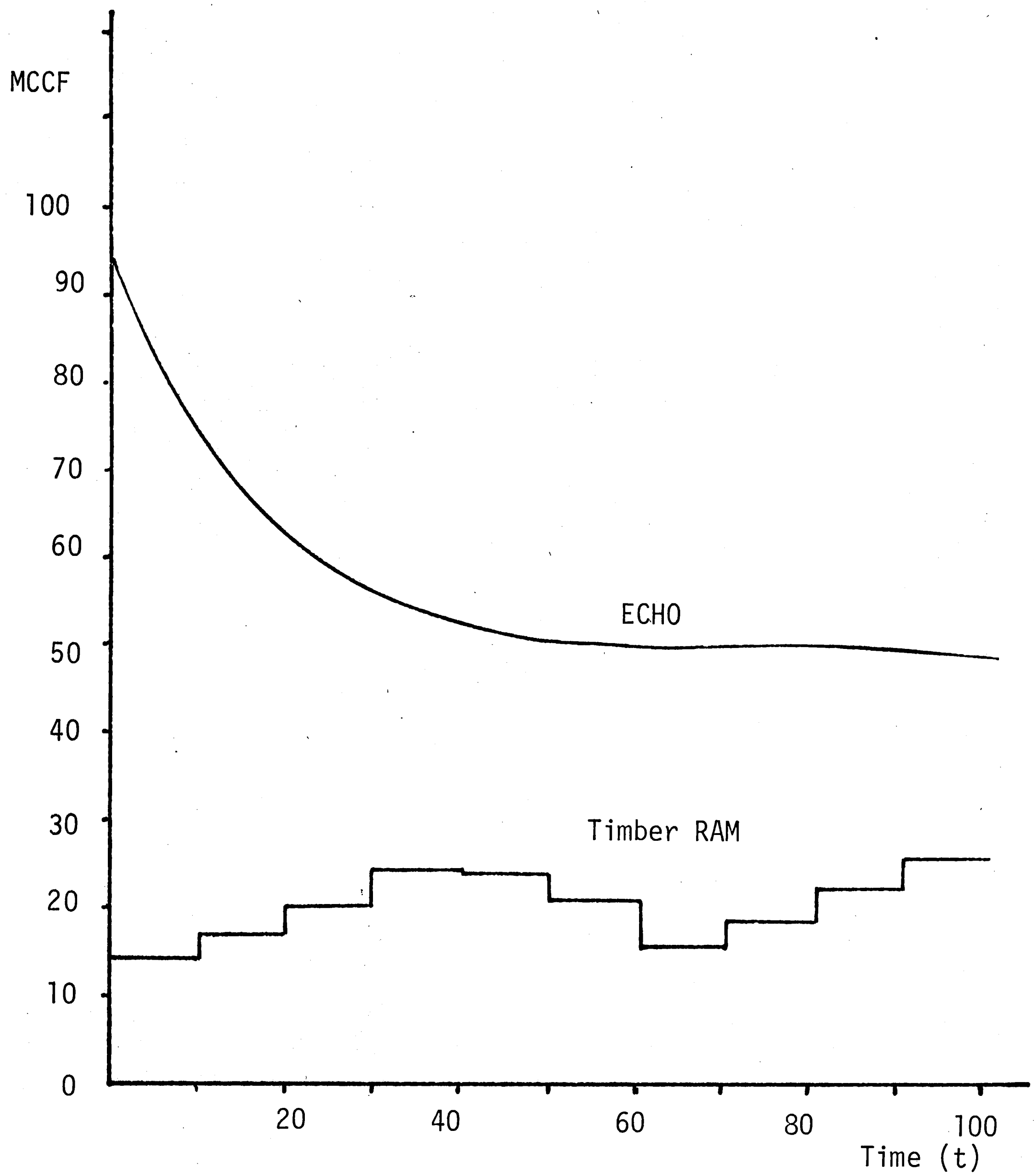


Figure 37. Timber RAM and ECHO Harvest Levels at an 8 Percent Discount Rate with Regular Yields.

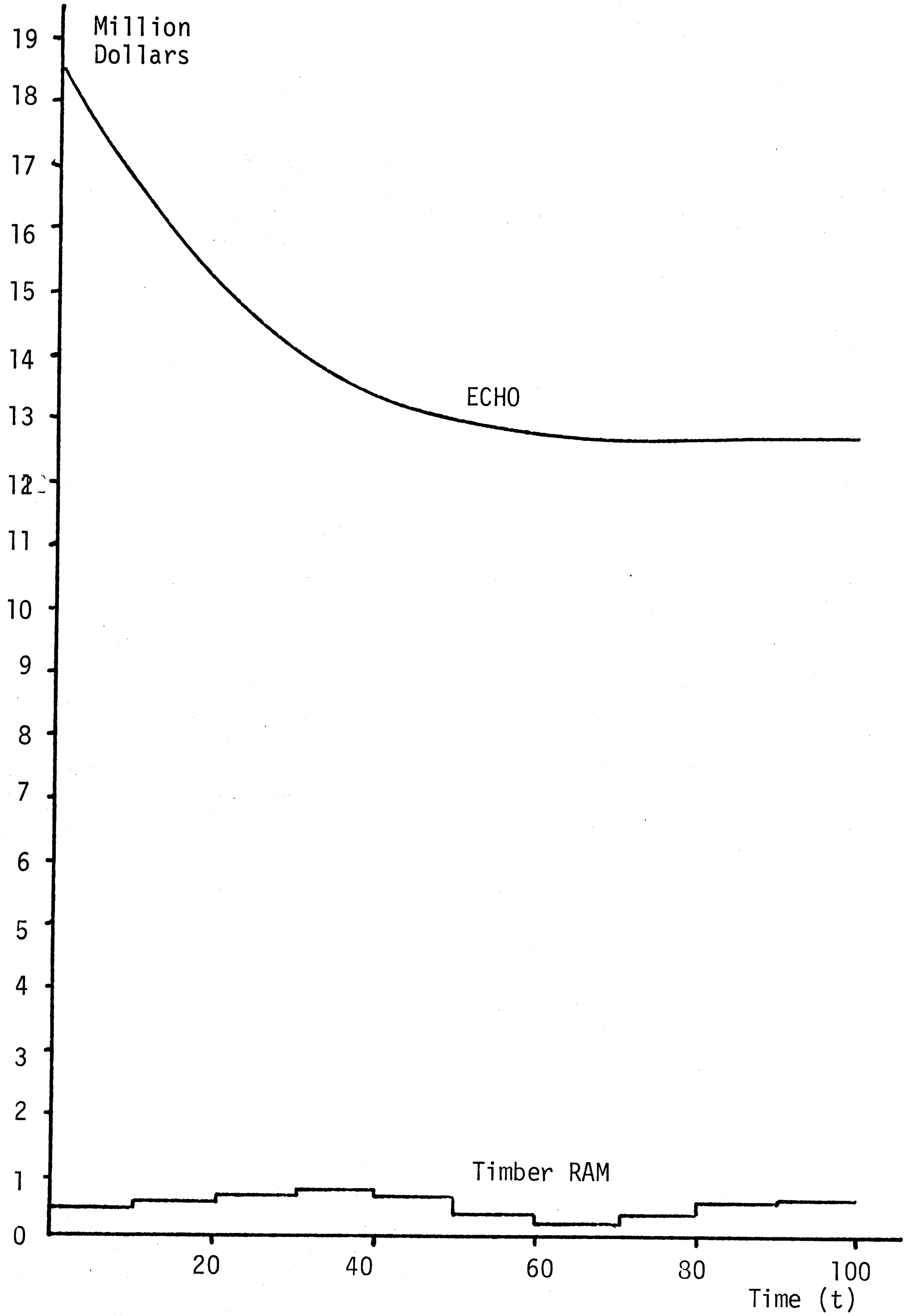


Figure 38. Timber RAM and ECHO Net Cash Flows at an 8 Percent Discount Rate with Regular Yields.

