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CLASSIFYING FOREST LAND BASED UPON ITS
TIMBER MANAGEMENT INVESTMENT POTENTIAL:
A CASE STUDY OF THE LOLO NATIONAL FOREST

by

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B.S., Oregon State University, 1969

Presented in partial fulfillment of the requirements
for the degree of

Master of Science Forestry

UNIVERSITY OF MONTANA

1979

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ABSTRACT

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Classifying forest land based upon its timber management investment potential: a case study of the Lolo National Forest (146 pp.)

Director: David H. Jackson

In this study of the Lolo National Forest, commercial forest land is classified according to its land expectation value, under a variety of management regimes. Rankings of land classes are made using discount rates of 3.5, 5.0, and 6.5 per cent. Factors affecting either timber management costs or revenues, such as slope, habitat type, and the species mix grown on a site, form the basis for these rankings.

Statistical models, which use site and policy factors to predict management costs, were developed. Jackson and McQuillan's (1979) stumpage valuation model is used to predict the current value of stumpage. Future stumpage values are predicted using cost, price, and overrun projections developed by Adams and Haynes (1979) for the 1980 R.P.A. assessment.

The results provide a rational basis for the economic delineation of commercial forest land, and can also be used to increase the efficiency of current management.

ACKNOWLEDGMENTS

This study could not have been accomplished without the encouragement and advice provided me by my committee chairman, Dr. David Jackson and my associate, Alan McQuillan. I am also indebted to these two individuals for their stumpage valuation and supply models, which complement this thesis.

A special note of thanks is extended to Dr. Enoch Bell, who was instrumental in formulating the study plan, directing the study, and providing me with financial assistance and to the members of my committee: Dr. Arnold Bolle, Dr. George Blake, Dr. Thomas Power, and Dr. Robert Ream.

Likewise, I thank the Lolo Forest Supervisor, Orville Daniels, and the forest and district level staff, for the assistance and encouragement they have given me.

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Chapter 1

INTRODUCTION

Critics of the Forest Service have charged that much of the forest land classified as commercial is not economically amenable to intensive stand management (Behan, 1977; Clawson, 1976). The lower productivity limit used to delineate commercial forest land is 20 cubic feet of wood per acre per year. This minimum was set administratively and is a reflection of biological, not economic, potential. This definition also fails to account for other factors which determine whether land is commercial such as timber type, accessibility, and geographic location. Vaux's calculations (1973), based on a minimum acceptable rate of return of 5 per cent, suggest that 39 per cent of California's commercial forest land cannot produce timber economically. Bennett's study (1973) indicates that a much larger portion of Montana's Bitterroot National Forest may be economically noncommercial.

Regardless of such studies, Forest Service personnel have acted as through the terms "commercial" and "economic" were synonymous. Clawson (1976) determined that the agency has made roughly equivalent per acre expenditures forest by forest and region by region irrespective of significant differences in site productivity. Since the Forest Service's budget is limited, this has resulted in the economically inefficient use of capital. The Forest Service could provide significantly greater outputs of both commodity and amenity resources if funds were spent on an economically prioritized basis (Clawson, 1976).

Behan (1977) stated that "to make the most of a productive situation, we need to make the least abundant resource work the hardest." In the case of the National Forests he felt that the least abundant resource is capital. The traditional Forest Service goal of maximizing biological potential on all commercial lands treats land as the scarce factor of production (Behan, 1977). Behan explained that this has resulted in the "economically irrational" allocation of dollars described by Clawson.

Two major governmental research teams have formed conclusions which parallel those of the above authors. Recommendation 30 of the Public Land Law Review Commission (1970) is that "Dominant timber production units should be managed primarily on the basis of economic factors so as to maximize net returns to the federal treasury...". A similar recommendation was contained in the Report of the President's Advisory Panel on Timber and the Environment (1973 : 55), namely "that the Forest Service reconsider its timber management priorities, in order to concentrate more of its efforts, manpower, and funds on intensive management of its more productive sites."

Long range planning of the nation's renewable resources was provided for with enactment of the Forest and Rangelands Renewable Resources Planning Act of 1974 (RPA). One of the major congressional intents of RPA was to improve the accountability of Forest Service expenditures and activities (Hyde, 1976). In 1976, Congress amended RPA with passage of the National Forest Management Act. Throughout the amended RPA are numerous references to supply and demand, the measurement of costs and benefits, and the accountability of government expenditures. The use of these terms clearly indicate that economic efficiency is a concern of Congress (Walker, 1977). Furthermore, section 6(k) of the act requires the Secretary of Agriculture to "identify lands which are not suited for timber production." This is to be accomplished by considering "physical, economic, and other pertinent factors to the extent feasible."

The biological definition of commercial forest land is not responsive to the needs of today's forest manager. A dynamic forest land classification system, based at least in part on economics, is urgently needed. The aim of this study is to develop a practical method of classifying forest land according to its economic investment potential. For the sake of simplicity, only the costs and revenues of second-growth management will be evaluated.

Although this is a case study of the Lolo National Forest, the methods devised could be modified and applied elsewhere.

Chapter 2

STUDY OVERVIEW

Objective

The objective of this analysis is to develop a practical method of classifying commercial forest land, based on site factors which affect timber management costs and revenues. The analysis utilizes management regimes that are specified in the Lolo National Forest Timber Management Plan, to determine the combination of regime and rotation length that is economically optimal for each defined land unit.

Determination of Costs and Revenues

In order to determine the costs and revenues resulting from second-growth timber management, estimates of projected stumpage values, yields, and management costs must be made.

Stumpage Value Determination

Using Lolo National Forest data, Jackson and McQuillan (1979) developed a regression model which predicts stumpage value as a function of: 1) tree d.b.h.; 2) harvested volume/acre; 3) logging method; 4) harvest method; and 5)lumber selling price.

Projections of real increases in production (logging and milling) costs, lumber prices, and milling efficiency for the Northern Rocky Mountain region, have been made by Adams and Haynes (1979).[1] In this study

[1]These projections were made for the 1980 RPA assessment.

expected stumpage values have been estimated using these projections and Jackson's and McQuillan's model.

Yield Determinations

Managed stand yield tables have been developed by Lolo forest personnel for three different habitat type groupings. These tables were modified for this study to show the expected relationship between stand age and average tree d.b.h. Information of these yield tables and associated habitat groupings is contained in appendices A.1 and A.2.

Management Cost Determinations

The timber management activities on the Lolo forest which can be viewed as long-term investments are site preparation, planting, and precommercial thinning. Regression analysis was used to determine the site and policy variables which affect the direct (contractual) cost of planting and precommercial thinning.[2] The additional prorated cost incurred on each site as a consequence of planting failures was also determined. Site preparation costs and contract preparation, administration, and material costs were determined from project records and from estimates made by personnel working on the forest.

Annual administrative costs (e.g. protection and road maintenance costs) were determined from forest budget records. Care was taken to seperate out those costs not chargeable to timber management.

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[2] In this study variables affecting costs or revenues, which are not site specific (e.g. trees per acre planted, contract size, harvest method, etc.) are referred to as "policy variables."

Timber sale preparation and administrative costs are incurred at the end of the rotation when timber is harvested. The estimated costs of this activity are based on a study recently completed by Lolo forest personnel.

Timber Management Regimes - Basic Assumptions

The two basic regeneration systems proposed for second-growth stands in the Lolo National Forest Timber Management (TM) plan are clearcutting and shelterwood cutting. The economic efficiency of managing lands using both of these systems is analyzed. To accomplish this the following assumptions were made.

1. All lands require site preparation prior to regeneration.
2. Prior to regeneration harvesting there may be zero, one, or two commercial thins. When two thins are conducted the interlapsing time interval is 30 years (this constraint is imposed by the yield tables).
3. Full stocking control (i.e., precommercial thinning) will be maintained on all sites.[3]

In the preliminary TM plan several shelterwood cutting strategies are explained. In this study only one shelterwood regime, consisting of two harvest entries, is analyzed. With this regime, 65 per cent of the volume is removed in the first entry. The remaining volume (plus growth) cannot be removed until 10 years following the initial entry.

The regeneration regime analyzed assumes continuation of present management practices on both clearcut and shelterwood cut units. Currently,

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[3]It would have been desirable to test each regime with and without precommercial thinning. Limitations imposed by the yield tables prevented this, however (see Appendix A.2).

planting is planned for all clearcut sites and for approximately 50 per cent of the shelterwood cut sites. Five alternative natural regeneration regimes, which show the sensitivity of the analysis to regeneration costs, are also examined.

The minimum allowable rotation lengths were determined according to when maximum mean annual increment is achieved. Mean annual increment is measured in terms of net cubic foot volume to a 6.5 inch minimum outside bark top diameter.

Several possible rotation ages were tested with each management regime to determine the combination of rotation age and management regime that is optimal on each defined land unit. Because of constraints imposed by the yield tables (see Appendix A.2) the number of commercial thinning and shelterwood cutting strategies that could be analyzed was extremely limited, however.

Economic Analysis

The present value of the costs and revenues resulting from timber management were computed for each habitat type group, under each significant forest situation (as defined by slope class, management regime, and rotation length) with the aid of the Faustmann formula. The analysis was done using discount rates of 3.5, 5.0, and 6.5 per cent.

By using calculated land expectation values, forest land is ranked under each management strategy, according to its timber management investment potential. These rankings are based on physical characteristics of the site (e.g. slope and habitat type group) which affect costs and timber values. The rankings provide a basis for an economic delineation of commercial forest land under current management practices. This is required by the National Forest Management Act of 1976. The manager, faced with the problem of budget allocation, could also use these rankings to determine spending priorities.

Chapter 3

LITERATURE REVIEW

Despite the recent upwelling of public interest concerning the marginal site question, a firm rationale for determining whether sites are economically suitable for timber production has not been developed. Most of the pertinent research on this issue is, in addition, highly generalized and serious consideration has not been given to the site factors which affect timber production costs and revenues.

Marty and Newman (1969) estimated the economic efficiency of timber management intensification on 60 of the major timber site-types which exist on National Forest lands. These site-types were then ranked according to the internal rate of return that intensive management would generate. The investigators concluded that 75 per cent of the National Forest commercial land base would produce a rate of return exceeding 3 per cent if intensively managed.[1] Investments in sites which produce less than this marginal rate were considered unacceptable, but the intangible benefits and costs may ultimately determine whether a site is economical to manage. The influence of tree dbh on value was estimated in this study as were projections of real increases in stumpage value. Because of the broad scope of the study, site factors which affect costs and revenues were not considered.

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[1]A timber site-type is the conjunction of a timber type with a site type. The Lolo National Forest contains timber site-types which ranked both above and below this margin.

In another study, Wickstrom and Hutchinson (1971) determined that the commercial forest land base had been overestimated in each of six western National Forests surveyed.[2] Areas identified by these investigators which should not have been classified as commercial included sites with extremely unstable soils and sites containing small patches of economically unmanageable timber. The investigators concluded that the simple commercial versus noncommercial division of forest land is inadequate to meet National Forest planning needs and urged the development of a land classification system which takes cognizance of site factors which affect costs.

A committee of scientists from the University of Montana evaluated timber management practices on the Bitterroot National Forest in 1970 (Bolle, et al.). This committee concluded that intensive timber management was being done to the detriment of all other resources on this forest and challenged these practices in the basis of both economic and environmental effects. In particular the practice of terracing and planting, which was shown by example to produce less than a 2 per cent rate of return, was criticized.[3] The committee expressed the need for a forest land classification system based on economics rather than physical output. They also concluded that extensive timber management (i.e. selection cutting, natural regeneration, etc.) is economically more viable on poor sites than intensive alternatives.

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[2] The portion of the Lolo forest contained on the Ninemile and Superior ranger districts was included in this study.

[3] In their example, the committee did not account for projected real increases in the value of stumpage.

In a detailed economic analysis of timber management alternatives on the Bitterroot National Forest, Bennett (1973) ranked silvicultural treatments according to the internal rate of return generated. The general management strategies considered in his study were clearcutting followed by planting, and seedtree, shelterwood, and selection cutting followed by natural regeneration. Each of these strategies were tested with and without precommercial thinning on 3 selected habitat types. All but two of the management strategies developed produced rates of return of less than 3 per cent. In general Bennett found that extensive regimes gave higher rates of return than intensive regimes. For this study forest wide averages were used to estimate both timber management costs and expected stumpage values. Because of a lack of available data, projections of real increases in stumpage value were also not made.

Using modified present net worth calculations and a discount rate of 5 per cent, Vaux (1973) estimated that 39 per cent of California's commercial forest land is not amenable to intensive timber management. These "sub-marginal" lands included all timber types in site class V (20-50 ft^3/acre/year) and a majority of the types in site class IV (50-85 ft^3/acre/year). In this study stumpage values were projected to the year 2030, costs were averaged and held constant, and the same management regime and rotation age was applied to each site. Vaux noted that since much of the forest land classified as commercial is in fact economically sub-marginal, several serious policy questions have to be answered. For example, what practices are appropriate on sites having low investment potential but high old growth timber values?

In summary, research on the economic suitability of lands for timber production has been done on a broad scale only and is mostly theoretical in nature. Furthermore, there has apparently been no meaningful attempt to statistically analyze the site variables which affect timber management costs. This type of analysis is essential if a meaningful forest land classification system based on economics is to be developed.

Chapter 4

TIMBER MANAGEMENT COSTS

Introduction

The economic suitability of lands for timber production is influenced by factors which affect management costs. The objective was not only to estimate the costs of timber management activities but to identify the variables which cause these costs to vary.

The three major long-term timber investments made on Lolo National Forest lands are site preparation, planting, and precommercial thinning. Planting and precommercial thinning projects are normally done by private contractors. Regression equations which predict the direct cost of these activities, using variables such as habitat group and slope, were developed. The variability in contract overhead costs could not be determined, however. Because of data deficiencies, the site preparation costs derived in this study are averages based mainly on professional judgement.