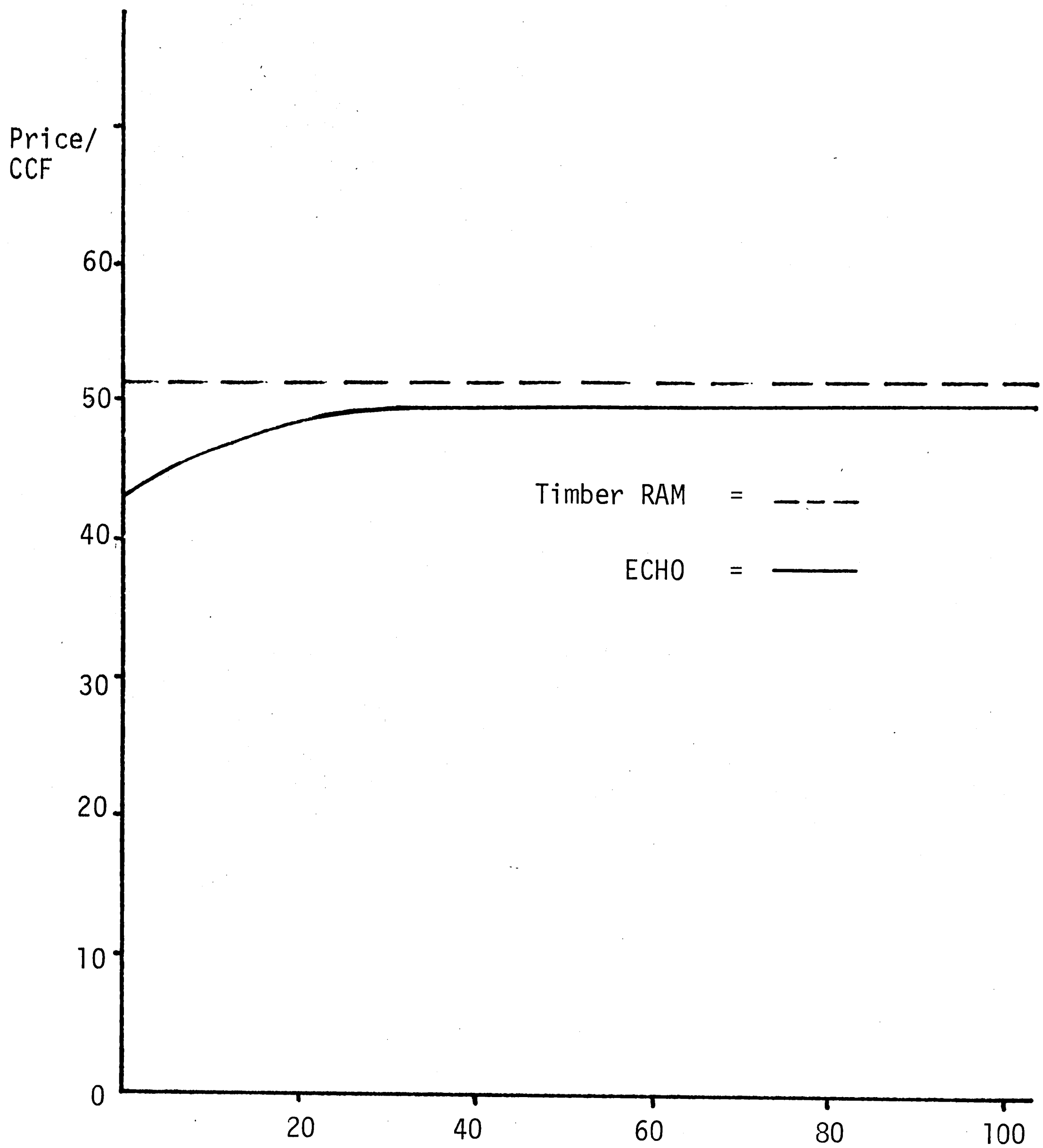


Figure 39. Timber RAM and ECHO Prices at an 8 Percent Discount Rate with Regular Yields.

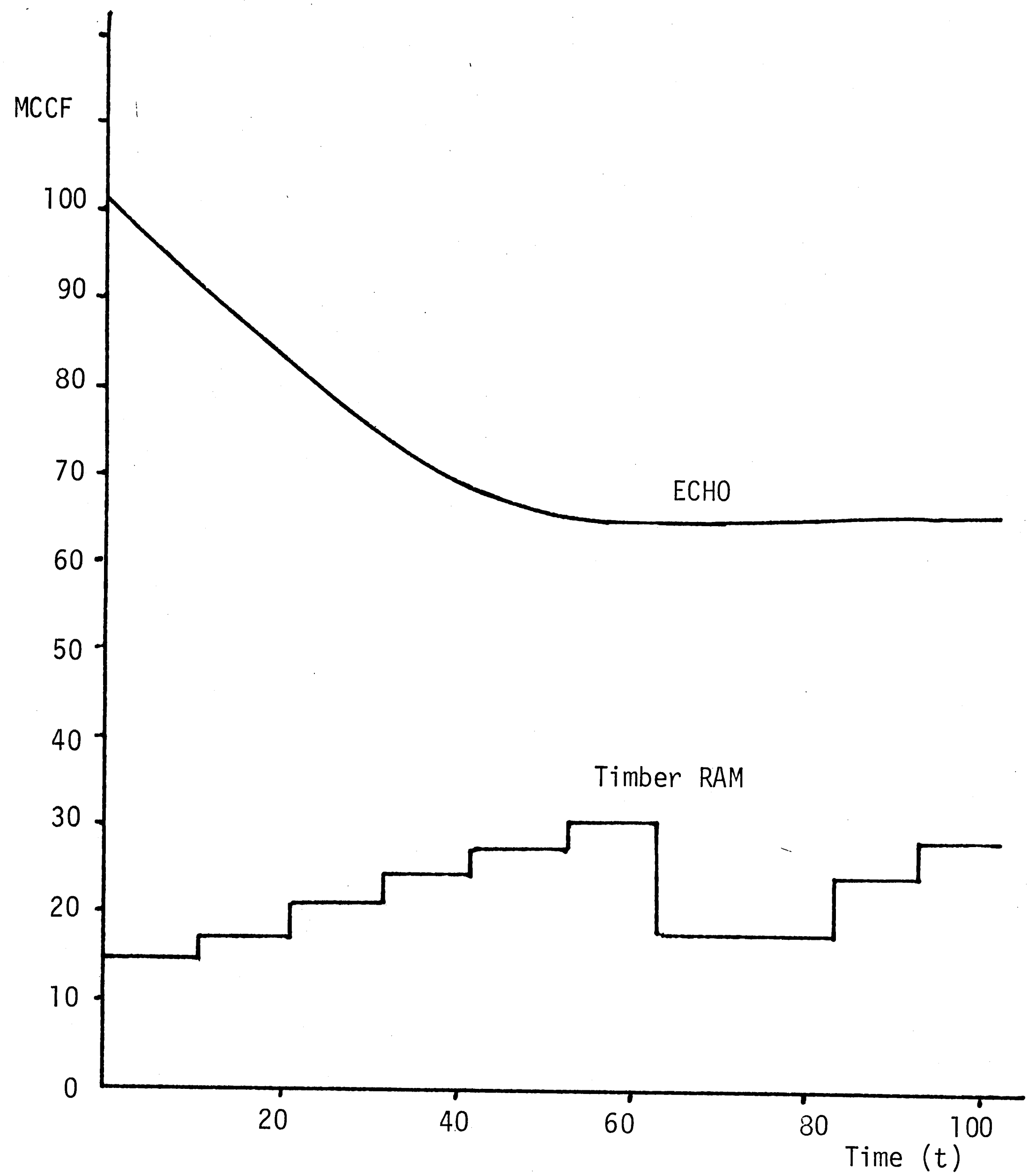


Figure 40. Timber RAM and ECHO Harvest Levels at an 8 Percent Discount Rate with Improved Yields.

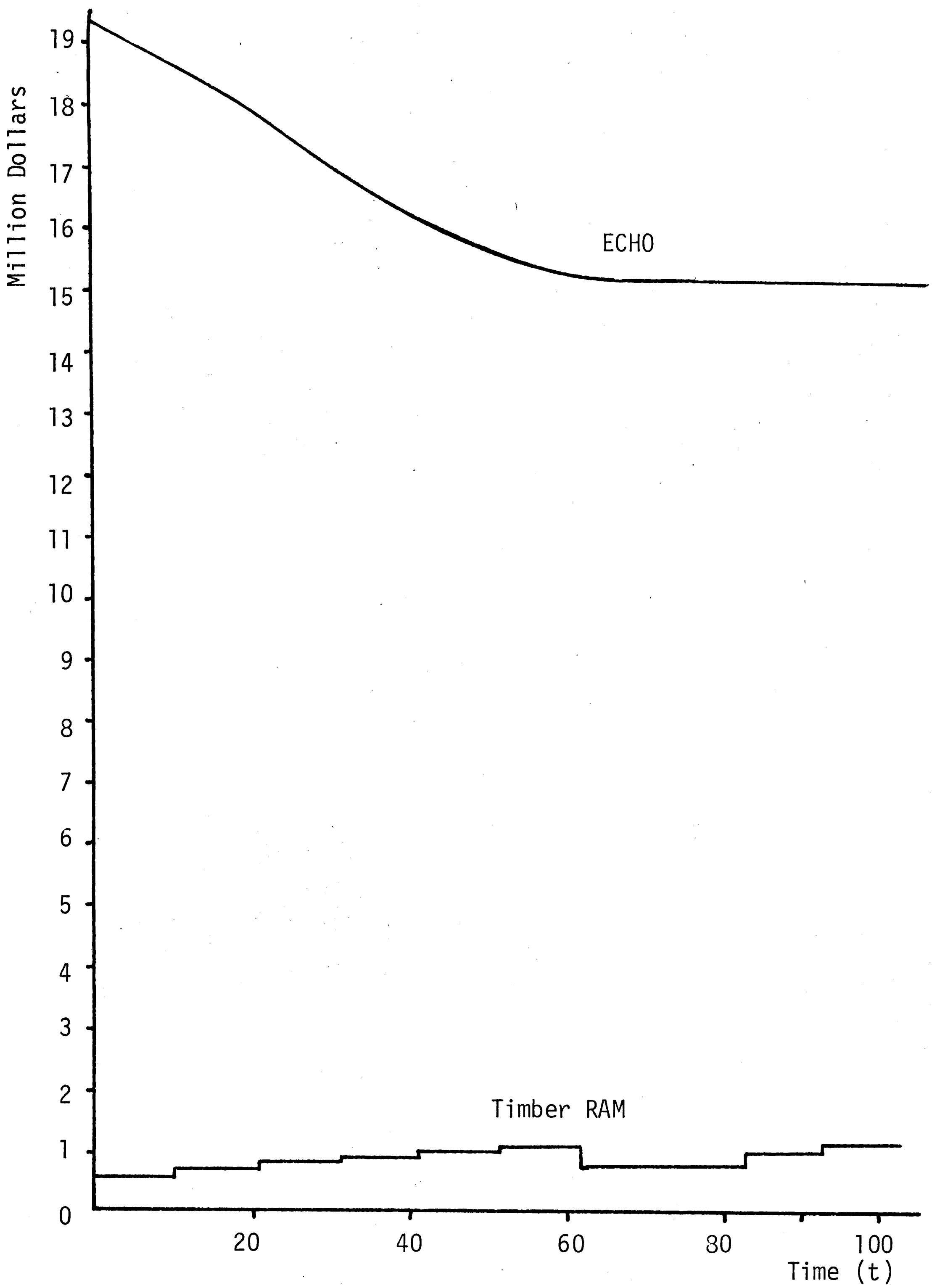


Figure 41. Timber RAM and ECHO Net Cash Flows at an 8 Percent Discount Rate with Improved Yields.

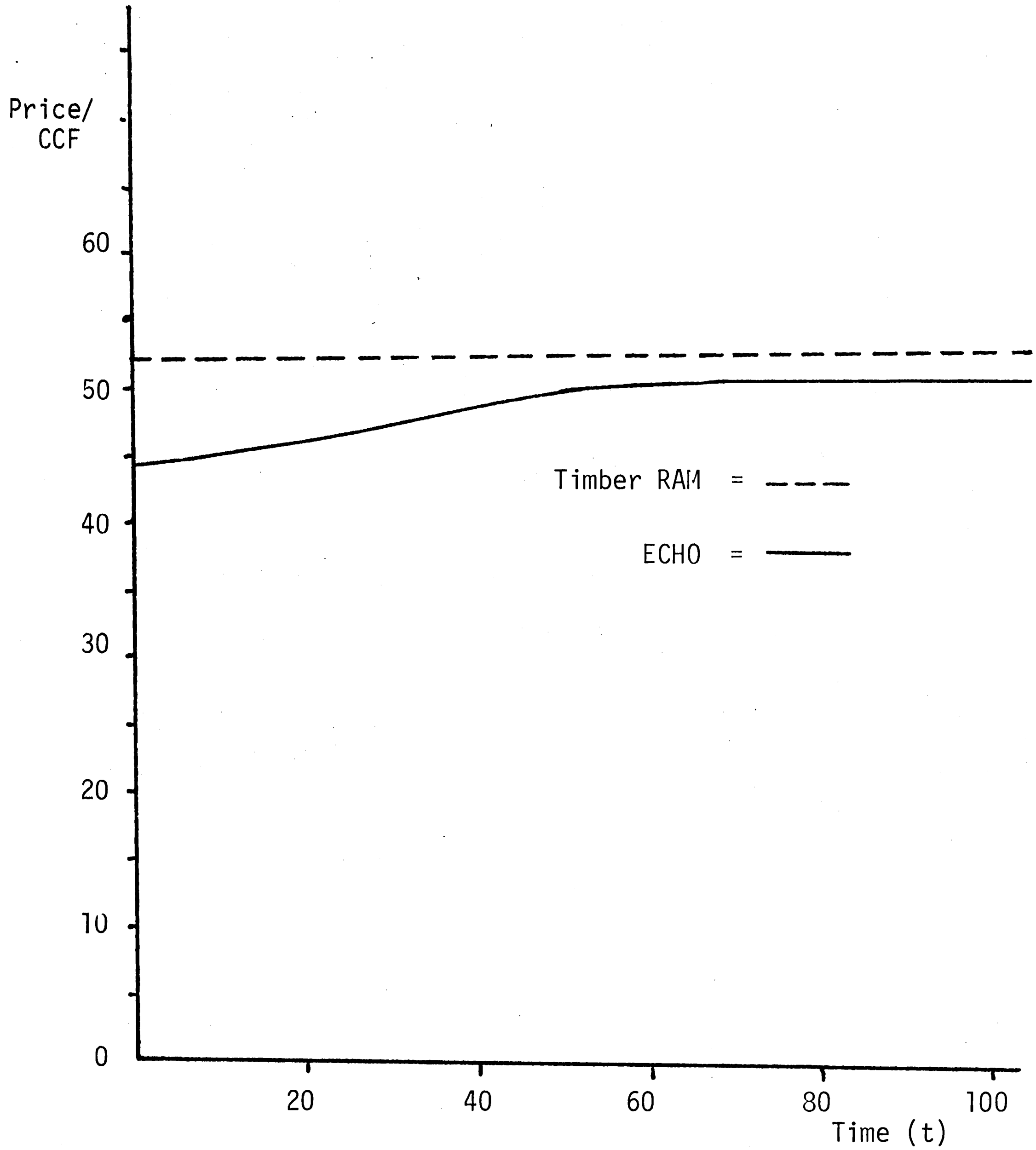


Figure 42. Timber RAM and ECHO Prices at an 8 Percent Discount Rate with Improved Yields.

The timber prices received graphs (Figures 39 and 42) show the time path of the prices received for timber in each model. In the Timber RAM case, prices were stable at $51.00/CCF. The constant price utilized in Timber RAM was explained in Chapter IV. The ECHO plan however, calculated prices which were below the level of the $51.00 at every level. In both the improved and regular plan under the ECHO management scheme, prices were lower when the harvest levels were higher and the prices were higher when harvest levels began to decrease. This situation is associated with the negatively sloped demand curve used in the ECHO model as explained in Chapter IV.

Conclusions

Two entirely different management techniques were employed in the analysis of the TIAK ranger district. The ECHO model derived values that were, for the most part approximately 3.5 times greater than those values arrived at by the Timber RAM model. These differences were attributable to the built in constraints applied to the Timber RAM model. These constraints consisted of specifying a beginning harvest level around which only minimum fluctuations could occur and specifying a harvest age from which no deviations were allowed. In each case, where the two models were compared, the ECHO plan indicated that the district could supply much higher harvest levels and at a lower price than the Timber RAM plan. This resulted because the ECHO model was able to harvest any age group and any harvest level. This should not imply that Timber RAM misallocates resources. Timber RAM is defined as a multiple-use planning tool. This definition implies that there are other considerations included in planning forest production. Other areas are wildlife, watershed, recreation, and range. Timber RAM can be used for multiple goal analysis, In this study, Timber RAM was used in analyzing only recreation.

ECHO is a profit maximizing tool designed to maximize profits from timber production. Therefore, it could be argued that ECHO misallocates resources by not considering the other four important areas of multiple-use planning. Another approach for comparing the harvest levels and cash flows of Timber RAM and ECHO may be to interpret the results such that the remaining four areas contribute the difference between the cash flows of Timber RAM and ECHO. Using the above reasoning, Timber RAM would be the best model if the forest was to be managed on a basis which recognizes the interdependence of the multiple products.

Clawson (6) indicates that the Forest Service goals in managing the National Forests have resulted in an excess of $12 billion dollars of excess timber inventory which results in a $600 million dollar annual loss to the public or about $3 per person per year. He further states that net growth and harvests are only 39 percent of optimum. The results obtained in this study substantiate Clawson's findings. In fact, the results indicate that the TIAK district has actually been managed at about 30 percent of capacity. However, if other areas of multiple use were considered, the results could have been interpreted to show that the remaining 70 percent of unused timber capacity could have been attributed to these other products.

If the value of the other forest products in either monetary or esthetic terms is greater than the difference between Timber RAM and ECHO results, then management is doing a good job. If however, the returns from the other areas is less than the differences between Timber

RAM and ECHO, then perhaps production, and as a result forest service profit, could be increased so that the benefits received are equal to their opportunity cost.

CHAPTER VII

SUMMARY

This study examined alternative management situations for timber land in the Southeast Oklahoma. Although there probably exist several thousand possible alternatives ranging from no management to the most intensively planned management scheme imaginable, only three different management schemes or situations were utilized. The three strategies were developed and evaluated under two yield equations, a regular yield equation and a genetically improved yield equation, and four separate discount rates, (6, 8, 10, and 12 percent).