Two other costs considered in this chapter are annual administrative costs and timber sale preparation and administrative costs. These costs were estimated from budget and administrative records and from studies done by professionals working on the forest.

The procedures used to determine the component costs of timber management are explained in the following sections. Special problems associated with the statistical analysis of contractual data are explained in Appendix G.

Site Preparation Costs

Site preparation is required prior to regeneration to expose mineral soil and to remove competitive vegetation. Site preparation costs are difficult to determine since site preparation, a regeneration cost, and slash disposal, a logging cost, are usually accomplished simultaneously.

The two general methods of site preparation (and slash disposal) used on the forest are broadcast burning and dozer-piling with scarification. In this study 30 per cent of the cost of these activities is charged as a regeneration (management) cost and 70 per cent is charged as a slash disposal, hence logging, cost. This simplistic cost breakdown was chosen after considerable study and consultation with several professionals working on the forest (see Appendix B.1).

Dozer-piling Costs

The logging slash on sites with less than 35 per cent slope is generally dozer- (machine-) piled and burned. In the process, soil is scarified and competitive vegetation is removed.

Dozer-piling is normally done by private contractors. In 7 of 12 contracts awarded during the period 1976 through 1978, the cost of treating the individual sites did not vary. Since these data were not amenable to statistical analysis, a weighted average cost was computed. The average contractual (direct) cost of dozer-piling, adjusted for inflation, is $60.73/acre (data and computation in Appendix B.2).

The cost of preparing and administering contracts must be added to this direct cost. This "overhead" cost is estimated to be $8.06/acre and $3.48/acre at the district and forest levels, respectively (see

Appendix F).[1]

The average cost of dozer-piling is thus $72.27/acre. Thirty per cent, or $21.68, of this cost is charged to second-growth timber management.

Broadcast Burning Costs

Sites which are too steep or unstable to be dozer-piled are generally broadcast burned. Because of the difficulty in obtaining cost data on any given broadcast burning project, the cost estimates used in this study are based on professional judgment.

Personnel working on the ranger districts were first interviewed. Although the cost estimates given in these interviews varied greatly, four basic conclusions were reached. These are:

1. Broadcast burning costs are increasing. This is due to both a decline in the average size of burn units and more stringent air quality control measures.

2. Costs fluctuate widely from year to year depending on weather conditions.

3. Costs are lower on the drier sites (as defined by either aspect or habitat type).

4. Burns in shelterwood units are generally more expensive than those in clearcut units.

To reconcile differences in the district cost estimates Dave Bunnell, Fuels Management Specialist for the Lolo forest, was consulted.

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[1]District overhead cost estimates of $6.93, $7.52, and $9.74/acre were obtained. A difference in the average size of contracts causes most of this cost variance. Since all district estimates were considered valid, their mean value of $8.06/acre is used in this study.

The cost estimates of Mr. Bunnell, presented in Table 1, are used in this study. These estimates show the effect of habitat group on average cost and are based on the assumption that future burn units will average 40 acres or less. Although Mr. Bunnell agrees that burns in shelterwood units are probably more expensive than those in clearcut units, this variable could not be accurately considered in these estimates.

TABLE 1

BROADCAST BURNING COSTS (1978 DOLLARS)

	Habitat Group		
	A & B	C & D[a]	E & F
Total Cost/acre	$50.00	$75.00	$150.00
Regeneration cost/acre (30 per cent)	15.00	22.50	45.00

[a](modified groupings) Four habitat types in group C and D: DF/Caru; DF/Cage; DF/Aruv; and DF/Arco, lack definite shrub understories. The cost of burning in these types is the same as in groups A and B.

Planting Costs

In an individual planting project there are three component costs. These are:

1) direct costs (payments made to contractors);

2) material costs; and

3) preparation and administrative (overhead) costs.

All plantings are not successful. When failure occurs, stands are generally replanted. An additional cost, dependent upon the probability of having an initially successful planting, is thus incurred on each site type.

Direct Cost of Initial and Inter Plantings

The objective of this analysis was to develop linear regression models, significant at the 95 per cent level, which predict the direct cost of initial plantings and inter (re)-plantings.[2]

General methods. Data were collected on all sites contractually planted during the period 1976 through 1978. These data were obtained from the contract files and the Stand Examination and Management Status record (Stand Exam list; reference FSH 2411.15R1).

These data were then adjusted for both inflationary and real cost increases. Average per acre planting costs were $40.01 in 1976 and rose to $53.57 in 1977 and $71.45 in 1978. Most of this cost increase is real and apparently the result of changes made in the contract specifications and an increased demand for planters (see Appendix C.1). An assumption was made that there has been a uniform percentage cost increase on all planting sites. To correct the data to a 1978 base, for real and inflationary cost increases, 1976 and 1977 costs were multiplied by 1.786 and 1.334 respectively. These factors were derived by dividing the average per acre cost for 1976 and 1977 into the per acre cost for 1978.

When regression analysis was attempted on this 3 year data base, idiosyncracies in the 1976 data caused major problems. The 1976 data was therefore excluded from the analysis (see Appendix C.2 for explanation).

Regression models were then developed using the 1977 and 1978 data only. In each model cost/acre was treated as the dependent variable. The independent variables tested are either intrinsic to a site (e.g. slope)

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[2]In this study, plantings planned prior to harvesting are called initial plantings. Inter (re-) plantings are done as a consequence of artificial or natural regeneration failure.

or can be predicted or controlled (e.g. trees/acre planted).

Initial plantings: Direct costs. In this study plantings planned prior to harvesting are termed initial plantings.

1. Methods. To determine the direct cost of initial planting, all stands planted within 3 years of site preparation were analyzed. This cutoff period was chosen since most stands with a delay of 4 or more years were found to be planted as a consequence of either natural or artificial regeneration failure.

The data base included 51 stands planted in 1977 and 24 planted in 1978. Thirty-four, 36, and 5 of these stands were planted 1, 2, and 3 years after site preparation, respectively.

The independent variables tested for significance were: 1) stand area; 2) elevation; 3) accessibility (driving hours from district offices); 4) walk-in distance; 5) slope (per cent); 6) trees per acre planted; and 7) the contract bid item size (acres). In addition, the following variables were tested using dummy replacements: 1) habitat group; 2) aspect; 3) the presence or absence of a shade clause in the contract; 4) site preparation method; and 5) geographic location (ranger district).

2. Results. The equation for predicting initial planting costs contains 4 of these variables and is as follows:

$$Y = 108.95 + 8.931x_1 + 0.2175x_2 - 7.985\ \ell_n\ x_3$$

where:

Y = cost/acre (1978 dollars)

x_1 = habitat group (1 = groups B,C, and D, 0 = groups E and F)

x_2 = slope in percent • site preparation method (0 = dozer-piled sites, 1 = broadcast burned sites)

x_3 = bid item size (acres)

The adjusted R^2 for this equation is .455 and the standard error of Y is $10.46. The equation is applicable for slopes ranging from 0 to 70 per cent and bid item sizes ranging from 40 to 650 acres. Further statistical information on this equation is presented in Appendix C.3.

3. Discussion. The variable which exerts the greatest influence on costs is the contract bid item size. The equation predicts that per acre costs decrease at a declining rate as the bid item size increases.[3] This relationship was predicted since most of the planting contractors who work on the Lolo are not headquartered in Montana. The bid item size should thus exert a strong influence on their per acre overhead costs.[4] Despite the importance of this variable, it is impossible to predict the average bid item size in the future. The current average (median) bid item size of 330 acres was thus used in the planting cost calculations.

The equation predicts that costs are $8.93 more per acre on the Douglas-fir habitat types (groups B,C, and D) than on the true fir and spruce types (groups E and F). The higher costs on these drier sites may be due to thin, rocky soils which make the digging of planting holes and the removal of competitive vegetation (scalping) more difficult.

Sites with slopes less than 35 per cent are generally dozer-piled, while steeper areas are broadcast burned. Slope and site preparation are thus interactive variables as indicated in the regression equation.

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[3](e.g.) According to the model, costs would decrease $5.53/acre as the bid item size is increased from 50 to 100 acres, but would only decrease $0.70/acre with a bid item increase from 550 to 600 acres.

[4](n.b.) Bid item and contract size are not equivalent. Contract solicitations usually contain several items which are bid upon separately. Since the contractor does not know the number of items that he (she) will be awarded, bid item size should have more influence on costs than contract size.

Lower costs are incurred if a site is dozer-piled. This was predicted since these sites are relatively free of obstructive debris. Gentle slopes should not increase costs since the amount of stooping required of the planter would be reduced. According to the equation, slope does not cause an increase in costs on sites which are dozer-piled. Hence, slope is not normally significant unless it exceeds 35 per cent. On steeper slopes, which are broadcast burned, the maneuverability of the planter is evidently hindered and costs increase with increasing slope.

Several of the variables tested for significance in this analysis were not used in the final regression model. The reasons for their lack of significance or omission from the model are now explained.

Most contractors camp on the planting site. This may explain why neither accessibility nor elevation were found to be significant. In addition, the measure of accessibility was very crude. Almost all of the planting sites were recorded as being either one or two roundtrip driving hours from the district offices.

The hypothesis was that plantings on south, south-west, and south-east aspects should be more expensive due to severe site. When treated alone this variable was statistically significant. There was strong multicollinearity between aspect and both slope and habitat group, however. When these variables were tested simultaneously, the aspect variable fell out of the equation.

Several stands are contained within an individual planting contract. The stand size influences the number of moves that a contractor must make. It was thus hypothesized that costs should decrease as stand size increases. This variable was insignificant, however. The average size of the stands within a bid item could possibly be significant, but was not tested.

When the shade clause is enforced, planters are required to plant next to logs, stumps, etc. to provide shade for the developing seedling. Surprisingly, there was very little multicollinearity between this variable and either aspect, or habitat group. Perhaps as a consequence of its seldom and indiscriminate application, this variable was not found to be significant.

Forty-one per cent of the sample stands were planted on the Superior Ranger District. The cost of planting on this district was significantly lower than elsewhere. This difference in costs was due to both the large size of the bid items on the Superior District and that a major portion of the stands on this district were dozer-piled. The "geographic location" variable was thus not used in the final regression model.

With a larger data base several of the other variables could prove to be significant. Seventeen of the 75 stands analyzed were inaccessible by road. Only three of these stands required a walk-in distance exceeding one-fourth of a mile, however. Walk-in distance could become significant if future management emphasizes harvest systems which do not require access roads (e.g. helicopter or long cable systems). The number of trees planted per acre should also be significant. However, ninety per cent of the sample stands were planted at a 10 by 10 foot spacing. All but three of the sample stands were planted with bare-root stock. There was thus insufficient evidence to determine whether containerized plantings are more or less expensive than bare-root plantings.

The direct cost of initial plantings, as predicted by the regression equation, are displayed in Table 2. The average (median) bid item size of 330 acres was used in the calculations.

TABLE 2

INITIAL PER ACRE PLANTING COSTS

DOZER-PILED SITES

HABITAT GROUPS B,C,&D	HABITAT GROUPS E & F
$71.58	$62.65

BROADCAST-BURNED SITES

SLOPE	HABITAT GROUPS B,C, &D	HABITAT GROUPS E & F
30%	$78.10	$69.17
40%	80.28	71.34
50%	82.45	73.52
60%	84.62	75.69
70%	86.80	77.89

Inter (Re-)Plantings. Inter (Re-)plantings are done as a consequence of natural or artificial regeneration failure. Interplantings differ from initial plantings in one important respect. There is a large amount of competitive vegetation that results from the lack of recent site preparation. This vegetation hinders the planter and is normally removed (scalped) from each planting site. Planting costs are thus increased. The average cost of initial plantings was $69.81/acre (adjusted 1977 and 1978 data), while sites planted without recent site preparation cost $81.24/acre.

1. Methods. Thirty of the 105 sample stands were planted 4 or more years after site preparation. Becasue of a large amount of random variation in costs, direct analysis of these 30 stands was fruitless. To determine the cost of interplantings all stands planted in 1977 and 1978 were thus analyzed. In addition to the variables tested to predict initial planting costs, "years since site preparation" was treated as an independent variable.

2. Results. The derived regression equation for predicting interplanting costs is as follows:

$$Y = 111.36 + 9.63x_1 + 1.88x_2 - 8.674\ \ell_n x_3$$

where:

Y = cost/acre (1978 dollars)

x_1 = site preparation method: (0 = dozer-piled sites, 1 = broadcast burned sites

x_2 = years since site preparation

x_3 = bid item size (acres)

The adjusted R^2 for this equation is .363 and the standard error of Y is \$11.74. The effective range of the data for variable x_2 is from 1 to 10 years.

Further statistical information on this equation is presented in Appendix C.4.

3. Discussion. The 30 stands planted without recent site preparation contain a large amount of random variation in cost. As a consequence, relationships apparent in the equation predicting initial planting costs have been masked in this equation.

Assuming an average delay period between site preparation and interplanting of 6 years, this equation predicts an interplanting cost of \$72.34/acre on dozer piled-sites and \$81.97/acre on broadcast burned sites.[5]

Planting Success and its effect on total planting costs

Because planting failures are generally replanted, a majority of the variability in planting costs may depend on the probability of having

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[5]The median size of bid items containing interplantings, i.e. 330 acres, was used in this calculation.

an initially successful planting.

The procedures used to determine initial planting success are summarized in this section. A complete description of the methods and results of this analysis is contained in Appendix C.5.

Data on plantings conducted during the period 1966 to 1975 were surveyed to determine the variables which have significantly (95% confidence level) affected planting success.