The three situations were analyzed by two separate forest management models, Timber RAM and ECHO. Timber RAM is a linear programming technique that requires pre-specified harvest levels, harvest level tolerances, and rotation ages. ECHO is a difference equation technique that allows the model to search for the rotation age and harvest levels that maximize profit for the timber owner.

Situations analyzed by the two models were a 200 acre recreational increase on the district, a $5.00 per unit harvesting cost increase, and a combination of a recreational increase of 200 acres and a $5.00 per unit harvesting cost increase. Harvest levels, cash flows, and prices were among the variables evaluated and the ECHO model consistently provided results that were 3 to 4 times greater than the values generated by the Timber RAM plan. The differences between the two models are attributed to the pre-specification of harvest levels and rotation ages in the Timber RAM model.

Several additional forest management situations were also analyzed. The forest was evaluated with the ECHO program to analyze the differences that could be found when a lumber corporation operated as if it were a monopolist in comparison to operation as a perfect competitor. Results indicated that if the firm operated as a monopolist, harvest levels would be lower, prices higher, and cash flows greater than those obtained by a perfect competitor indicating a social loss under monopoly. The forest was also evaluated by the Timber RAM plan to determine what amounts of land could be withdrawn from production without greatly affecting the harvest levels found by the Timber RAM plan. It was found that acreages totaling approximately 7000 acres could have been withdrawn from production under the Timber RAM plan without affecting harvest levels. Other situations analyzed by the Timber RAM plan included altering the pre-specified harvest levels upward to approach results obtained by the ECHO model. Results indicated that with a 60 year rotation age, the forest could produce only one-half that obtained by the ECHO model. The final situation analyzed by the Timber RAM plan was to examine alternative younger rotation ages to see if the younger ages affected harvest levels and cash flows. Results indicated that harvest rotation ages of 20 and 40 years did not considerably alter the harvest levels or cash flows.

Findings indicate that the forested area studies is underutilized. Underutilization, as used here must be understood in the proper context. If as pointed out in the previous chapter, the TIAK district is managed with a centralized scheme which treats the five multiple-use products as interrelated, then the forest managers could argue that they are producing timber at an optimum rate. If they are managing the forest for timber production, they are falling far short of the optimum. Determining what the goals of timber managers should be is beyond the scope of this study. Pending legislation in our national congress is designed to prepare guidelines for forest management.

This study evaluated two alternative management models that can used in Oklahoma forest management studies. Each method has limitations, many of which are discussed in the study. Previously, analysis of this type has been performed only on forests located in the Western portions of the United States. Results obtained in this study indicate that this type of analysis can be used on the Southern forests. Forest managers in the South and East need to specify their goals and then choose the forest management tool appropriate to determine how to best achieve their goals.

Research Needed

Fedkiw (10) points out that there are five priorities that forest economic research should include, they are; 1) Reliable, dynamic national timber supply coefficients and models to forecast how much and where timber will be harvested or imported and at what prices for alternative assumptions about timber demands . . . 2). . . methods and coefficients to assess the national net economic, social and environmental benefits and impacts of alternative levels of timber supplies and prices, . . . 3) . . . how the effects of third party timber price and market reporting will influence the timber supply investment and growth responses of private woodland owners and their incomes from woodland operations. . . 4) better information on how landowners respond to alternative types and levels of incentives. and 5) . . . we need to know how to evaluate the cost-effectiveness of various types of forestry programs which have timber supply improvement for our objectives.

Fedkiw's comments are appropriate as they corroborate many of the research needs found during the course of this study. Accurate and reliable demand and supply relationships for the Southeast timber region containing Oklahoma are needed. These relationships need to be developed because planning based only on demand and future demand in useless if the accompanying supply relationships are absent.

Much work needs to be performed to determine the tradeoffs in Oklahoma of timber production and the other four areas that make up the multiple use package. If benefits are accuring to the economy from these other forest uses, then research needs to identify the inputs or inflows and quantify them in identifiable terms so that they may be accurately compared with the other outputs of the forest measured in dollars.

Study needs to be initiated on methods to effectively gather, combine and disseminate current timber prices and supply situations. The availability of this material to timber owners must be free or nearly free for effective use.[2] Examination should be made into the mechanics of current crop reporting systems and something similar should be the goal for reporting timber prices and markets.

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[2] There exists in the Western United State several price and market reporting agencies, however the cost of their material is relatively high.

Currently, there exists only one federally sponsored incentive program for forest farmers. The futility of this program is that no single program can be effectively utilized throughout the entire country. Pilot forest incentive programs should be developed, evaluated, and implemented on a regional or district basis. These programs should be suitable to the timber/soil type of the area and the payments should, if possible, be indexed with the rate of inflation. Only when these incentive plans are developed on a regional basis will the desired increase in timber supply from the private sector be forthcoming. The cost-effectiveness of each plan must be determined to provide the maximum increase in timber per dollar expended.

Other areas of needed research include area volume and yield tables for southeast Oklahoma, estimation of alternative harvesting and reproduction costs, and simulation to determine the availability of timber supply to attract new industry to the area. Research in the last area mentioned would greatly enhance the possiblity of assuring industry of available timber supplies and attract them to Oklahoma.

Areas of research mentioned here are needed for the State of Oklahoma to fully realize and develop the timber producing potential that is present. If the research needs mentioned in this section were achieved and the results utilized to make timber production more efficient, the State of Oklahoma could more fully utilize the timber producing potential available.

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APPENDIXES

APPENDIX A

RAW CISC DATA

TIAK DISTRICT BY CPO UNITS

CPO UNIT	WATER AREA	NON-FOR LAND	UNPRO-DUCTIVE	RESERVED	DEFERRED	STANDARD	SPECIAL	MARGINAL	TOTAL REGULATED	EXPER FOR	REC SITES	UN-INVEN	TOTAL UNREG	TOTAL COMPT
1	161	557	0	0	0	42099	180	95	42374	0	128	0	128	43220

CPO UNIT	IN REG	DAM POLE	DAM SWT	LITTLE LEAF	SP POLE	SP SWT	LOW POLE	LOW SWT	MAT POLE	MAT SWT	IMM POLE	IMM SWT	SEED ADQ	SEED INADE	NON STOCK	OTHER	TYPE	TOTAL
3	1576	0	0	0	0	0	0	0	0	1520	3605	5833	7568	101	85	0	Loblolly Pine	20288
4	1576	0	0	0	0	0	0	0	0	1520	3605	5833	7568	101	85	0	Loblolly Pine	20288

CPO UNIT	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	80+	UNCLASSED	TYPE	TOTAL
6	4255	7681	4034	2481	1740	4380	257	0	0	0	Age Class	25253

CPO UNIT	040	050	060	070	080	090	100	110	120	UNCLASSED	TYPE	TOTAL
7	0	0	0	200	8022	13041	3490	500	0	0	Site Index	25253

CPO UNIT	GROUP 1	GROUP 2	GROUP 3	GROUP 4	TYPE	TOTAL
8	18142	6911	200	0	Productivity Class	25253

APPENDIX B

TIMBER RAM OUTPUT

TIAK DISTRICT
LONG RANGE ECONOMIC POTENTIAL

OBJECTIVE: TNR34 - NET REVENUE OPTIMIZED THROUGH PERIOD 16 ; DISCOUNT RATES =0.080 (REVENUES) AND0.080 (COSTS)

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*                                *
*    TIMBER HARVEST SCHEDULE     *
*        PERIODS 1 - 10          *
*                                *
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ACTIVITY NAME / ACRES CUT — TOTAL VOLUME CUT - MMBF (VOLUME CUT / ACRE - MBF/AC)

ACTIVITY NAME ACRES CUT	1	2	3	4	5	6	7	8	9	10
E07,G, 1, 1 244.000	18.30* (75.00)						18.79* (77.00)			
E06,G, 2, 2 319.629		23.97* (75.00)						24.61* (77.00)		
E05,G, 2, 2 1740.000		133.98* (77.00)						133.98* (77.00)		
E04,G, 1, 1 1948.000	146.10* (75.00)						150.00* (77.00)			
E04,G, 2, 2 403.998		31.11* (77.00)						31.11* (77.00)		
E03,G, 3, 3 2823.624			217.42* (77.00)						217.42* (77.00)	
E02,G, 4, 4 3247.167				250.03* (77.00)						250.03* (77.00)
E02,G, 5, 5 3205.792					246.85* (77.00)					
E02,G, 6, 6 633.375						47.50* (75.00)				
E01,G, 6, 6 2108.000						162.32* (77.00)				
OVERSTORY REMOVAL CUTS										
ACRES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MMBF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
INTERMEDIATE CUTS										
ACRES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MMBF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HARVEST CUTS										
ACRES	2192.00	2463.63	2823.62	3247.17	3205.79	2741.38	2192.00	2463.63	2823.62	3247.17
MMBF	164.40	189.06	217.42	250.03	246.85	209.82	168.78	189.70	217.42	250.03
TOTAL CUTS										
ACRES	2192.00	2463.63	2823.62	3247.17	3205.79	2741.38	2192.00	2463.63	2823.62	3247.17
MMBF	164.40	189.06	217.42	250.03	246.85	209.82	168.78	189.70	217.42	250.03