Habitat group, aspect, harvest method, site preparation method, and the delay period between site preparation and planting were tested for significance using a z test for comparing proportions. Only the last variable was found to be statistically significant. The success rate for plantings declines rapidly as the delay period between site preparation and planting increases.

Since site characteristics were not found to affect planting success, the analysis did not show the variability in cost (by site) that was expected.

Assuming that all initial plantings will be done within 3 years of site preparation, the probability of initial planting success, based on this historical data, is 71% for all sites.

Because of recent changes in the contract specifications (see Appendix C.1) and an improvement in the quality of planting stock, the probability of planting success is now greater than during the period 1966 to 1975. Dr. Pete Laird, USFS Region 1 reforestation specialist, estimates that initial plantings are now successful on approximately 90 per cent of the sites planted.[6]

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[6]This does not mean that 90 per cent of the planted seedlings survive Most plantings are done at a density of 436 trees per acre. In general, plantings are considered successful if 300 or more of these seedlings survive.

Assuming a 90 per cent success rate for initial plantings and a 75 per cent success rate for subsequant interplantings, the additional costs incurred due to the possibility of planting failure are $18.05 per acre for dozer-piled sites and $19.34 per acre for broadcast burned sites (calculation in sec. 5, Appendix C.5).

Material Costs

Material costs do not normally vary by site but depend instead on whether an area is planted with bare root or containerized stock. The calculations in Table 3, of actual actual 1978 material costs, were prepared by Steve Ludwig of the Superior Ranger District.

TABLE 3

PLANTING MATERIAL COSTS/1000 SEEDLINGS

	BARE ROOT STOCK	CONTAINERIZED STOCK
COST OF TREES	65.00	130.00
DELIVERY FROM NURSERY	3.30	10.00
STORAGE & WATERING	0.75	3.00
JELLY ROLLING	12.80	--
BURLAP & BOXES	0.36	--
VERMICULITE	0.71	--
DELIVERY TO FIELD	2.02	2.02
	$85.94	$145.02

Initial plantings are normally done at a 10 by 10 foot spacing (436 trees/acre). The material costs per 1000 seedlings have been converted to costs per acre in Table 4.

TABLE 4

PLANTING MATERIAL COSTS/ACRE
(ASSUMING 436 TREES/ACRE)

BARE ROOT STOCK	CONTAINERIZED STOCK
$37.03	$63.22

Preparation and Administrative Costs

Intrinsic site variables undoubtedly affect the cost of preparing and administering planting contracts. However, there is presently no data base to determine the variability of these costs by site.

A large proportion of the plantings conducted on the Lolo National Forest during the past 3 years have occurred in the Superior Ranger District. This district's cost estimate of $4.88 per acre for contract preparation and $15.00 per acre for administration (contract inspections) is used in this study. In addition, the preparation and administrative cost incurred at the forest level is estimated to be $2.55 per acre (for an explanation of these costs see Appendix F).

Reforestation surveys are conducted in years 1, 3, and 5, following planting and cost approximately $3.00 per acre (personal discussion with Steve Ludwig, Superior Ranger District). The cost of these surveys discounted at a 5 per cent rate to the year of planting is $7.80/acre.[7]

The preparation and administrative costs, associated with plantings are displayed in Table 5.

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[7]This discounting was done in order to include reforestation surveys as a portion of the total planting cost.

TABLE 5

PLANTING CONTRACT PREPARATION
AND ADMINISTRATIVE COSTS

ACTIVITY	COST/ACRE
CONTRACT PREPARATION (DISTRICT)	$4.91
CONTRACT ADMINISTRATION (DISTRICT)	15.00
CONTRACT PREP. & ADMIN. (FOREST)	2.55
REFORESTATION SURVEYS	7.80
	$30.26

Total Planting Costs

Total planting costs, that is initial costs plus a prorated replanting cost, are displayed in Table 6. These costs are based on the assumption that 436 trees/acre are planted and that plantings are done with bare root stock. Containerized plantings cost an additional $26.19 per acre on all sites.

TABLE 6

TOTAL PLANTING COSTS (1978 DOLLARS)

DOZER-PILED SITES

HABITAT GROUPS	
B,C,& D	E & F
$156.92	$147.99

BROADCAST BURNED SITES

	HABITAT GROUPS	
SLOPE	B,C,&D	E & F
30%	164.73	$155.80
40%	166.91	157.97
50%	169.08	160.15
60%	171.25	162.32
70%	173.43	164.52

Precommercial Thinning Costs

Forty plantation (second-growth) stands, established as a result of harvesting, were precommercially thinned in 1976 and 1977. These stands provided the data base for this analysis.

Direct Cost Determination

The objective of this analysis was to develop a linear regression model, significant at the 95 per cent confidence level, which predicts the per acre cost of precommercially thinning second-growth stands.

Methods. Data were obtained from the contract files and the stand exam list on all second-growth stands contractually thinned during the period 1976 to 1978. A visual review of this data indicated a high default rate on thinning contracts. Since none of the 1978 contracts were completed at the time of this analysis, and defaults cannot be predicted, stands contracted for thinning in 1978 were not analyzed.

The final data base contained 40 stands. Twenty-four of these were thinned in 1976 and 16 were thinned in 1977. At the time of thinning the sample stands varied in age from 4 to 27 years, but 75 per cent were thinned between the ages of 10 and 19.

The average per acre cost of precommercial thinning has not increased in real terms from 1976 to 1978. This is apparently due to intense competition between bidders for most thinning contracts. However, 1976 data were adjusted to a 1977 base to account for inflation. The wholesale price index inflation rate of 6.12 per cent was used.

Regression analysis was then conducted on this data. Cost per acre was treated as the dependent variable. The independent variables tested for significance were: 1) stand area (acres); 2) elevation; 3) accessibility; 4) stand age; 5) slope (per cent); 6) the number of leave trees per acre; and 7) the contract size (acres). In addition, 1) habitat group, 2) height specification, and 3) aspect were tested using dummy replacements.

The variable which should most significantly affect precommercial thinning costs is the stand density prior to thinning. This variable could not be tested for significance, however, since data was available for only 17 of the 40 sample stands.

Results. In the final regression equation 4 of these variables are significant. The equation for predicting precommercial thinning costs in second-growth stands is as follows:

$$Y = 306.09 - 22.849 \, \ell_n x_1 + .5790 x_2 - 34.734 \, \ell_n x_3 + 14.482 x_4$$

where:

Y = cost/acre (1977 dollars)

x_1 = thinning stand area (acres)

x_2 = slope (per cent)

x_3 = number of leave trees per acre

x_4 = height specification (0 = 24 inches, 1 = 6 inches)

The adjusted R^2 value of this equation is .673 and the standard error of Y is \$14.22. The equation is reliable for stand areas varying from 10 to 70 acres, thinning regimes leaving 225 to 538 stems per acre, and slopes ranging from 0 to 70 per cent.

The average (median) thinning stand area is 40 acres. If this number is substituted into the equation, it can be simplified to the form:

$$Y = 221.80 + .5790x_2 - 34.734\ell_n x_3 + 14.482x_4$$

Further statistical information on this equation is presented in Appendix D.1.

Discussion. The only intrinsic characteristic of the site found to significantly affect precommercial thinning costs is slope. According to the equation costs increase \$5.79/acre for every 10 per cent increase in slope.

The thinning stand size influences the number of moves that a contractor must make and thus affects his per acre costs. It was thus hypothesized that costs should decrease as stand size increases. The equation supports this hypothesis and shows that the rate of this decrease in cost declines as the stand size increases.

Contract specifications also have a significant influence on costs. The equation shows that thinning costs increase at a declining rate as the number of leave trees per acre decreases. This is to be expected since more trees are removed when a wide spacing is specified. The following illustration shows the importance of this variable. If the cost of thinning to a 12 foot spacing (302 trees/acre) is \$50.00 per acre, it would cost \$37.25 to thin to a 10 foot spacing (436 trees/acre) and \$29.95 to thin to a 9 foot spacing (538 trees per acre). For all thinning contracts the contractor is required to remove the excess trees only if they exceed a specified height. The height specification is normally either 6 or 24 inches.[8] The equation shows that thinning to a 6 inch

[8]Two sample stands were thinned to a 12 inch height specification. An inspection of these stands showed that they had few excess trees shorter than 24 inches prior to thinning. They were thus treated as if they had been thinned to a 24 inch specification.

height costs $14.48 more per acre than thinning to a 24 inch height.

To estimate the effect of these contract variables on future precommercial thinning costs, Wes Kellie, Lolo National Forest silviculturalist, was consulted. It was determined from this discussion that the present thinning strategy on nearly all lands managed intensively for timber production is identical. According to Mr. Kellie, thinning will normally be done to a 12 by 12 foot spacing (302 leave trees/acre), with a 24 inch height specification, on all habitat types.[9] In addition, Mr. Kellie feels that approximately 90 per cent of the second-growth stands will require precommercial thinning. The influences of factors such as habitat type and regeneration method, on the probability of having to precommercially thin a stand, are presently unknown.

Since a median thinning stand area of 40 acres has already been assumed, the precommercial thinning cost estimates used in this study will vary according to the slope variable only. Using the above assumptions, and a correction for inflation from 1977 to 1978, the average per acre direct cost of thinning level areas is $23,04 (1978 dollars). This average cost increases $5.68 per acre for every 10 per cent increase in slope (see calculations in Appendix D.2).

Several of the variables tested for significance in this analysis were not used in the final regression model. The elevation and accessibility variables were insignificant in the planting cost model. For identical reasons they exert little or no influence on precommercial thinning costs.

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[9]The Forest Service has concluded that thinning to a 6 inch height specification is usually unnecessary since the trees that are under two feet in height are normally suppressed and do not compete with the dominant trees on the site.

Stand age was not found to be significant in any of the regression runs. Some contractors apparently prefer to thin smaller diameter trees (younger stands) where clippers can be used. Others prefer older stands where they can use a chain saw. These factors may be counteracting each other.

The possible importance of bid item size was not known when data was collected. However, the contract size (acres) was tested as an independent variable. The lack of significance of this variable is probably due to the following factors. First, most of the thinning contractors live in the communities surrounding the Lolo Forest. Contract size thus has little affect on transportation costs. Second, much of the variability in the contractor's overhead cost has been explained by the stand size variable, as evidenced by the strong multicollinearity between the stand size and contract size variables.

A comparison of the correlation coefficients showed strong multicollinearity between habitat group and both height specification and the number of leave trees per acre. These latter two variables may be masking the influence of habitat group on cost.

There was also strong multicollinearity between aspect and slope. The regression model using the slope variable alone produces as good a fit as the one using both of these variables.

Contract Preparation and Administrative Costs

Estimates on the per acre cost of preparing and administering precommercial thinning contracts were obtained from 3 ranger districts. These estimates are \$11.63 on the Seeley Lake district, \$12.12 on the

Plains district, and $13.79 on the Ninemile district. Since these figures are all in close agreement, their mean value of $12.51/acre is used as the estimate of district level cost.

The estimated cost of preparation and administration at the forest level is $7.42/acre. This cost is high because of the relatively small average size (94 acres) of precommercial thinning contracts.

A complete description of these district and forest level cost estimates are presented in Appendix F.

Total Precommercial Thinning Costs

Using the assumption that 90 per cent of the stands, on all habitat types, will require precommercial thinning, the expected costs of this activity are displayed in Table 7.[10]

TABLE 7

PRECOMMERCIAL THINNING - TOTAL COSTS

SLOPE	COST/ACRE(1978 DOLLARS)	SLOPE	COST/ACRE (1978 DOLLARS)
0	$40.95	40	$63.67
10	46.63	50	69.35
20	52.31	60	75.03
30	57.99	70	80.71

Annual Costs

Timber management related costs that are incurred on a periodic or annual basis are termed annual costs. These costs cover such on-going activities as road maintenance and insect and disease control.

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[10]On precommercial thins done in stands which are older than 20 years or heavily overstocked, a slash disposal cost is often incurred. However, it is assumed that this cost will not be incurred in plantation thinnings.

Annual costs were determined from an examination of the Lolo forest's budget records (Advent Summaries) and from estimates made by professionals working on the Lolo forest. These costs have been converted to a per acre basis and are presented in Table 8. A detailed explanation of the derivation of these costs is contained in Appendix E.1.

TABLE 8

ANNUAL COSTS (1978 DOLLARS)

ACTIVITY	COST/ACRE (DOLLARS)
ROAD MAINTENANCE	0.688
TIMBER MANAGEMENT OVERHEAD	0.512
MISCELLANEOUS TIMBER MNGT. COSTS	0.134
	$1.33/ACRE

Timber Sale Preparation and Administrative Costs

Timber sale preparation and administrative costs are incurred when a stand is harvested. Charlie Fudge, of the Lolo National Forest Timber Management staff, has just completed a detailed study of these costs. He estimates a timber sale and preparation cost of $26.16 per mbf, with a projected annual cut on the forest of 125 million board feet.

This cost figure was determined from timber sales in old growth stands, where the engineering and transportation planning needs are great. These costs now total $12.69/mbf or close to 50 per cent of the total cost. However, engineering costs should be significantly less when managed second-growth stands are harvested. In this study, an assumption is made that they will be reduced by 50 per cent. The assumed current cost of timber sale preparation and administration in second-growth stands is thus $19.81/mbf (26.16 - 6.35).

A list of the activities which comprise this cost is located in Appendix E.2.

Discussion

The cost analysis is considered only partially successful since much of the variation in costs, by site, could not be demonstrated. Planting costs will be used as an example. According to Table 6, these costs vary by only $25.00/acre (from $147.99 to $173.43). This lack of variation is due in part to an assumed bid item size of 330 acres. However, because of a lack of reliable data, it was also assumed that planting success does not vary by site. Most likely factors such as aspect, soil type, and the effectiveness of site preparation on a given habitat type influence long term planting success. Field studies should be conducted to determine the site factors which affect seedling survival and the resultant effect on total regeneration costs. The cost of preparing and administering planting contracts should also vary according to factors such as contract size, accessibility, and slope.