+ = OVERSTORY REMOVAL CUT; * = HARVEST CUT

TIAK DISTRICT
LONG RANGE ECONOMIC POTENTIAL

OBJECTIVE' TNR34 - NET REVENUE OPTIMIZED THROUGH PERIOD 16 ; DISCOUNT RATES =0.080 (REVENUES) AND0.080 (COSTS)
TOTAL OBJECTIVE VALUE = 6057.56 (UNITS = $1000)

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*                        *
*    OBJECTIVE REPORT    *
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ACTIVITY NAME	ACRES CUT	OBJECTIVE VALUE (UNITS = $1000)	OBJECTIVE VALUE/ACRE (UNITS = $/ACRE)
E07,G, 1, 1	244.00	326.64	1338.68
E06,G, 2, 2	319.63	198.19	620.07
E05,G, 2, 2	1740.00	1108.21	636.90
E04,G, 1, 1	1948.00	2607.74	1338.68
E04,G, 2, 2	404.00	257.31	636.90
E03,G, 3, 3	2823.62	833.00	295.01
E02,G, 4, 4	3247.17	443.72	136.65
E02,G, 5, 5	3205.79	202.89	63.29
E02,G, 6, 6	633.38	18.08	28.54
E01,G, 6, 6	2108.00	61.80	29.32

TIAK DISTRICT
LONG RANGE ECONOMIC POTENTIAL

OBJECTIVE' TNR34 = NET REVENUE OPTIMIZED THROUGH PERIOD 16 ; DISCOUNT RATES =0.080 (REVENUES) AND0.080 (COSTS)
TOTAL OBJECTIVE VALUE = 6057.56 (UNITS = $1000)

LONG RANGE SUSTAINED YIELD AVERAGE = 213.98 MMBF/DECADE

AVERAGE OF POST-CONVERSION PERIODIC HARVESTS = 210.98 MMBF/DECADE

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*    HARVEST REPORT    *
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PERIOD	OVERSTORY REMOVAL CUTS			INTERMEDIATE CUTS			HARVEST CUTS			TOTAL CUTS		
	ACRES	MMBF		ACRES	MMBF		ACRES	MMBF		ACRES	MMBF	
		PERIODIC	TOTAL		PERIODIC	TOTAL		PERIODIC	TOTAL		PERIODIC	TOTAL
1	0.	0.0	0.0	0.	0.0	0.0	2192.	164.40	164.40	2192.	164.40	164.40
2	0.	0.0	0.0	0.	0.0	0.0	2464.	189.06	353.46	2464.	189.06	353.46
3	0.	0.0	0.0	0.	0.0	0.0	2824.	217.42	570.88	2824.	217.42	570.88
4	0.	0.0	0.0	0.	0.0	0.0	3247.	250.03	820.91	3247.	250.03	820.91
5	0.	0.0	0.0	0.	0.0	0.0	3206.	246.85	1067.76	3206.	246.85	1067.76
6	0.	0.0	0.0	0.	0.0	0.0	2741.	209.82	1277.58	2741.	209.82	1277.58
7	0.	0.0	0.0	0.	0.0	0.0	2192.	168.78	1446.36	2192.	168.78	1446.36
8	0.	0.0	0.0	0.	0.0	0.0	2464.	189.70	1636.06	2464.	189.70	1636.06
9	0.	0.0	0.0	0.	0.0	0.0	2824.	217.42	1853.48	2824.	217.42	1853.48
10	0.	0.0	0.0	0.	0.0	0.0	3247.	250.03	2103.51	3247.	250.03	2103.51
11	0.	0.0	0.0	0.	0.0	0.0	3206.	246.85	2350.36	3206.	246.85	2350.36
12	0.	0.0	0.0	0.	0.0	0.0	2741.	211.09	2561.44	2741.	211.09	2561.44
13	0.	0.0	0.0	0.	0.0	0.0	2192.	168.78	2730.23	2192.	168.78	2730.23
14	0.	0.0	0.0	0.	0.0	0.0	2464.	189.70	2919.92	2464.	189.70	2919.92
15	0.	0.0	0.0	0.	0.0	0.0	2824.	217.42	3137.34	2824.	217.42	3137.34
16	0.	0.0	0.0	0.	0.0	0.0	3247.	250.03	3387.38	3247.	250.03	3387.38

TIAK DISTRICT
LONG RANGE ECONOMIC POTENTIAL

OBJECTIVE' TNR34 = NET REVENUE OPTIMIZED THROUGH PERIOD 16 ; DISCOUNT RATES =0,080 (REVENUES) AND0,080 (COSTS)
TOTAL OBJECTIVE VALUE = 6057,56 (UNITS = $1000)

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*                        *
*    ECONOMIC REPORT     *
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(UNITS = $1000)

	DISCOUNT RATES		GROSS REVENUE 1		GROSS REVENUE 2		COSTS		NET REVENUE	
PERIOD	REVENUES	COSTS	PERIODIC	TOTAL	PERIODIC	TOTAL	PERIODIC	TOTAL	PERIODIC	TOTAL
1	0.0	0.0	8384,39	8384,39	8384,39	8384,39	4116,57	4116,57	4267,82	4267,82
	0.060	0.060	6265,33	6265,33	6265,33	6265,33	3076,15	3076,15	3189,18	3189,18
	0.080	0.080	5706,29	5706,29	5706,29	5706,29	2801,68	2801,68	2904,62	2904,62
	0.100	0.100	5206,07	5206,07	5206,07	5206,07	2556,08	2556,08	2649,99	2649,99
	0.120	0.120	4757,54	4757,54	4757,54	4757,54	2335,86	2335,86	2421,68	2421,68
2	0.0	0.0	9642,06	18026,45	9642,06	18026,45	4730,89	8847,46	4911,17	9179,00
	0.060	0.060	4023,35	10288,68	4023,35	10288,68	1974,06	5050,21	2049,29	5238,46
	0.080	0.080	3039,60	8745,89	3039,60	8745,89	1491,38	4293,06	1548,22	4452,83
	0.100	0.100	2308,26	7514,33	2308,26	7514,33	1132,55	3688,63	1175,71	3825,70
	0.120	0.120	1761,58	6519,11	1761,58	6519,11	864,32	3200,18	897,26	3318,94
3	0.0	0.0	11088,37	29114,82	11088,37	29114,82	5439,99	14287,45	5648,38	14827,38
	0.060	0.060	2583,63	12872,30	2583,63	12872,30	1267,54	6317,75	1316,09	6554,55
	0.080	0.080	1619,12	10365,02	1619,12	10365,02	794,35	5087,40	824,78	5277,61
	0.100	0.100	1023,43	8537,76	1023,43	8537,76	502,10	4190,73	521,33	4347,04
	0.120	0.120	652,26	7171,37	652,26	7171,37	320,00	3520,18	332,26	3651,19
4	0.0	0.0	12751,63	41866,45	12751,63	41866,45	6255,99	20543,43	6495,64	21323,01
	0.060	0.060	1659,10	14531,41	1659,10	14531,41	813,96	7131,71	845,14	7399,70
	0.080	0.080	862,47	11227,48	862,47	11227,48	423,13	5510,53	439,34	5716,94
	0.100	0.100	453,77	8991,52	453,77	8991,52	222,62	4413,34	231,15	4578,18
	0.120	0.120	241,51	7412,88	241,51	7412,88	118,49	3638,66	123,03	3774,22
5	0.0	0.0	12589,14	54455,59	12589,14	54455,59	6176,27	26719,71	6412,87	27735,88
	0.060	0.060	914,64	15446,04	914,64	15446,04	448,72	7580,43	465,91	7865,61
	0.080	0.080	394,40	11621,88	394,40	11621,88	193,49	5704,02	200,91	5917,85
	0.100	0.100	172,72	9164,24	172,72	9164,24	84,74	4498,08	87,98	4666,16
	0.120	0.120	76,77	7489,65	76,77	7489,65	37,66	3676,33	39,11	3813,33
6	0.0	0.0	10700,77	65156,36	10700,77	65156,36	5250,75	31970,45	5450,03	33185,91
	0.060	0.060	434,12	15880,16	434,12	15880,16	213,02	7793,45	221,10	8086,71
	0.080	0.080	155,28	11777,16	155,28	11777,16	76,20	5780,21	79,09	5996,93
	0.100	0.100	56,60	9220,84	56,60	9220,84	27,77	4525,85	28,83	4694,99
	0.120	0.120	21,01	7510,66	21,01	7510,66	10,31	3686,64	10,70	3824,03
7	0.0	0.0	8607,98	73764,31	8607,98	73764,31	4223,10	36193,55	4384,88	37570,79
	0.060	0.060	195,00	16075,17	195,00	16075,17	95,67	7889,11	99,33	8186,04
	0.080	0.080	57,86	11835,02	57,86	11835,02	28,39	5808,59	29,47	6026,41
	0.100	0.100	17,55	9238,40	17,55	9238,40	8,61	4534,46	8,94	4703,93
	0.120	0.120	5,44	7516,10	5,44	7516,10	2,67	3689,31	2,77	3826,80