The regression analyses indicated that policy variables, such as the bid item size in planting contracts, and the number of leave trees per acre in thinning contracts, have a significant effect on costs. Total costs could be reduced considerably if closer attention were paid to these variables in the future. Basic research is also needed to determine the economically optimal stocking levels that should be planted, then maintained, on each site.

Despite the inadequacies of this analysis, the equations developed provide a much better estimate of intensive management costs than the gross averages commonly used in investment analysis. The equations can also be used to reduce current costs.

Chapter 5

STUMPAGE VALUE DETERMINATION

Predicting Current Stumpage Values

Using data from 52 major timber sales, sold on the Lolo National Forest during the period 1968 through 1977, Jackson and McQuillan (1979) developed a regression model which explains 82 per cent of the variation in total sale value (adjusted $R^2 = .816$). If all timber in a managed stand is in the same diameter class when harvested, their model can be simplified to the form:

$$Y = -281.32 + 79.912 \ln x_1 + .4237x_2 + 39.28x_3 + 32.02x_4 + 1.482x_5$$

Where:

Y = stumpage value per m.b.f. log scale (1972 dollars)[1]

x_1 = d.b.h. class of timber harvested (inches)

x_2 = weighted average lumber price (1972 dollars)

x_3 = logging method (0 = cable or jammer logged areas; 1 = tractor logged areas)

x_4 = harvest method (0 = partial, selection, or shelterwood cut areas; 1 = clearcut or seed tree cut areas)

x_5 = net volume harvested per acre (m.b.f., log scale)

The independent variables contained in this model are all significant at the 95 percent confidence level. A discussion of their relative

[1]The stumpage values determined by this equation include Knutsen-Vandenburg (KV) funds which are allocated to sale area betterment.

influence on stumpage value follows.

According to the equation stumpage value increases logarithmically (at a declining rate) as tree d.b.h. increases. The following example shows the importance of this variable. If stumpage from a 12 inch d.b.h. tree is worth $20.00 per m.b.f., 14, 16, and 18 inch trees would be worth $38.91, $55.29, and $69.75 per m.b.f., respectively (1978 dollars).[2]

The selling price of lumber should have a strong influence on stumpage value. The model predicts that stumpage value increases $0.42 per m.b.f. for every dollar increase in lumber price. One factor which drives up lumber prices is real increases in production costs. The fact that time, and hence production costs, could not be held constant in this analysis may explain why the coefficient on the lumber price variable is less than one. The lumber price variable is defined as a weighted average which is dependent upon the proportion of each timber species sold in a sale. The model can thus be used to predict the stumpage value of any species mix grown on a site. Because this variable has also been adjusted for inflation, the model accounts for real changes in the value of stumpage which have occurred during the period covered by the data.

Sites with slopes of less than 35 per cent are generally tractor logged, while steeper areas are logged using cable systems. With other factors held constant, the model predicts that the stumpage from tractor logged areas is worth $60.29 more per m.b.f. (1978 dollars) than the stumpage from cable logged areas. Stumpage value may in fact decrease continuously as slope increases. However, since the data for each timber

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[2]To convert these values from 1972 to 1978 dollars the Gross National Product Implicit Price Inflator of 153.5, for August 1978 was used.

sale contained only an "average" slope, this hypothesis could not be tested by Jackson and McQuillan.

The model shows that both the harvest method and the volume per acre harvested have a significant effect on stumpage value. The stumpage from sites harvested by the clearcut or seed tree methods is predicted to be $49.15 per m.b.f. greater in value (1978 dollars) than the stumpage from sites in which a partial cutting system is used. Stumpage value increases linearly as the volume per acre harvested off a site is increased. For each additional thousand board feet of stumpage removed, stumpage value increases $2.27 per m.b.f.

Production Cost, Lumber Price, and Overrun Projections

Historically the price of stumpage has risen faster than the price of other goods and services in the economy. During the period 1910 to 1970, for instance, relative prices of Douglas-fir stumpage rose at an average rate of 3.5 per cent annually (USDA Forest Service, 1970). This rise in real, not inflationary, value is a result of increasing competition for stumpage and increasingly efficient log utilization.

Projections of stumpage prices to the year 2030 are being made by Adams and Haynes (1979) for the 1980 RPA assessment. These projections are based in turn on projected increases in lumber prices, production costs, and log utilization. Before discussing the projections for the Rocky Mountain region, the relationship between these factors and stumpage value must be understood.

Stumpage value can be calculated by subtracting the total costs of production from the value of the derived products.[3] That is, stumpage value equals "End Product Value" less "Production costs." A problem with using this formula arises since sawtimber stumpage is normally measured in terms of m.b.f. log scale, while product prices and production costs are expressed in terms of m.b.f. lumber tally. These measures are not equivalent since a thousand board feet of stumpage can normally be converted into a greater volume of finished products. The difference between the log scale and lumber tally measures is due to a predictable log scaling error and is termed overrun. With other factors held constant (e.g. timber species, log diameter, and log quality), an increase in overrun means an increase in log utilization. It follows that the relationship between these factors can be expressed mathematically as:

$$SV = (1 + OR)(LP - PC)$$

where:

SV = stumpage value/m.b.f., log scale Scrib.

OR = overrun expressed as a decimal

LP = lumber price/m.b.f., lumber tally

PC = production costs/m.b.f., lumber tally

If projected lumber prices, production costs, and overrun factors are known, this formula can be used to calculate projected future stumpage values.

Adams and Haynes (1979) projections of increases in production costs, lumber prices, and overrun, to the year 2030, are explained in the following

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[3]In this analysis production costs are meant to include all logging and milling costs plus a margin for profit and risk.

sections. These projections were obtained via personal communication with Adams during the period of October, 1978, to March, 1979.

Production Cost Projections

Production costs are projected to increase approximately 67 per cent between the present and the year 2030.[4] The important factors contributing to this expected increase are briefly discussed below.

The primary component of production costs in the wood products industry is labor. Historically, increases in real wage rates in this industry have not been matched by commensurate increases in labor productivity. This has resulted in real increases in production costs per unit of output. This trend is predicted to continue throughout the projection period.

Environmental constraints have recently caused substantial logging and milling costs increases. In the short term further constraints will cause additional cost increases. The importance of this factor diminishes with time.

Relative to other industries, the wood products industry is slow to adapt to substitutes when the real price of inputs rise. This fact, coupled with the forest industry's high dependence on petroleum products, will contribute to these cost increases.

Lumber Price Projections

Because of an increase in the demand for wood products and increasing production costs, lumber prices are projected to increase approximately 95 per cent by the year 2030. The rate of this increase is not constant

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[4]The production cost and lumber price projections of Adams and Haynes, made on a decade by decade basis, are presented in appendix H.

but diminishes over the projection period (e.g. the annual projected increase averages 2.3 per cent between 1980 and 1990 but only 0.7 per cent between 2020 and 2030).

Overrun Projections

According to a recent study by Keegan (1979), the average overrun on timber purchased from the Lolo Forest in 1976 was 31 per cent. Because of improvements in milling efficiency, average overrun on the forest is expected to increase according to the formula.[5]

B.F., lumber tally/B.F., log scale Scrib. = .1955/(.1704 - .0002778T)

where:

T = 78,..,80,...,90,...,130 is a time trend, and the average d.b.h. of the trees harvested is assumed constant.

This formula predicts average overrun factors of 31.44 per cent in 1978 and 45.58 per cent in 2030. This improvement in log utilization will result in higher stumpage values.

Since overrun increases with decreasing log diameter, the average overrun in second-growth stands will likely be greater than this equation indicates. However, the per unit value of lumber that can be obtained from stumpage diminishes as log diameter decreases. Because these factors are counteractive, the projected overrun was not modified to reflect an expected decrease in average log diameter.

Conclusion

As a consequence of these three projections, average stumpage values are projected to increase from the present to the year 2030, by a

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[5]This formula was derived by Adams and Haynes from projections by Thomas H. Ellis, USDA, Forest Products Lab., Madison, Wisconsin. It was modified for this study to reflect the existing situation on the Lolo National Forest.

factor of 3.08.

Adams and Haynes (1979) projections suggest that increases in lumber prices beyond the year 2030 will be largely offset by increases in production costs. Since the increase that can be gained in overrun also has obvious physical limitations, it is assumed in this study that stumpage values beyond the year 2030 will remain constant.

Predicting Future Stumpage Values

Methods

The current value of the stumpage (i.e., the value at today's costs and prices) is first determined using the valuation model of Jackson and McQuillan (1979). The values generated by this model are in 1972 dollars. These values are multiplied by the GNP Implicit Price Inflator of 1.535 (August, 1978) to convert to current dollars.

Once the current (1978) stumpage value is known, current production costs are determined using the formula described in the preceeding section of this chapter. That is:

$$SV = (1 + OR)(LP - PC); \text{ or } PC = LP - \frac{SV}{(1+OR)}$$

Future lumber prices and production costs are then determined using the projections explained previously. That is:[6]

$$PC_{2030} = PC_{1978}(1.6685)$$

$$LP_{2030} = LP_{1978}(1.9510)$$

Using the projections of increase in overrun, future stumpage value is then calculated as follows:

$$SV_{2030} = (1 + OR_{2030})(LP_{2030} - PC_{2030})$$

[6]In this study second-growth harvests that occur before the year 2030 are not analyzed. However, the overrun formula and projections contained in appendix H could be used to predict future stumpage values on harvests conducted before 2030.

Discussion

The reader may ask why this complicated calculation is necessary when projections of real increases in average stumpage value are available. The following illustration answers this question.

Assume that there are two stands identical in all but one respect. Stand A is on a 50 per cent slope, while stand B is on level ground. Stand A will thus require cable logging, while stand B can be tractor logged. Assume further that both of these stands can be either clearcut or shelterwood cut and that the current stumpage value on stand A when shelterwood cut is $0 (zero) per m.b.f. Using the stumpage value model to determine current values and the projection of a 3.08 fold increase in average value between 1978 and 2030, the present and expected values of stumpage are presented in Table 9.

TABLE 9

PRESENT AND FUTURE STUMPAGE VALUES/M.B.F.,
LOG SCALE (1978 DOLLARS)

(assuming constant stumpage price increase, regardless of present value)

	STAND A (Cable Logged)		STAND B (Tractor Logged)	
	Shelterwood Cut	Clearcut	Shelterwood Cut	Clearcut
1978	$0.00	$60.51	$60.29	$120.80
2030	0.00	180.37	185.69	372.06

Since any percentage of zero is zero, stand A would not increase in value if shelterwood cut. Not also the extreme divergence in predicted future stumpage values.

The value of stumpage in these 4 situations differs now because of differences in production costs. By assuming that stumpage value will increase by a constant factor, regardless of current value, an erroneous assumption is made that these differences in production costs will also increase by that same factor.

To overcome this difficulty and to maintain the relationships inherent in the stumpage value model, the effects of increases in production costs, lumber prices and overrun must be considered separately for each current stumpage value generated. When the future value of stumpage is calculated for these same stands, using the method described in this chapter, the following results are obtained:[8].

TABLE 10

PRESENT AND FUTURE STUMPAGE VALUES/M.B.F., LOG SCALE (1978 DOLLARS)

(as predicted by this study)

	STAND A (Cable Logged)		STAND B (Tractor Logged)	
	Shelterwood cut	Clearcut	Shelterwood cut	Clearcut
1978	\$0.00	\$60.51	\$60.29	\$120.80
2030	105.33	217.21	216.80	328.66
multiplicative increase	∞	3.6	3.6	2.7

This table shows that while the mean current stumpage value may increase by a factor of 3.08, current stumpage values below and above this mean will increase at higher and lower rates respectively.[9] With this method of projecting stumpage value, it is even possible to project a positive stumpage value in the future when the current stumpage value is

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[8]The mean weighted average lumber selling price of \$256.08 (1978 dollars), from Jackson's and McQuillan's data, was used in the calculations.

[9]The mean stumpage value in 1978 dollars, estimated from the means of the data used to generate the stumpage value model, is \$85.27 per m.b.f. log scale Scrib.

negative, reflecting for example the trend towards small log utilization. The difference in stumpage value growth rates is primarily due to the fact that production costs are increasing at a much slower rate than mean stumpage value.

By using this method of projection, the general relationships inherent in the stumpage value model are also left intact. In essence, the whole model has been shifted forward in time with modifications made to reflect predicted increases in lumber prices, production costs, and milling efficiency.

Chapter 6

ECONOMIC ANALYSIS

Methods

Jackson and McQuillan have developed a "Montana Timber Supply Model" (1979), which calculates land expectation values and available timber supplies, under a variety of economic assumptions. A special version of this model, which incorporates the cost, value and projection functions described in this study, was developed to perform the economic analysis. This modified model uses regeneration regime, harvest regime, and yield data (i.e. stand age, yield, d.b.h.) to calculate land expectation values. The Faustmann formula for an infinite series of rotations is used. The component costs, revenues, and yields that are produced on each given land unit under each tested management strategy, are also given as output by the model.

A regeneration regime, as defined by the model, is the combination of a site preparation and a regeneration method. Sites may be prepared by either broadcast burning or dozer-piling, as determined by per cent slope. Regeneration may be accomplished naturally or by planting. For each regeneration regime analyzed, the probabilities of initial and subsequent regeneration success, within given time periods are inputted.[1] The model uses these probabilities to determine

[1]To meet the reforestation requirements of the 1976 National Forest Management Act, it is assumed in this study that all regeneration failures, either artificial or natural, are interplanted after an average delay period of 5 years.

the average delay between harvesting and successful stand establishment and in turn the rotation length. The initial and interplanting cost equations are used with inputted data on slope, habitat type group, etc. to calculate regeneration costs. When natural regeneration is attempted, the only initial cost incurred is for reforestation inspections.