APPENDIX C

ECHO OUTPUT

ECHO HARVEST, NET CASH FLOW, AND PRESENT VALUE REPORT
WITH NO PRICE DISCRIMINATION

TIME	XT	XA	XB	PA	PB	ACRES REGEN	REGEN COST	FIXED COST	LOGGING COST	NET CASH FLOW	1/(1+I)**T	DISCOUNTED NCF
0	93135.	93321.	0.	44,446	44,446	0,0	0.	43093.	2262453.	1833967.	1,0000	1833967.
1	92300.	92484.	0.	44,586	44,586	1207,6	65341.	43093.	2242155.	1764675.	0,9259	1633958.
2	90992.	91174.	0.	44,804	44,804	1183,6	64043.	43093.	2210388.	1759298.	0,8573	1508314.
3	89559.	89738.	0.	45,044	45,044	1174,7	63566.	43093.	2175583.	1751816.	0,7938	1390648.
4	88109.	88285.	0.	45,286	45,286	1155,9	62545.	43093.	2140326.	1744105.	0,7350	1281969.
5	86526.	86699.	0.	45,550	45,550	1096,1	59310.	43093.	2101878.	1736978.	0,6806	1182158.
6	84960.	85130.	0.	45,812	45,812	1083,9	58650.	43093.	2063875.	1726542.	0,6302	1088014.
7	83491.	83658.	0.	46,057	46,057	1110,9	60108.	43093.	2028214.	1713937.	0,5835	1000066.
8	81896.	82060.	0.	46,323	46,323	1122,0	60713.	43093.	1989448.	1700436.	0,5403	918693.
9	80162.	80323.	0.	46,613	46,613	1087,5	58843.	43093.	1947335.	1687329.	0,5002	844085.
10	78683.	78840.	0.	46,860	46,860	1057,7	57233.	43093.	1911475.	1675277.	0,4632	775978.
11	77067.	77222.	0.	47,130	47,130	1193,9	64604.	43093.	1872216.	1652252.	0,4289	708623.
12	75306.	75457.	0.	47,424	47,424	1144,0	61903.	43093.	1829413.	1636890.	0,3971	650032.
13	73388.	73535.	0.	47,744	47,744	1095,5	59276.	43093.	1782805.	1618666.	0,3677	595180.
14	71301.	71443.	0.	48,093	48,093	1047,8	56698.	43093.	1732096.	1597159.	0,3405	543771.
15	69031.	69169.	0.	48,472	48,472	1000,7	54148.	43093.	1676958.	1571868.	0,3152	495519.
16	66565.	66698.	0.	48,884	48,884	953,7	51604.	43093.	1617041.	1542191.	0,2919	450151.
17	64619.	64748.	0.	49,209	49,209	928,3	50232.	43093.	1569834.	1516633.	0,2703	409899.
18	62475.	62600.	0.	49,567	49,567	1059,5	57330.	43093.	1517758.	1478499.	0,2502	369993.
19	61751.	61875.	0.	49,688	49,688	1027,7	55609.	43093.	1500274.	1469276.	0,2317	340449.
20	60751.	60873.	0.	49,855	49,855	1409,4	76265.	43093.	1475983.	1433389.	0,2145	307531.
21	59730.	59849.	0.	50,025	50,025	1352,5	73185.	43093.	1451169.	1420548.	0,1987	282200.
22	58686.	58804.	0.	50,199	50,199	1337,4	72369.	43093.	1425809.	1404734.	0,1839	258387.
23	57619.	57734.	0.	50,378	50,378	1322,4	71553.	43093.	1399890.	1388180.	0,1703	236428.
24	56605.	56718.	0.	50,547	50,547	1306,4	70689.	43093.	1375245.	1372170.	0,1577	216390.
25	56151.	56263.	0.	50,623	50,623	1303,8	70551.	43093.	1364218.	1364645.	0,1460	199262.
26	55324.	55435.	0.	50,761	50,761	1306,8	70714.	43093.	1344140.	1350356.	0,1352	182570.
27	54484.	54593.	0.	50,901	50,901	1299,1	70295.	43093.	1323735.	1336186.	0,1252	167273.
28	53631.	53738.	0.	51,044	51,044	1289,9	69794.	43093.	1303001.	1321621.	0,1159	153194.
29	52763.	52869.	0.	51,189	51,189	1281,9	69361.	43093.	1281931.	1306496.	0,1073	140223.
30	51685.	51789.	0.	51,369	51,369	1275,0	68988.	43093.	1255741.	1287181.	0,0994	127916.
31	51522.	51625.	0.	51,396	51,396	1261,5	68260.	43093.	1251764.	1284882.	0,0920	118230.
32	50994.	51096.	0.	51,484	51,484	1268,8	68657.	43093.	1238937.	1274668.	0,0852	108602.
33	50460.	50561.	0.	51,573	51,573	1270,6	68751.	43093.	1225987.	1264570.	0,0789	99760.
34	49922.	50022.	0.	51,663	51,663	1275,6	69023.	43093.	1212918.	1254101.	0,0730	91606.
35	49829.	49928.	0.	51,679	51,679	1299,1	70294.	43093.	1210648.	1251042.	0,0676	84613.
36	49735.	49835.	0.	51,694	51,694	1327,6	71836.	43093.	1208374.	1247707.	0,0626	78137.
37	49641.	49740.	0.	51,710	51,710	1348,4	72963.	43093.	1206092.	1244787.	0,0580	72180.
38	49547.	49646.	0.	51,726	51,726	1341,0	72563.	43093.	1203807.	1243387.	0,0537	66758.
39	49453.	49552.	0.	51,741	51,741	1337,5	72372.	43093.	1201517.	1241771.	0,0497	61732.
40	49358.	49457.	0.	51,757	51,757	1334,9	72229.	43093.	1199224.	1240102.	0,0460	57083.
41	49264.	49362.	0.	51,773	51,773	1333,2	72139.	43093.	1196928.	1238375.	0,0426	52781.
42	49169.	49268.	0.	51,789	51,789	1332,6	72110.	43093.	1194628.	1236579.	0,0395	48800.
43	49074.	49173.	0.	51,805	51,805	1332,3	72088.	43093.	1192323.	1234770.	0,0365	45119.
44	48979.	49077.	0.	51,820	51,820	1331,6	72052.	43093.	1190017.	1232970.	0,0338	41716.
45	48884.	48982.	0.	51,836	51,836	1331,5	72046.	43093.	1187704.	1231134.	0,0313	38569.
46	48789.	48887.	0.	51,852	51,852	1332,1	72078.	43093.	1185389.	1229253.	0,0290	35657.
47	48693.	48791.	0.	51,868	51,868	1333,3	72146.	43093.	1183070.	1227328.	0,0269	32964.
48	48598.	48695.	0.	51,884	51,884	1335,2	72248.	43093.	1180749.	1225366.	0,0249	30474.
49	48502.	48599.	0.	51,900	51,900	1338,3	72416.	43093.	1178423.	1223332.	0,0230	28169.
50	48406.	48503.	0.	51,916	51,916	1341,1	72565.	43093.	1176091.	1221309.	0,0213	26040.
51	48310.	48407.	0.	51,932	51,932	1343,9	72718.	43093.	1173758.	1219276.	0,0197	24071.
52	48214.	48310.	0.	51,948	51,948	1346,5	72861.	43093.	1171420.	1217248.	0,0183	22251.
53	48117.	48214.	0.	51,964	51,964	1347,6	72916.	43093.	1169079.	1215301.	0,0169	20569.
54	48021.	48117.	0.	51,981	51,981	1346,4	72855.	43093.	1166732.	1213466.	0,0157	19017.
55	47570.	47665.	0.	52,056	52,056	1343,6	72702.	43093.	1155785.	1204723.	0,0145	17482.
56	47833.	47929.	0.	52,012	52,012	1331,1	72027.	43093.	1162165.	1210591.	0,0134	16265.
57	47736.	47831.	0.	52,028	52,028	1338,0	72400.	43093.	1159806.	1208302.	0,0124	15032.
58	47639.	47734.	0.	52,044	52,044	1335,9	72266.	43093.	1157445.	1206514.	0,0115	13898.
59	47463.	47558.	0.	52,074	52,074	1335,0	72129.	43093.	1153178.	1203169.	0,0107	12853.
60	47725.	47821.	0.	52,030	52,030	1328,1	71864.	43093.	1159553.	1208631.	0,0099	11956.
61	47628.	47723.	0.	52,046	52,046	1335,1	72244.	43093.	1157191.	1206329.	0,0091	11031.
62	47504.	47599.	0.	52,067	52,067	1332,7	72115.	43093.	1154183.	1204004.	0,0085	10194.
63	47767.	47862.	0.	52,023	52,023	1329,3	71927.	43093.	1160560.	1209387.	0,0078	9481.
64	47634.	47729.	0.	52,045	52,045	1336,5	72320.	43093.	1157336.	1206370.	0,0073	8757.
65	47897.	47993.	0.	52,001	52,001	1332,9	72124.	43093.	1163717.	1211756.	0,0067	8145.
66	47835.	47931.	0.	52,011	52,011	1340,2	72519.	43093.	1162228.	1210149.	0,0062	7531.
67	48098.	48195.	0.	51,968	51,968	1338,5	72428.	43093.	1168616.	1215417.	0,0058	7004.
68	47915.	48011.	0.	51,998	51,998	1345,8	72819.	43093.	1164161.	1211418.	0,0053	6464.
69	48178.	48275.	0.	51,954	51,954	1340,8	72549.	43093.	1170553.	1216860.	0,0049	6012.
70	48082.	48178.	0.	51,970	51,970	1347,7	72923.	43093.	1168208.	1214592.	0,0046	5556.
71	47985.	48081.	0.	51,987	51,987	1345,0	72777.	43093.	1165861.	1212838.	0,0042	5137.
72	47888.	47984.	0.	52,003	52,003	1342,2	72625.	43093.	1163509.	1211083.	0,0039	4750.
73	47566.	47661.	0.	52,057	52,057	1339,4	72472.	43093.	1155672.	1204862.	0,0036	4375.
74	47828.	47924.	0.	52,013	52,013	1331,0	72019.	43093.	1162051.	1210506.	0,0034	4070.
75	47731.	47827.	0.	52,029	52,029	1337,8	72387.	43093.	1159694.	1208224.	0,0031	3762.
76	47634.	47729.	0.	52,045	52,045	1335,2	72249.	43093.	1157330.	1206439.	0,0029	3478.
77	47456.	47551.	0.	52,075	52,075	1332,8	72120.	43093.	1153019.	1203049.	0,0027	3211.
78	47719.	47814.	0.	52,031	52,031	1327,9	71855.	43093.	1159393.	1208511.	0,0025	2987.
79	47622.	47717.	0.	52,047	52,047	1334,9	72229.	43093.	1157032.	1206214.	0,0023	2760.
80	47577.	47672.	0.	52,055	52,055	1332,3	72091.	43093.	1155951.	1205470.	0,0021	2554.
81	47840.	47935.	0.	52,011	52,011	1331,3	72037.	43093.	1162330.	1210716.	0,0020	2375.
82	47734.	47829.	0.	52,028	52,028	1338,2	72412.	43093.	1159759.	1208251.	0,0018	2195.
83	47997.	48093.	0.	51,985	51,985	1335,7	72274.	43093.	1166145.	1213570.	0,0017	2041.
84	47891.	47987.	0.	52,002	52,002	1342,7	72653.	43093.	1163581.	1211115.	0,0016	1886.
85	48154.	48251.	0.	51,958	51,958	1340,1	72511.	43093.	1169973.	1216430.	0,0014	1754.
86	47843.	47939.	0.	52,010	52,010	1347,0	72886.	43093.	1162423.	1209942.	0,0013	1616.
87	48106.	48203.	0.	51,966	51,966	1338,8	72441.	43093.	1168813.	1215562.	0,0012	1503.
88	48010.	48106.	0.	51,982	51,982	1345,4	72802.	43093.	1166467.	1213504.	0,0011	1389.
89	47913.	48009.	0.	51,999	51,999	1342,8	72657.	43093.	1164116.	1211544.	0,0011	1284.
90	47816.	47912.	0.	52,015	52,015	1340,1	72513.	43093.	1161761.	1209777.	0,0010	1187.
91	47562.	47657.	0.	52,057	52,057	1337,5	72370.	43093.	1155588.	1204896.	0,0009	1095.
92	47825.	47920.	0.	52,013	52,013	1330,9	72012.	43093.	1161967.	1210446.	0,0008	1018.
93	47728.	47823.	0.	52,029	52,029	1337,7	72381.	43093.	1159609.	1208160.	0,0008	941.
94	47630.	47726.	0.	52,046	52,046	1335,1	72244.	43093.	1157247.	1206376.	0,0007	870.
95	47462.	47557.	0.	52,074	52,074	1332,8	72116.	43093.	1153148.	1203158.	0,0007	804.
96	47724.	47820.	0.	52,030	52,030	1328,1	71863.	43093.	1159524.	1208609.	0,0006	747.
97	47627.	47722.	0.	52,046	52,046	1335,1	72240.	43093.	1157161.	1206308.	0,0006	691.
98	47668.	47764.	0.	52,039	52,039	1332,6	72105.	43093.	1158170.	1207265.	0,0005	640.
99	47931.	48027.	0.	51,995	51,995	1333,8	72173.	43093.	1164552.	1212384.	0,0005	595.
END VALUE										14682446.	0,0005	7208.

STAND STRUCTURE

AGE CLASS	ACRES T = 0	ACRES T = 100
0	2102.00	1340.83
1	0.0	1333.82
2	0.0	1332.56
3	0.0	1335.06
4	0.0	1328.08
5	0.0	1332.77
6	0.0	1335.13
7	0.0	1337.66
8	0.0	1330.85
9	0.0	1337.46
10	2108.00	1340.11
11	0.0	1342.77
12	0.0	1345.44
13	0.0	1338.77
14	0.0	1346.99
15	0.0	1340.07
16	0.0	1342.64
17	0.0	0.0
18	0.0	0.0
19	0.0	0.0
20	7282.00	0.0
21	0.0	0.0
22	0.0	0.0
23	0.0	0.0
24	0.0	0.0
25	0.0	0.0
26	0.0	0.0
27	0.0	0.0
28	0.0	0.0
29	0.0	0.0
30	3824.00	0.0
31	0.0	0.0
32	0.0	0.0
33	0.0	0.0
34	0.0	0.0
35	0.0	0.0
36	0.0	0.0
37	0.0	0.0
38	0.0	0.0
39	0.0	0.0
40	1152.00	0.0
41	0.0	0.0
42	0.0	0.0
43	0.0	0.0
44	0.0	0.0
45	0.0	0.0
46	0.0	0.0
47	0.0	0.0
48	0.0	0.0
49	0.0	0.0
50	1740.00	0.0
51	0.0	0.0
52	0.0	0.0
53	0.0	0.0
54	0.0	0.0
55	0.0	0.0
56	0.0	0.0
57	0.0	0.0
58	0.0	0.0
59	0.0	0.0
60	4289.00	0.0
61	0.0	0.0
62	0.0	0.0
63	0.0	0.0
64	0.0	0.0
65	0.0	0.0
66	0.0	0.0
67	0.0	0.0
68	0.0	0.0
69	0.0	0.0
70	244.00	0.0

APPENDIX D

U.S.F.S. RAW HARVESTING COST DATA

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
OUACHITA NATIONAL FOREST
P. O. BOX 1270
HOT SPRINGS, ARKANSAS 71901

ABSTRACT OF BIDS DATE: February 24, 1976

COMPARTMENT: 27

RANGER DISTRICT: Tiak

Sealed bids were opened at 2 P.M., February 24, 1976, for timber on the above compariment as follows:

	TOTAL LUMP-SUM BID
*Fry Forest Products	$133,911.14
Reynolds-Wilson	129.229.59
Huffman Tbr. Co.	111,727.00
Clouse Sawmill	106,457.83

*Sight Draft drawn against Irrevocable Letter of Credit No. 12 deposited First National Bank of Hot Springs, Hot Springs, Arkansas.

The high bidder's guarantee ($2,200.00) was deposited and all other checks were returned at bid opening or by certified mail.

DONALD W. WOODS

Timber Sale Administrator

cc: Tiak

APPRAISAL REPORT SUMMARY

1. Ranger District Tiak Sale Area 1536 Acres
   Compartment(s) 27' Operable Area 267' Acres
   Location McCurtain County(s) (Arkansas) (Oklahoma)
   Section(s) ______ Township 85' Range 27E'

2. Products:

	No. of Trees	Unit	Volume	Rate Per Unit	Total Value
Pine Sawtimber	6,692'	MBF	1,224'	77.26'	94,566.24'
Pine Roundwood	5,518'	CCF	240'	6.35'	1,524.60'
Conv. Factor 1.541'					
Pine Topwood		CCF	218'	4.70'	188.00'OPT.
Hwd. Roundwood	8,488'	CCF	515'	4.47'	2,554.55'
Conv. Factor 1.464'					
White Oak		MBF			
Mixed Hardwoods	1,639'	MBF	137'	9.02'	1,235.74'

TOTAL SALE VALUE

3. K. V. Collection Plan $22,341.
4. Road Maintenance $ 1,280.
5. Specified Road $44,223. No. T-27A Name: Caney Creek Mi. 1.4
6. Erosion Control $608 (District Cost)
7. S.B.A. (Yes) X (No) ______
8. Diposit with Bid $2200.00'
9. Termination Date April 31,1979 (Operating Months 637'
10. Advertising Period 30 days in Hot Springs Paper
11. Prepared and Recommended by: L. E. Brossy (Date) 12/30/75

This sale is prepared in accordance with an approved prescription and/or current forest Policy.