The final reforestation harvest system, together with the precommercial and commercial thinning strategy, defines the harvest regime.[2] Using inputted data on slope to determine the logging method applied, and yield data specific to harvest regimes and habitat types groups, the model uses the stumpage valuation equation and projection data to calculate the future and present value of revenues. Future stumpage values per m.b.f., volumes per acre removed, and the average d.b.h. of trees harvested are outputted for each harvest entry within a harvest regime. The mean annual board foot increment produced under each management strategy is also calculated and displayed.

The regeneration harvest systems analyzed in this study are clearcutting and shelterwood cutting. Due to the paucity of available yield data, the number of commercial thinning regimes that would be analyzed with these final harvest strategies was severely limited (see Appendix A.2). Assumptions made concerning each harvest regime are contained in the results section of this chapter.

The managed stand yield tables used in the analysis are based upon habitat type groupings, of which there are three. Most of the

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[2]In this study an assumption is made that precommercial thinning at age 15 will be required on 90% of all managed stands.

Douglas-fir habitat types on the forest are contained in yield group CD.[3] This group comprises 41.5 per cent of the commercial forest land on the Lolo Forest, and produces an average net yield under intensive management of approximately 45 cubic feet/acre/year.[4] Habitat type group E contains Engelmann spruce, grand fir, western red cedar, and some subalpine fir habitat types. Projected net average yields are slightly in excess of 60 cubic feet/acre/year and group E lands comprise 30 per cent of the commercial area. White bark pine, mountain hemlock and less productive subalpine fir habitat types are contained in group F. This group is intermediate in productivity with estimated yields under intensive management of 53 cubic feet/acre/year. Group F lands comprise 25 per cent of the commercial land area. Habitat type groups A and B contain ponderosa pine and dry-site Douglas-fir habitat types. These groups were not included in the analysis due to limited yield information, but occupy only 3.5 per cent of the Forest's commercial land base.

The future timber revenues that will be generated on each habitat type group depend in part ont he timber species grown. The species mixes assumed in this study are: 1) 50% ponderosa pine : 50% Douglas-fir-larch, for group CD; 2) 30% ponderosa : 40% Douglas-fir-larch : 20% lodgepole pine : 5% Engelmann spruce : 5% western white pine, for group E; and 3) 40% Douglas-fir-larch : 50% lodgepole and other white woods : 10%

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[3]The vegetative habitat types contained within each group are listed in Appendix A.1.

[4]The volume is measured to a 6.5 inch minimum (outside bark) top diameter. An expected regeneration delay was not considered when calculating this figure.

Engelmann spruce, for group F.[5] The resultant weighted average lumber selling prices in 1978 dollars are $297.80, $237.10, and $221.28 per m.b.f. lumber tally, for groups CD, E, and F, respectively.[6] These prices are used in the calculation of both present and future stumpage values.

In this study the principle factors found to affect both timber management costs and revenues are slope and habitat type group. An "area class," the land unit on which the economic analysis is based, is defined on the basis of these two factors. In the output alphanumeric codes are used to denote each area class, with the letter referring to the habitat type group and the numeral referring to the slope category. The four slope categories used are: 1) 0-20%; 2) 20-40%; 3) 40-60%; and 4) greater than 60%.[7] Area class E-3 would thus refer to group E sites with slopes varying form 40 to 60 per cent.

The economic analysis was done using discount rates of 3.5, 5.0, and 6.5 per cent. The mid rate of 5.0 per cent was chosen since it is the rate recommended by the Forest Service in the 1976 Renewable Resources Program (U.S. GAO, 1978). The 6.5 per cent rate approximates the rate recommended by the Water Resources Council and the 3.5 per cent rate is the minimum rate recommended by the National Forest Products Association.

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[5]The species mixes to be grown on each habitat type group were estimated by Wes Kellie, Lolo National Forest silviculturalist.

[6]Lumber selling prices were determined from the "Western Wood Products Lumber Price Index (Inland species)" August, 1978.

[7]In the economic analysis the mid points of the slope classes, ie. 10, 30, 50, and 70 per cent, are used to calculate per acre stumpage revenues and management costs.

Results

Introduction

The results of the economic analysis for clearcutting and shelterwood cutting, with and without commercial thinning, are presented in this section. These analyses were done assuming continuation of present regeneration strategies. An analysis of an alternative, and more economically viable, regeneration strategy is also explained and discussed.

Clearcutting without commercial thinning

The current management strategy on clearcut areas is to site prepare and plant, as soon as practicable following harvesting. Initial plantings are normally done 2 years after harvesting and are 90 per cent successful. Interplantings, when necessary, are done in year 6 (and at 5 year intervals thereafter) and are 75 per cent successful.[8] The average delay period between clearcutting and successful stand establishment is 3 years.

The rankings of area classes by land expectation value (LEV) for the clearcutting without commercial thinning regime, at the three alternative discount rates, are shown in Table 11.[9]

With a 5.0 per cent discount rate none of the area classes produce a positive LEV and the optimal rotation length is generally

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[8]Initial plantings and interplanting success rates are discussed in Appendix C.5.

[9]This table is abbreviated to ease interpretation. Complete tables are listed in Appendix J.

TABLE 11

RANKING OF AREA CLASSES UNDER PRESENT MANAGEMENT STRATEGY

CLEARCUTTING WITHOUT COMMERCIAL THINNING

(Values are in 1978 dollars)*

Area Class	Rotation Age	Harv. Vol. (m.b.f.)	Price (FV/mbf)	MAI (bf)	PV_R	PV_C	LEV
5.0% Discount Rate							
E-1	63	10.530	$307.69	167	$157.10	$213.87	-56.77
CD-1	63	8.444	315.00	134	129.01	220.36	-91.35
F-1	63	9.342	200.77	148	90.94	212.73	-121.78
E-3	73	13.905	238.82	190	97.04	252.09	-155.05
CD-3	63	8.444	203.60	134	83.38	242.24	-158.66
F-3	73	9.342	121.01	144	37.21	250.13	-212.92
3.5% Discount Rate							
E-1	73	13.905	$350.25	190	$430.19	$258.39	$171.80
CD-1	63	8.444	315.08	134	343.98	272.48	71.50
E-3	73	13.905	238.82	190	293.33	308.26	-14.93
F-1	63	9.342	200.77	148	242.50	265.36	-22.87
CD-3	63	8.444	203.66	134	222.34	299.68	-77.35
F-3	73	10.523	121.01	144	112.48	302.35	-187.87
6.5% Discount Rate							
E-1	63	10.530	$307.69	167	$62.49	$187.10	-124.61
CD-1	63	8.444	315.08	134	51.31	194.33	-143.02
F-1	63	9.342	200.77	148	36.18	186.65	-150.47
CD-3	63	8.444	203.66	134	33.17	213.04	-179.87
E-3	63	10.530	196.26	167	39.86	227.35	-187.49
F-3	73	10.523	121.01	144	12.97	223.63	-210.67

*In this and succeeding tables:

FV = future (non-discounted) value

PV_R = present value of the revenues/acre

PV_C = present value of the costs/acre

LEV = land expectation value (PV_R - PV_C)

63 years. The volume and diameter growth that occurs beyond a stand age of 60 years is thus insufficient to offset the influence of a 5.0 per cent discount rate. The importance of slope is also illustrated by the table. The rankings indicate that this factor, which influences both stumpage values and management costs, may be as critical as productivity in identifying submarginal timberlands on the Lolo Forest. In addition, the least productive sites (with slope held constant) do not necessarily produce the lowest expected returns. For example, although habitat type group CD lands are slightly less productive than those in group F, the LEVs for group CD are consistently higher. THis is due to the more desirable species mix that can be grown on group CD lands and the larger average d.b.h. of the trees harvested.

At 3.5 per cent, clearcutting and planting produces positive LEVs on some of the more productive sites under 40 per cent slope. Land values are still negative, however, on all sites exceeding 40 per cent slope and on all habitat type group F lands. With this lower discount rate, the optimal rotation length has also shifted from 63 to 73 years in two of the area classes.

With a 6.5 per cent discount rate the present value of the revenues produced are relatively low for all area classes, i.e. between $12.97 and $62.49/acre. As a consequence, differences in management costs have more influence on the ranking than differences in projected revenues. Note also that the range of the expected land values is relatively narrow when compared to the rankings at 3.5 and 5.0 per cent. It can be seen that differences between the economic potential of area classes become less obvious as the discount rate is increased.

Clearcutting with commercial thinning

Lolo Forest personnel have developed three commercial thinning strategies for each habitat type group. The first two strategies consist of one commercial thinning at either age 70 or 80. The third strategy consists of two commercial thinnings at ages 70 and 100. Commercial thinning is always done from below, and the proportion of the volume removed varies from 25 to 35 per cent (see Appendix A.2).

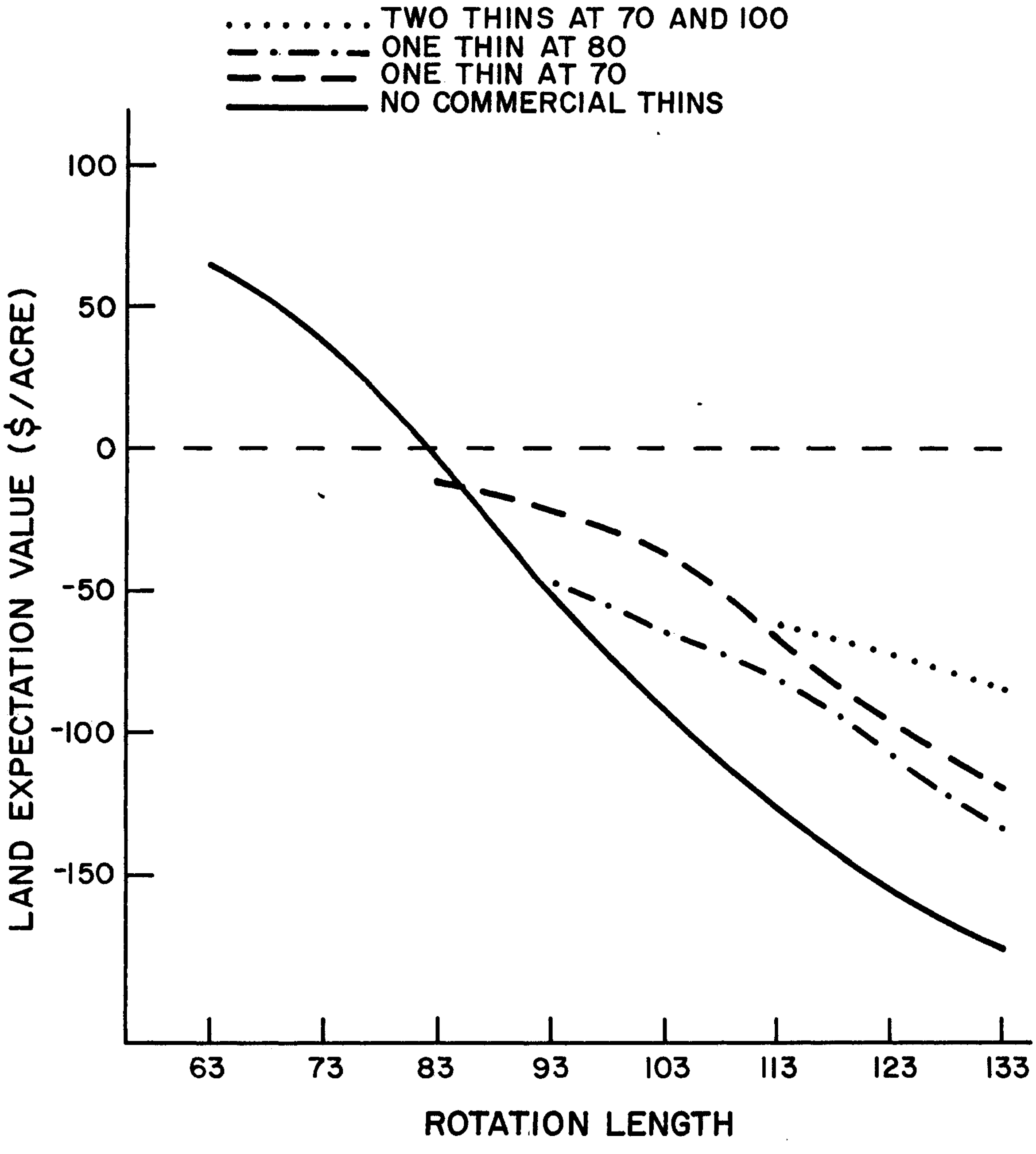
Graphs A and B show land expectation values with and without commercial thinning for area class CD-2. Graphs for other area classes are contained in Appendix I. The following general relationships, depicted by these graphs, are valid for all area classes under all tested regeneration regimes and discount rates:

1. Unless there is a compelling reason to have rotation lengths greater than 83 (or sometimes 93) years, clearcutting without commercial thinning is economically more efficient than any of the commercial thinning regimes tested. This inefficiency occurs regardless of the fact that high commercial thinning revenues are projected in this analysis. In the example, for instance, the per m.b.f. value of stumpage is $211.60, $237.95, and $290.72 for thinnings conducted at stand ages of 70,80, and 100 years, respectively.
2. Despite the volume and diameter growth response that occurs following commercial thinning, it is optimal to clearcut thinned stands as soon as practicable, i.e. 10 years, following thinning.

GRAPH A

ECONOMIC COMPARISON OF CLEARCUTTING REGIMES, WITH AND WITHOUT COMMERCIAL THINNING

AREA CLASS	:	CD - 2
REGENERATION METHOD	:	PLANTING
DISCOUNT RATE	:	3.5 %

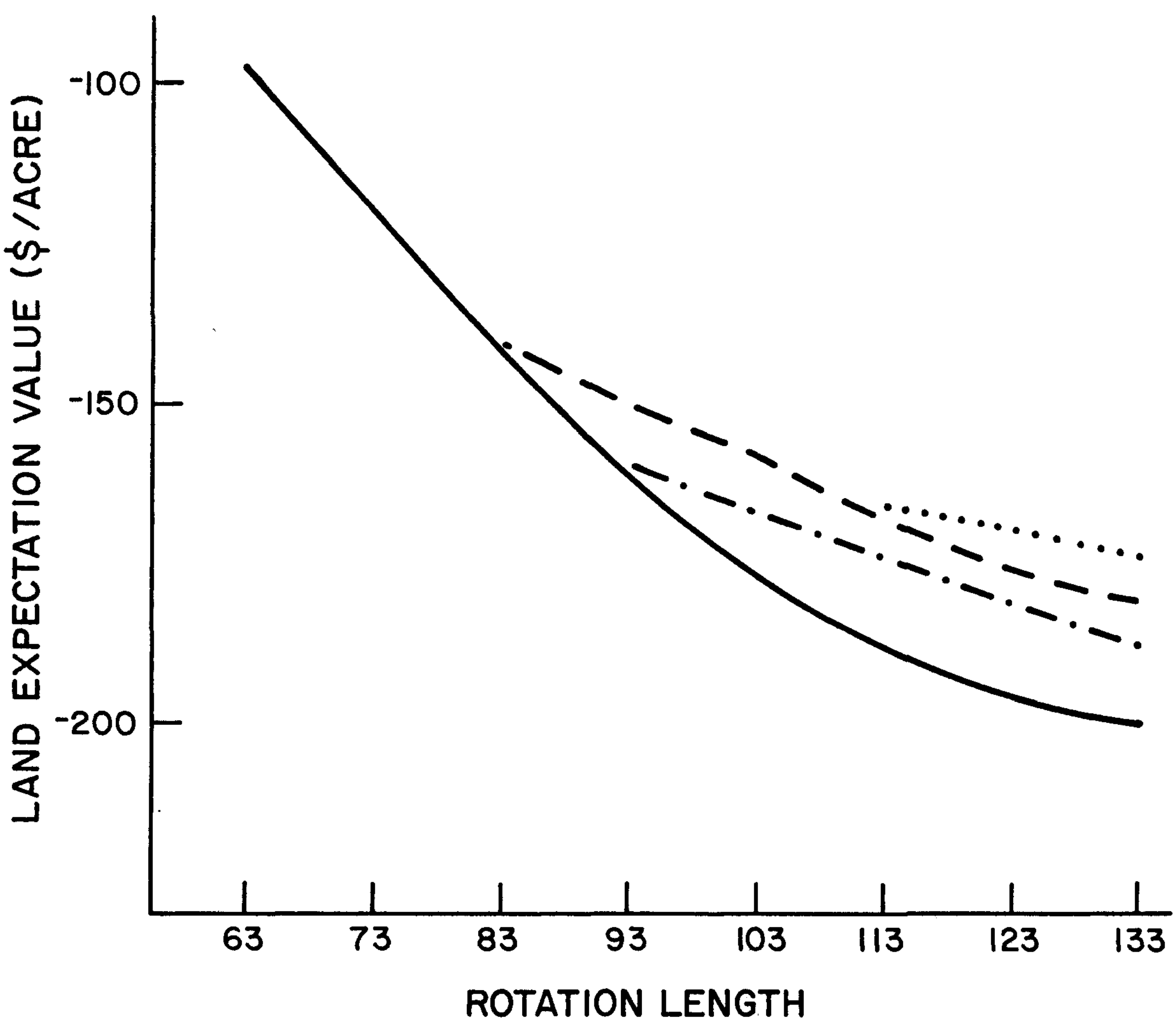


GRAPH B

ECONOMIC COMPARISON OF CLEARCUTTING REGIMES, WITH AND WITHOUT COMMERCIAL THINNING

AREA CLASS : CD - 2
REGENERATION METHOD : PLANTING
DISCOUNT RATE : 5.0 %

.... TWO THINS AT 70 AND 100
—·—·— ONE THIN AT 80
— — — ONE THIN AT 70
——— NO COMMERCIAL THINS



3. Thinning at a stand age of 70 is always more efficient than a similar thinning at age 80.
4. Two commercial thinnings at ages 70 and 100 produce lower land expectation values than one thinning at age 70 or 80, unless rotation lengths exceeding 113 years can be justified.

Shelterwood Cutting without Commercial Thinning

Two shelterwood regimes were analyzed for each habitat type group. The first regime consists of an initial entry at age 70 removing 65 per cent of the cubic foot volume. This is followed by an overstory removal which can occur at a minimum of 10 years following the initial entry. The second regime is analogous to the first but has its initial entry at age 80. Other possible shelterwood regimes could not be tested due to yield data deficiencies.

It is currently estimated that 50 per cent of the shelterwood units can be naturally regenerated within an average delay period of 5 years. In this analysis an assumption is made that the remaining units, that is those units in which natural regeneration fails, will be interplanted 6 years following harvesting with a planting success rate of 75 per cent. The average delay period between the initial shelterwood entry and successful stand establishment is 10 years. The ranking of area classes by land expectation value, for the three discount rates, are presented in Table 12.

With a 5.0 per cent discount rate, shelterwood cutting is shown to produce slightly higher land expectation values than clearcutting. This is primarily due to the lower regeneration costs incurred. When the value of the existing old growth inventory is considered, however,

TABLE 12

RANKING OF AREA CLASSES UNDER PRESENT MANAGEMENT STRATEGY

SHELTERWOOD CUTTING WITHOUT COMMERCIAL THINNING

(Values are in 1978 dollars)*

Area Class	Rot. Age	In.Ent. Harv.Vol. (mbf)	Price (FV/mbf)	Ov.Rem. Vol. (mbf)	Price (FV/mbf)	MAI (bf)	PV_R	PV_C	LEV
-5.0% Discount Rate									
E-1	80	9.038	$238.96	6.243	$339.82	191	$71.29	$122.04	-50.74
CD-1	80	6.393	245.61	4.283	354.05	133	51.50	120.47	-68.96
F-1	80	6.840	126.12	4.588	233.42	143	31.30	120.73	-89.42
CD-3	80	6.393	134.19	4.283	242.62	133	30.80	131.42	-100.62
E-3	80	9.038	127.53	6.243	228.39	191	41.76	154.86	-113.10
F-3	80	6.840	14.70	4.588	122.00	143	9.15	153.55	-144.40
3.5% Discount Rate									
E-1	80	9.038	$238.96	6.243	$339.82	191	$249.64	$162.29	$80.36
CD-1	80	6.393	245.61	4.283	354.05	133	180.24	163.84	16.40
F-1	80	6.840	126.12	4.588	233.42	143	110.52	164.73	-54.22
E-3	90	10.995	154.05	7.348	249.72	204	141.84	201.94	-60.10
CD-3	80	6.393	134.19	4.283	242.62	133	108.65	179.19	-70.54
F-3	90	7.264	48.46	5.991	163.71	135	40.02	196.37	-156.35
6.5% Discount Rate									
E-1	80	9.038	$238.96	6.243	$339.82	191	$21.48	$97.37	-75.89
CD-1	80	6.393	245.61	4.283	354.05	133	15.53	96.89	-81.37
F-1	80	6.840	126.21	4.588	233.42	143	9.36	96.87	-87.61
CD-3	80	6.393	134.19	4.283	242.62	133	9.22	105.08	-95.87
E-3	80	9.038	127.53	6.243	228.39	191	12.49	126.82	-114.34
F-3	80	6.840	14.70	4.588	122.00	143	2.60	128.79	-126.19

*This is an abbreviated table. Complete tables are presented in Appendix J. The rotation age is always 10 years greater than the stand age at initial entry because of the average 10 year delay between harvesting and successful stand establishment. Except for area class F-3, overstory removals produce optimal returns when conducted 10 years following the initial entry.

shelterwood cutting is economically less efficient due to the lower per unit logging costs, and resultant higher stumpage values, associated with clearcutting.

With a 3.5 per cent discount rate, the shelterwood regime produces lower land expectation values than clearcutting on all but the steepest and least productive area classes. At this lower discount rate the ranking of area classes is based primarily on the revenues produced, not the costs incurred. Shelterwood cutting appears less economical than clearcutting because of the lower expected values of stumpage.

With a 6.5 per cent discount rate, the range of the present values of expected revenues is extremely narrow, i.e. from $2.60 to $21.48 per acre. Because costs overwhelm revenues at this discount rate, the area classes which can be managed at the lowest costs will always produce the highest expected land values, regardless of the volumes per acre produced. Since the regeneration costs associated with shelterwood cutting are lower than those associated with clearcutting, shelterwood cutting appears preferable to clearcutting at this higher discount rate.

Shelterwood Cutting with Commercial Thinning

The two commercial thinning regimes analyzed were thinning at either age 70 or 80, followed by an initial shelterwood harvest at age 100. Other possible strategies were not tested due to yield data limitations.

Land expectation values for shelterwood regimes, with and without commercial thinning, are compared in Table 13. As is the case with clearcutting regimes, commercial thinnings produce significantly lower land expectation values than those without. Additionally, thinning at age 70 is generally preferable to thinning at age 80.

TABLE 13

ECONOMIC COMPARISONS OF SHELTERWOOD REGIMES,

WITH AND WITHOUT COMMERCIAL THINNING

(Land Expectation Values/Acre - 1978 Dollars)

Area Class	No Commercial Thinning Initial S.W. Entry Age		Initial S.W. Entry Age 100 Commercial Thinning Age	
	70	80	70	80
-3.5% Discount Rate				
CD-1	16.40	-14.98	-14.57	-33.61
CD-3	-70.54	-82.22	-83.45	-91.62
E-1	80.36	63.25	32.37	25.51
E-3	-60.44	-60.10	-76.38	-80.14
F-1	-54.22	-62.78	-69.82	-79.28
F-3	-166.65	-156.35	-163.79	-162.65
5.0% Discount Rate				
CD-1	-68.96	-82.59	-85.24	-91.38
CD-3	-100.62	-106.66	-109.31	-111.74
E-1	-50.74	-62.89	-76.61	-78.82
E-3	-113.10	-117.12	-125.62	-126.32
F-1	-89.42	-94.61	-98.89	-101.34
F-3	-144.80	-141.50	-145.22	-144.06
6.5% Discount Rate				
CD-1	-81.37	-86.75	-87.31	-89.46
CD-3	-95.87	-98.42	-99.17	-100.01
E-1	-75.89	-81.54	-85.31	-86.28
E-3	-114.34	-116.67	-119.15	-119.42
F-1	-87.61	-89.93	-91.05	-91.85
F-3	-123.82	-123.10	-124.31	-123.81

Analysis of Alternative Regeneration Regimes

Due to the high cost of planting, the present assumption that all clearcut sites, and 50 per cent of the shelterwood cut sites, must be hand-planted with conifers is economically untenable. To illustrate the sensitivity of the analysis to planting costs, five alternative regeneration regimes were tested with each harvest regime. These regimes were constructed by assuming that the probability of natural regeneration success, within an average delay period of five years, could be either 20, 40, 60, 80, or 100 per cent. With these alternative regimes, natural regeneration failures are assumed to be interplanted after an average delay period of six years. The assumed success rate on these interplantings, within five year subsequent delay periods, is 75 per cent.

The results of the analysis, using discount rates of 3.5 and 5.0 per cent, are shown in tables 14 and 15. In each of these tables the solid line separates out those opportunities with positive land expectation values. The dashed lines distinguish natural regeneration regimes which produce higher land expectation values than full scale planting, immediately following harvesting.

The analysis shows that many area classes, which produce negative land expectation values when planted, can produce positive land values if natural regeneration is accomplished. Furthermore, it may be desirable to attempt natural regeneration even when the probability of success is low. With a 5.0 per cent discount rate, for example, natural regeneration produces higher expectation values than planting when the probability of success is only 20 per cent. This applies to all area classes, whether clearcut or shelterwood cut. When a 3.5 per cent discount rate is used,

TABLE 14

CLEARCUTTING WITHOUT COMMERCIAL THINNING

LAND EXPECTATION VALUES/ACRE

(1978 $)

Area Class	Stand Age at Rotation	0.0*	20.00	40.00	60.00	80.00	100.00
		Probability of N.R. Success					
5.0 % Discount Rate							
E-1	60	-56.77	-52.18	-27.37	2.45	28.16	59.84
E-2	60	-61.72	-55.48	-30.84	-1.38	24.13	55.37
CD-1	60	-91.35	-69.57	-45.66	-17.78	6.88	36.28
CD-2	60	-96.30	-72.87	-49.12	-21.61	2.84	31.81
F-1	60	-121.78	-95.51	-72.94	-47.96	-24.87	1.13
F-2	60	-126.73	-98.80	-76.40	-51.79	-28.91	-3.34
E-3	60	-158.01	-125.24	-101.37	-75.20	-50.82	-23.65
CD-3	60	-158.86	-112.99	-89.60	-64.46	-40.63	-14.67
E-4	60	-167.10	-128.54	-104.84	-79.04	-54.86	-28.12
CD-4	60	-167.95	-116.29	-93.07	-68.30	-44.67	-19.64
F-3	60	-216.61	-164.29	-142.44	-120.64	-98.62	-76.56
F-4	60	-225.70	-167.59	-145.90	-124.48	-102.65	-81.03
3.5 % Discount Rate							
E-1	70	171.80	111.64	147.55	195.16	232.67	283.52
E-2	70	165.14	106.69	142.41	189.64	226.94	277.35
CD-1	60	71.50	43.03	77.34	120.90	156.73	203.30
CD-2	60	64.59	37.95	72.05	115.20	150.81	196.90
E-3	70	-14.93	-31.04	2.38	42.76	77.26	119.78
F-1	60	-22.87	-33.40	-2.04	35.26	67.77	107.24
E-4	70	-26.01	-35.99	-2.76	37.23	71.53	113.60
F-2	60	-29.78	-38.49	-7.32	29.56	61.85	100.85
CD-3	60	-77.35	-64.79	-32.55	4.62	37.91	77.04
CD-4	60	-88.84	-69.88	-37.83	-1.08	31.99	70.64
F-3	70	-189.87	-161.12	-135.31	-102.51	-73.47	-42.57
F-4	70	-200.94	-166.07	-137.71	-108.03	-79.21	-48.75

*This represents the current management strategy which is to plant all clearcut sites, as soon as practicable following harvesting.