L.E. Brossy (Signature) (Acting) District Ranger 12/30/75 (Date)

12. Forest Approval by: ______ ______

______ (Signature) Acting Forest Supervisor ______ (Date)

Oua 2400-7 (Rev. 12/73)

APPENDIX E

TIAK SALE DATA

TREE AND VOLUME SUMMARY BY PAYMENT UNIT

			TREES (Estimated)				VOLUME (Estimated)				
UNIT	Approx. Acres	Color Paint	Pine Swt.	Mixed Hdw. Swt.	Pine Rdwd.	Hdw. Rdw.	Pine Swt. MBF	Mixed Hdw. Swt. MBF	Pine Rdwd. CCF	Hdw. Rdwd. CCF	Pine Topwd CCF
1	11	White	367	90	365	259	70	8	14	19	14
2	70	Orange	2,091	450	2,002	3,286	272	42	90	175	81
3	53	Orange	1,027	329			155	28			40
4	53	Yellow	2,752	92	3,051	432	551	8	130	23	106
5	42	Blue	336	264	72	2,258	124	19	4	153	13
6	38	Blue	119	414	28	2,253	52	32	2	145	4

TREE AND VOLUME SUMMARY BY PAYMENT UNIT

			TREES (Estimated)				VOLUME (Estimated)				
UNIT	Approx. Acres	Color Paint	Pine Swt.	Hdw. Swt.	Pine Rdwd.	Hdw. Rdw.	Pine Swt. MBF	Hdw. Swt. MBF	Pine Rdwd. CCF	Hdw. Rdwd. CCF	Pine Topwd. CCF
1	9	White	699	58	380	360	136	3	17	18	30
2	46	Yellow	1,465	196			318	12			64
3	88	White			7,520				243		
4	83	Blue	400				53				17
5	51	Yellow	1,946	104	1,300	780	429	7	55	46	84
6	74	Orange	818				103				36
7	44	Yellow	1,324	301	1,180	1080	286	19	54	52	58
8	20	White			1,654				110		
9	59	Yellow	3,296	254	1,400	1100	675	17	61	63	144
10	41	Blue	242				24				9
11	63	Yellow	2,974	412	2,040	2693	638	27	76	157	130
12	64	Blue	373				37				16
13	94	White	398				40				16
14	56	Orange	3,247	333	2,380	1900	625	22	106	106	142

AT5b-For Species and Products to be Paid for at Flat Rates

Species and Product	Unit of Measure	RATES PER UNIT OF MEASURE				
		Base $	Advertised $	Bid Premium $	Bid (Flat) $	Required Deposits Slash Disposal $
Pine Sawtimber	15,769 Trees					
Pine Small Roundwood	17,854 Trees					
Topwood						
Mixed Hardwood Swt.	1,698 Trees					
Mixed Harwood Bdwd.	7,913 Trees					
Pine Sawtimber (Opt.)	1,413 Trees					
Topwood (Opt.)						
Total Lump Sum	44,607	12,173	164,930.58	98,849.42	263,700.00	

The purchaser and the Forest Service agree that the total merchantable timber designated to be cut is a total of 43,194 sawtimber and small roundwood trees, more or less, and 1,413 optional sawtimber trees more or less: Provided that the Forest Service may designate additional trees for cutting, if necessary because of clearing of roads or for other reasons at the following rates for stumpage:

Pine Sawtimber	MBF	72.64
Pine Roundwood	CCF	10.64
Topwood	CCF	18.64
Mixed Hardwood Swt.	MBF	66.83
Mixed Hardwood Rdwd.	CCF	1.97

For purposes of convenience in collection and bookkeeping, Bid Rates stated in AT5 include payment of deposits for sale area betterment required pursuant to 16 U.S.C. 576b. Such deposits are not included as Required Deposits defined hereunder.

TREE AND VOLUME SUMMARY BY PAYMENT UNIT

			TREES (Estimated)				VOLUME (Estimated)				
UNIT	Approx. Acres	Color Paint	Pine Swt.	Mixed Hdw. Swt.	Pine Rdwd.	Hdw. Rdw.	Pine Swt. MBF	Mixed Hdw. Swt. MBF	Pine Rdwd. CCF	Hdw. Rdwd. CCF	Pine Topwd. CCF
1	8	WHITE	647	27	630	220	142	2	17	13	26
2	70	YELLOW	3,663	157	5,190	1,374	751	14	200	82	149
3	70	YELLOW	3,368	170	7,350	1,027	619	14	337	55	137
4	50	YELLOW	2,893	42	2,730	575	552	3	98	31	118
5	40	BLUE	414	518	171	1,514	128	55	9	109	17

AT5b-For Species and Products to be Paid for at Flat Rates

Species and Product	Unit of Measure	RATES PER UNIT OF MEASURE				
		Base $	Advertised $	Bid Premium $	Bid (Flat) $	Required Deposits Slash Disposal $
Pine Sawtimber	10,095 Trees					
Pine Topwood						
Pine Small Roundwood	16,071 Trees					
Mixed Hardwood Swt.	914 Trees					
Hardwood Roundwood	4,710 Trees					
Total Lump Sum	32,680 Trees	8.208	132,449.56	9,3430.45	225,800.01	

The Purchaser and the Forest Service agrees that the total merchantable timber designated to be cut is a total of 32,680 sawtimber and small roundwood trees, more or less: Provided that the Forest Service may designate additional trees for cutting, if necessary because of clearing for roads or for other reasons at the following rates for stumpage:

Pine Sawtimber	MBF	96.39
Mixed Hardwood Swt.	MBF	15.25
Pine Roundwood	CCF	11.25
Pine Topwood	CCF	11.26
Hardwood-Roundwood	CCF	2.69

For purposes of convenience in collection and bookkeeping, Bid Rates stated in AT5 include payment of deposits for sale area betterment required pursuant to 16 U.S.C. 576b. Such deposits are not included as Required Deposits defined hereunder.

TREE AND VOLUME SUMMARY BY PAYMENT UNIT

UNIT	Approx. Acres	Color Paint	TREES (Estimated) Pine Swt.	Mixed Hdw. Swt.	Pine Rdwd.	Hdw. Rdw.	VOLUME (Estimated) Pine Swt. MBF	Mixed Hdw. Swt. MBF	Pine Rdwd. CCF	Hdw. Rdwd. CCF	Pine Topwd. CCF
1	50	YELLOW	400	104			108	8			

AT5b-For Species and Products to be Paid for at Flat Rates

Species and Product	Unit of Measure	RATES PER UNIT OF MEASURE				
		Base $	Advertised $	Bid Premium $	Bid (Flat) $	Required Deposits Slash Disposal $
Pine Sawtimber	400 Trees					
Mixed Hardwood	104 Trees					
Total Lump Sum	504 Trees	348	$8,403.40	276.60	8,600.00	

The purchaser and the Forest Service agrees that the total merchantable timber designated to be cut is a total of 504 sawtimber times, more or less: Provided that the Forest Service may designate additional trees for cutting, if necessary because of clearing for roads or for other reasons at the following rates for stumpage:

Pine Sawtimber	MBF	79.67
Mixed Hardwood	MBF	9.67

For purposes of convenience in collection and bookkeeping, Bid Rates stated in AT5 include payment of deposits for sale area betterment required pursuant to 16 U.S.C. 576b. Such deposits are not included as required Deposits defined hereunder.

VITA 2

Philip Lance Tedder

Candidate for the Degree of

Doctor of Philosophy

Thesis: AN EVALUATION OF FOREST MANAGEMENT ALTERNATIVES IN SOUTHEAST OKLAHOMA UNDER DIFFERING ECONOMIC AND SILVICULTURAL ASSUMPTIONS

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Lawton, Oklahoma, October 30, 1947, the son of Mr. and Mrs. Dow Tedder.

Education: Graduated from Lawton High School, Lawton, Oklahoma, in May, 1965; received Bachelor of Science degree in Forest Management from Oklahoma State University in 1969: received Master of Science degree in Forest Resources Management from Oklahoma State University in July, 1973; completed requirements for the Doctor of Philosophy degree at Oklahoma State University in December, 1976.

Professional Experience: Commissioned Officer in the United States Marine Corps, 1969-1972; graduate assistant, Oklahoma State University, Department of Forestry, 1972-1974; Chief of Administration, Division of Forestry, Oklahoma Department of Agriculture, State of Oklahoma, 1974-1975; graduate assistant, Oklahoma State University, Department of Agricultural Economics, 1975-1976.