TABLE 15

SHELTERWOOD CUTTING WITHOUT COMMERCIAL THINNING

LAND EXPECTATION VALUES/ACRE

(1978 $)

Area Class	Stand Age at Rotation	0.0	20.0	40.0	50.0*	60.0	80.0	100.0
		Probability of N.R. Success						
		5.0 % Discount Rate						
E-1	70	-106.78	-85.77	-63.00	-50.74	-37.33	-14.05	12.66
E-2	70	-111.64	-89.03	-66.42	-54.17	-41.12	-18.03	8.26
CD-1	70	-140.97	-103.11	-81.22	-68.96	-57.46	-35.21	-10.73
CD-2	70	-145.83	-106.36	-84.64	-72.39	-61.25	-39.19	-15.12
F-1	70	-161.67	-122.57	-101.68	-89.42	-80.07	-58.97	-36.99
F-2	70	-166.53	-125.83	-105.10	-92.85	-83.85	-62.95	-41.38
CD-3	70	-191.83	-135.67	-113.73	-100.62	-91.49	-69.40	-46.89
CD-4	70	-200.75	-138.93	-117.16	-104.04	-95.27	-73.38	-51.29
E-3	70	-192.23	-148.58	-126.21	-113.10	-103.03	-80.44	-56.83
E-4	70	-201.15	-151.84	-129.64	-116.52	-106.81	-84.41	-61.23
F-3	80	-231.51	-175.35	-154.51	-144.40	-134.47	-113.68	-93.78
F-4	80	-240.33	-178.58	-157.91	-147.83	-138.22	-117.62	-98.13
		3.5 % Discount Rate						
E-1	70	66.62	32.97	65.93	80.36	107.31	141.51	185.34
E-2	70	59.34	28.02	60.80	75.22	101.78	135.77	179.16
CD-1	70	-25.98	-28.68	1.98	16.40	38.47	70.07	108.40
CD-2	70	-32.63	-33.63	-3.16	11.27	32.94	64.34	102.22
F-1	70	-108.46	-96.76	-68.65	-54.22	-37.56	-8.81	23.43
F-2	70	-115.11	-101.71	-73.78	-59.35	-43.08	-14.55	17.25
E-3	80	-114.54	-105.29	-75.25	-60.10	-41.52	-10.87	24.03
E-4	80	-125.34	-110.15	-80.28	-65.13	-46.93	-16.48	17.99
CD-3	70	-145.00	-115.44	-85.99	-70.54	-54.03	-23.98	9.05
CD-4	70	-156.07	-120.39	-91.13	-75.67	-59.56	-29.72	2.88
F-3	80	-238.61	-198.14	-171.50	-156.35	-144.98	-118.14	-91.32
F-4	80	-249.41	-203.00	-176.54	-161.39	-150.39	-123.75	-97.36

*This is the assumed current regeneration strategy on shelterwood cut units.

the value of planting is directly related to the economic potential of the site. On high valued area classes, the probability of natural regeneration success must be 60 per cent or greater before natural regeneration is preferable to planting. On low valued area classes exceeding 40 per cent slope, this percentage need only be 20 per cent or greater.

Chapter 7

CONCLUSION

The portion of the Lolo National Forest land base which is "economically efficient" to manage is highly dependent upon the discount rate and regeneration assumptions used.

With a 6.5 per cent discount rate, little if any of the land on the forest can produce a positive land expectation value, even when natural regeneration can be accomplished within five years. The outlook using a 5.0 per cent discount rate is only slightly more favorable, unless regeneration and other management costs can be substantially reduced. If a 3.5 per cent discount rate can be justified, the outlook is significantly more optimistic. Sites with slopes greater than 40 per cent, and/or in habitat type group F, will not produce this rate of return, however, unless substantial reductions in management costs can be accomplished.

While more reliance on natural regeneration would result in longer average delay periods between harvesting and successful stand establishment, this slight loss in potential productivity is outweighed by the substantial increases in land expectation value that could be realized. This is true regardless of the discount rate or harvest system applied. Without reductions in regeneration costs, intensive management on many of the area classes on the forest may be hard to justify. Undoubtedly, factors such as aspect, habitat type, and timber type significantly affect the probability of natural regeneration success and, in turn, the suitability of lands for timber management. However, additional research and more exact data recordation are required before the importance of these variables can be measured (see Appendix A.3). In the interim, forest personnel should concentrate their efforts on reducing the harvested acreage that requires planting and on lowering per acre planting costs. This is especially critical on steep slopes, i.e., greater than 40 per cent, where all land values under current management strategies are negative, even when using a 3.5 per cent discount rate.

Clearcutting is substantially more efficient than shelterwood cutting except at a discount rate of 6.5 per cent, or on area classes with extremely negative land expectation values. This is due to the higher logging costs, and subsequent lower stumpage values, associated with shelterwood cutting. It is also a consequence of the relatively low level of natural regeneration success currently accomplished with shelterwood cutting. In individual circumstances, where shelterwood cutting could result in natural regeneration while clearcutting could not, the shelterwood harvest regime may be more efficient. Research is needed to determine, and minimize, the factors which create the currently large difference in value between clearcut and shelterwood cut stumpage. In addition, alterations of the general shelterwood cutting strategy could possibly result in higher land expectation values than indicated in this study.

Three important principles demonstrated by this analysis are independent of the discount rate, regeneration regime, or final harvest system applied. These are:

1) The commercial thinning regimes developed by forest personnel are economically inefficient, unless an increase in external benefits (e.g. wildlife), or a decrease in external costs (e.g. water quality), can justify relatively long rotations.
2) Slope, and the species mix that can be grown on a site, significantly affect land expectation values. These factors must be considered together with productivity when identifying submarginal timber lands.
3) The ranking of area classes by land expectation value is only slightly influenced by changes in regneration regimes or the discount rate. The rankings thus provide a reliable means of determining where investment dollars should first be spent.

There are several problems associated with this analysis which deserve elaboration. Solutions to these problems could significantly affect the acreage deemed "suitable" for timber management on the Lolo National Forest.

The board foot volumes used in both the yield tables and the stumpage valuation model are measured to a 6.5 inch minimum, outside bark, top diameter. An implicit assumption is thus made that logs smaller than 6.5 inches in diameter will be nonmerchantable in the future. Recent trends in the utilization of smaller logs show the fallacy of this assumption. The future values of stumpage, particularly for small d.b.h. trees, are therefore most likely underestimated in this study. If the yield tables and stumpage valuation model were based on total cubic foot log volumes, this problem could be eliminated.

When personnel developed the commercial thinning strategies tested in this analysis, thinnings which produce less than 1,000 cubic feet per acre were assumed to be uneconomical. As a consequence, the thinnings are scheduled for most stands after culmination of mean annual cubic foot increment is reached. This accounts, in part, for the poor economic performance of the thinning regimes. Thinnings done prior to culmination of MAI would increase the d.b.h. of trees at final harvest and perhaps increase land expectation values over those obtained from clearcutting or shelterwood cutting alone. With earlier commercial thinnings, the number of stands requiring precommercial thinning could also be reduced and the number of leave trees in a precommercial thinning could be increased. Both of these factors would lower costs and possibly result in an increase in per acre yeilds, since more of the natural mortality could be captured. The proportion of the volume removed in a commercial thinning and the type of thinning, i.e. thinnings may be done from above or below, could also be critical in arriving at an economically optimal harvest regime. The precommercial and commercial thinning strategies tested in this analysis may thus be far from optimal. To determine optimal strategies for each area class, a growth and yield model, such as that developed by Stage (1973), should be made applicable to the Lolo National Forest.

The analysis shows that the species mix grown on a site, and the associated lumber selling price has a significant influence on land expectation value. The importance of this factor may be exaggerated, however, because of the method in which lumber price indices are determined. The price indices developed by the Western Wood Products Association are based on hypothetical recovery logs representing each species growth range. The indices for lodgepole pine and white woods are thus based on smaller average diameter logs than the indices for species such as ponderosa pine or Douglas fir. With d.b.h. held constant (as was done in this analysis), the indices underestimate the value of characteristically small species (e.g. lodgepole) and overestimate the value of relatively large species (e.g. ponderosa). The difference in land expectation value due to species mix is thus probably less than indicated in this study. To correct this problem, the lumber price indices for each species would have to be adjusted to a common base.

Section 6(1)(1) of the National Forest Management Act requires determination of timber management costs and revenues on a "representative sample basis". The habitat type groups and resultant yield tables, developed by Lolo Forest personnel, appear to be unrepresentative of the range of site indices present on the forest. According to Pfister, et al. (1977), the productivity of habitat types contained within Lolo groups C, D, E, and F vary from approximately 20 to 100 cubic feet per acre per year. Yield tables developed by Alan McQuillan, using Lolo Forest Stand data and Stage's (1973) growth model, show productivity within these same groups ranging from 22 to

62 cubic feet per acre per year.[1] When these habitat types are placed into the Lolo's groups, however, productivity varies from only 45 to 60 cubic feet per acre per year. To correct this deficiency, additional yield groups should be developed.

This study considers the economic suitability of lands for timber growing only, since neither opportunity costs, nor multiple-use benefits, are explicitly analyzed. Externalities are considered indirectly, however, in the determination of stumpage values. For example, more costly logging methods, and sale size and design decisions that are currently employed, are used to mitigate external costs or enhance external benefits. The stumpage values projected in this analysis are thus somewhat lower than would be expected if lands were being managed solely for timber production.

In the "Draft of Revised Proposed Rules" developed by the Forest Service to implement Section 6(k) of NFMA, it is stated that standing inventory values will be considered (along with land expectation values) to determine the lands suitable for timber management (USDA Forest Service, 1979). Presumably, suitability would then depend on whether the sum of the standing inventory and land expectation value is positive or negative. If this method of identifying suitable lands is in fact implemented, the following considerations must be made:

1) The area classes on the Lolo National Forest which have consistently negative land expectation values are those which require cable logging, i.e. area classes with slopes exceeding

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[1]Personal discussion, Spring, 1979.

40 per cent. Standing inventory values are also correspondingly low on these sites.

2) Road construction costs must be considered if standing inventory and land expectation values are combined. In addition, the factors affecting road costs (e.g. slope, underlying parent material) should be statistically analyzed.

3) Timber sale preparation and administration costs are not accounted for in the stumpage valuation equation. These costs, now estimated to total $26.16 per m.b.f., must be subtracted from the value of the standing inventory.

4) The value of the existing inventory is considerably greater if stands are clearcut rather than shelterwood cut. In the 52 timber sales analyzed by Jackson and McQuillan, only 17 per cent of the total area was clearcut, however. The value of the standing inventory should be based on the harvest system that will be used on the site, not the one that will produce the highest present valu

With a 5.0 per cent discount rate, most sites on the Lolo National Forest do not generate positive land expectation values. Inclusion of standing inventory values, when using this discount rate, would thus increas the acreage classified as suitable for timber management. The addition of standing inventory and land expectation values could reduce the acreage classified as economically suitable if a 3.5 per cent discount rate is used, since the value of the standing inventory is negative, or nearly so, on many of the steeper sites on the forest. In addition, some of the sites containing stagnated or poorly stocked stands may have positive land expectation values and negative standing inventory values.

The major findings and contributions of this study are now summarized. Because of the aforementioned problems and the dilemma concerning the appropriate discount rate, this summary contains no specific recommendations on the lands which should be classified as economically suitable for timber production.

1) It is feasible to statistically analyze the site and policy variables which affect both timber management costs and revenues. In particular, the slope of a site may be as important as site productivity in identifying economically submarginal timber lands on the Lolo Forest.
2) A method of predicting future stumpage values on a site specific basis has been developed. This method utilizes the most recent cost, price, and overrun projections available, while maintaining the relationships inherent in Jackson and McQuillan's (1979) stumpage valuation equation.
3) Sites have been ranked, by land expectation value, under a variety of management regions and discount rates. These rankings provide a means of establishing spending priorities, where investment funds are limited. The economic consequence of selecting a "suboptimal timber regime", to protect or enhance other multiple-use values, can also be determined from these rankings.

4) The commercial thinning regimes developed for the forest were shown to be economically inefficient, unless an increase in external benefits (e.g. aesthetics) or a decrease in external costs (e.g. water quality) can be used to justify relatively long rotations.

5) Clearcutting is significantly more efficient than shelterwood cutting except at a 6.5 per cent discount rate or on area classes with extremely negative land expectation values. This is due to the higher stumpage revenues generated by clearcutting, and the relatively low level of natural regeneration success associated with shelterwood cutting.

6) The major unresolved problems in need of further analysis or action are as follows:

   a) Factors which affect both artificial and natural regeneration success must be identified. To accomplish this, better regeneration inspection procedures and more exact data recordation are required of forest personnel. Research aimed at reducing regeneration costs is also critical, since the cost of stand establishment is typically the most difficult to justify.

   b) The yield tables developed by Lolo Forest personnel appear to be unrepresentative of the range of site indices present on the forest.

   c) Research is needed to determine the precommercial and commercial thinning strategies that are economically optimal on each area class. This could be accomplished if a growth and yield model, such as that developed by stage (1973) is made applicable to the Lolo Forest.

d) Yield tables and stumpage valuation equations, used to predict land expectation values, should be based on total cubic foot log volumes. Because the volumes used in this study were measured to a 6.5 inch minimum top diameter, an implicit (and fallacious) assumption was made that merchantibility standards would not change. Small diameter trees are thus most likely undervalued in this study.

e) The comparative value of timber species with d.b.h. held constant, must be determined. Because of problems associated with the lumber price indices, this analysis most likely underestimates the value of characteristically small species (e.g. lodgepole) and overestimates the value of large species (e.g. ponderosa).

The statistical models described in this study and the supply model used to perform the economic analysis are valuable tools that have many applications beyond the scope of this analysis. These models are not exact, however, and the relationships that they explain are dynamic. A mechanism for revising and improving these models as situations change should be established.

Many of the problems, concerning the economic suitability of lands for timber production, may have to be dealt with subjectively. Hopefully, this analysis provides a sound basis for making both objective and subjective land management decisions.

APPENDIX A.1

Listing of Habitat Type Groups

The yield tables developed by the Lolo National Forest are based upon the habitat groupings listed in this appendix. Descriptions of the habitat types comprising each group are contain in "Forest Habitat Types of Montana" (Pfister, et al. 1977).

Habitat type	Acres on Forest	Habitat type	Acres on Forest
- - -Habitat type group A- - - - - - - -		-Habitat type group B- - - - - -	
PP/Agsp	933	DF/Agsp	257
PP/Syal	905	DF/Feid	116
		DF/Fesc	43,723
	1,838	DF/Syal-Agsp Phase	1,390
		DF/Caru-Agsp Phase	5,800
			51,286

Acres in Habitat type groups A and B 53,124
Percent of forest in combined h.t. group A and B 3%

Habitat type	Acres on Forest	Habitat type	Acres on Forest
- - -Habitat type group C- - - - - - -		-Habitat type group D- - - - - - -	
DF/Vaca	19,425	DF/Xete	231,988
DF/Phma	204,048	DF/Xete-Vagl Phase	358
DF/Phma-Phma Phase	56,048	DF/Xete-Aruv Phase	107
DF/Phma-Caru Phase	61,877	DF/Vagl	623
DF/Syal	21,458	DF/Vagl-Vagl Phase	179
DF/Syal-Caru Phase	3,163	DF/Libo	6,176
DF/Syal-Syal Phase	15	DF/Libo-Caru Phase	127
DF/Caru-Aruv Phase	7,865	DF/Caru	78,228
DF/Caru-Pipo Phase	3,840	DF/Caru-Caru Phase	6,879
DF/Arco	55	DF/Cage	2,615
		DF/Aruv	44
	378,722		
			327,324

Acres in Habitat type groups C and D 706,046
Percent of forest in combined h.t. group C and D 36%

Habitat type	Acres on Forest	Habitat type	Acres on Forest
-Habitat Type Group E-			
S/Eqar	36	AF/Opho	309
S/Gatr	25	AF/Clun	72,180
S/Libo	636	AF/Clun-Clun Phase	74
GF/Xete	144,756	AF/Clun-Vaca Phase	37
GF/Clun	47,708	AF/Clun-Xete Phase	2
GF/Clun-Clun Phase	3	AF/Clun-Mefe Phase	107
WRC/Clun	68,018	AF/Gatr	1,281
WRC/Clun-Clun Phase	7	AF/Caca	1,719
WRC/Clun-Arnu Phase	115	AF/Libo	2,504
WRC/Clun-Mefe Phase	7	AF/Libo-Libo Phase	19
WRC/Opho	381	AF/Libo-Vasc Phase	34
WH/Clun	507	AF/Mefe	173,769
		MH/Mefe	705
		Total E	514,939

Percent of forest in h.t. group E 26%

-Habitat Type Group F-			
AF/Vaca	1,755	AF(WBP)/Vasc	2,797
AF/Xete	346,732	AF/Luhi	77,031
AF/Xete-Vagl Phase	611	AF/Luhi-Vasc Phase	277
AF/Xete-Vasc Phase	785	AF/Luhi-Mefe Phase	198
MH/Xete	2,670	WBP-AF	425
AF/Vagl	1,108	WBP	41
AF/Vasc	2,560		
		Total F	436,990

Percent of forest in h.t. group F 22%

APPENDIX A.2

Yield Tables: Explanation

The managed stand yield tables used in this study were developed by Bob Meuchel of the Lolo National Forest Timber Management Planning Staff. They are based on an assumption that all stands will be precommercially thinned to a density of 300 trees per acre at age 15. The habitat types which apply to each yield table are listed in appendix A.1.

When these tables were first constructed, the expected relationship between age and average tree diameter was not determined. To correct this deficiency, silviculturalists working on the forest were asked to estimate the average diameter of crop trees for each 10 year increment on each yield table. The diameters shown in the tables are averages of these estimates.

Because of the difficulty of estimating the diameter and volume growth response following a commercial thinning, only two commercial thinning strategies were developed for each habitat type (yield table) grouping. The first strategy consists of one commercial thinning at age 80. The second strategy consists of two commercial thinnings at ages 70 and 100. The proportion of the volume removed in each commercial thinning also varies according to the habitat type grouping and the age of the stand at the time of thinning.

The shelterwood cutting strategies that can be tested are also limited, since the growth response following the initial entry is difficult to determine. In this study initial shelterwood entries are treated as if they were heavy commercial thins. The initial entry can thus occur only at ages 70, 80, or 100. The percentage volume growth response following the initial shelterwood entry is assumed to be identical to the growth response obtained by commercially thinning the stand at the same age. One commercial thinning may precede the initial shelterwood entry.

The yield tables used in this study are listed on the following pages. For each of these tables the following statements apply:

1. The d.b.h. values given represent the average outside bark diameter of crop trees, prior to commercial thinning.
2. Commercial thinning is always done from below. The average diameter of the trees thinned is assumed to be one inch less, and the average diameter of the residual stand is assumed to be one-half inch greater, than the average diameter of the stand prior to thinning.
3. In commercial thinnings, the per cent volume removed is in cubic foot measurements (6.5 inch minimum, outside bark, top diameter). In terms of the percentages given, the proportion of the board foot volume removed is slightly less.
4. The average diamters of the harvest and residual trees in a shelterwood entry are assumed to be identical.
5. Thinning volumes are included in the M.A.I. calculations.
6. Any inconsistencies in these yield tables are not the responsibility of this researcher.

YIELD TABLE 1(a)

Habitat Type Group C D

One Commercial Thinning at age 80

Age	d.b.h. (inches)	Net CF vol/acre	Thinning vol. CF/acre	Net BF vol/acre	Thinning vol. BF/acre	M.A.I. CF/acre/year	M.A.I. BF/acre/year
40	6.9	1450		4497		36.25	112.43
50	8.3	2186		6682		43.72	133.64
60	9.9	2694		8444		44.90	140.73
70	11.3	3012		9835		43.03	140.50
80	12.6	3181	954	10108	3110	39.76	126.35
90	14.3	2557		9256		39.01	127.40
100	15.5	2888		11032		38.42	141.42
110	16.5	3219		12908		37.94	145.62
120	17.4	3137		13681		34.09	139.93
130	18.1	3143		13358		31.52	126.68

*30 percent of volume thinned at age 80.

YIELD TABLE 1(b)

Habitat Type Group C D

Two commercial thinnings at ages 70 and 100

Age	d.b.h. (inches)	Net CF vol/acre	Thinning vol. CF/acre	Net BF vol/acre	Thinning vol. BF/acre	M.A.I. CF/acre/year	M.A.I. BF/acre/year
40	6.9	1450		4497		36.25	112.43
50	8.3	2186		6682		43.72	133.64
60	9.9	2694		8444		44.90	140.73
70	11.3	3012	1054	9835	3299	43.03	140.50
80	13.2	2371		8133		42.81	142.90
90	14.3	2784		10078		42.64	148.63
100	15.4	3197	1119	12213	4051	42.51	155.12
110	17.3	2491		9989		42.40	157.63
120	18.4	2904		12110		42.31	162.17
130	19.5	3238		13762		41.62	162.40
140	20.4	3200		13504		38.38	148.96

* 35 percent of volume thinned at age 70 and at age 100.

YIELD TABLE 1 (c)

Habitat Type Group C D

No Commercial Thinnings

Age	d.b.h. (inches)	Net CF vol/acre	Net BF vol/acre	M.A.I. CF/acre/year	M.A.I. BF/acre/year
60	9.9	2694	8444	44.90	140.73
70	11.3	3012	9835	43.03	140.50
80	12.6	3181	10908	39.76	136.35
90	13.6	3238	11716	35.98	130.18
100	14.4	3224	12312	32.24	123.12
110	15.1	3177	12749	28.88	115.90
120	15.7	3137	13080	26.14	109.00
130	16.2	3143	13359	24.18	102.76

YIELD TABLE 2(a)

Habitat Type Group E

One Commercial Thinning at age 80

Age	d.b.h. (inches)	Net CF vol/acre	Thinning vol. CF/acre	Net BF vol/acre	Thinning vol. BF/acre	M.A.I. CF/acre/year	M.A.I. BF/acre/year
40	7.4	1569		5125		39.23	128.13
50	9.0	2231		7358		44.60	147.16
60	10.5	3002		10531		50.03	175.52
70	11.9	3761		13905		53.73	198.64
80	13.1	4419	1326	16915	4906	55.24	211.44
90	14.6	3822		14906		57.20	220.93
100	15.8	4551		17885		58.77	227.91
110	16.9	5280		20645		60.05	232.28
120	17.9	5211		20114		54.48	208.50
130	18.9	4998		18942		48.65	183.45

*30 percent of volume thinned at age 80.

YIELD TABLE 2(b)

Habitat Type Group E

Two Commercial Thinnings at ages 70 and 100

Age	d.b.h. (inches)	Net CF vol/acre	Thinning vol. CF/acre	Net BF vol/acre	Thinning vol. BF/acre	M.A.I. CF/acre/year	M.A.I. BF/acre/year
40	7.4	1569		5125		39.23	128.13
50	9.0	2231		7358		44.62	147.16
60	10.5	3002		10531		50.03	175.52
70	11.9	3761	940	13905	3299	53.73	198.64
80	13.6	3552		13604		56.15	211.28
90	14.7	4283		16704		58.03	222.26
100	16.0	5014	1504	19705	5866	59.54	230.04
110	17.7	4084		15968		59.35	228.48
120	18.9	4658		17980		59.18	226.21
130	20.1	5232		19829		59.05	223.03

*25 percent of volume thinned at age 70; 30 percent of volume thinned at age 100.

YIELD TABLE 2 (c)

Habitat Type Group E

No Commercial Thinnings

Age	d.b.h. (inches)	Net CF vol/acre	Net BF vol/acre	M.A.I. CF/acre/year	M.A.I. BF/acre/year
60	10.5	3002	10531	50.03	175.50
70	11.9	3761	13905	53.73	198.64
80	13.1	4419	16915	55.24	211.44
90	14.1	4912	19173	54.58	212.48
100	15.0	5207	20461	52.07	204.61
110	15.7	5299	20739	48.17	188.54
120	16.4	5211	20137	43.43	167.81
130	17.6	4998	18962	38.45	145.86

YIELD TABLE 3(a)

Habitat Type Group F

One Commercial Thinning at age 80.

Age	d.b.h. (inches)	Net CF vol/acre	Thinning vol. CF/acre	Net BF vol/acre	Thinning vol. BF/acre	M.A.I. CF/acre/year	M.A.I. BF/acre/year
40	6.7	1211		4097		39.28	102.43
50	7.6	2538		7323		50.76	146.46
60	8.8	3196		9342		53.27	155.70
70	9.9	3418		10523		48.83	150.33
80	10.9	3394	1188	11176	3659	42.43	139.70
90	12.5	2646		9340		42.60	144.43
100	13.5	3086		11511		42.74	151.70
110	14.1	3141		12124		39.35	143.48
120	14.7	3217		12482		36.71	134.51
130	15.2	3200		12256		33.75	122.42

* 35 percent of volume thinned at age 80

YIELD TABLE 3(b)

Habitat Type Group F

Two Commercial Thinnings at ages 70 and 100

Age	d.b.h. (inches)	Net CF vol/acre	Thinning vol. CF/acre	Net BF vol/acre	Thinning vol. BF/acre	M.A.I. CF/acre/year	M.A.I. BF/acre/year
40	6.7	1211		4097		39.28	102.43
50	7.6	2538		7323		50.76	146.46
60	8.8	3196		9342		53.27	155.70
70	9.9	3418	1196	10523	3492	48.83	150.33
80	11.6	2662		8758		48.23	153.13
90	12.7	3102		10950		47.76	160.47
100	13.7	3542	1240	13212	4377	47.38	167.04
110	15.3	2522		9735		45.07	160.04
120	16.2	2742		10639		43.15	154.23
130	17.2	2962		11344		41.52	147.79

* 35 percent of volume thinned at age 70 and 100.

YIELD TABLE 3 (c)

Habitat Type Group F

No Commercial Thinnings

Age	d.b.h. (inches)	Net CF vol/acre	Net BF vol/acre	M.A.I. CF/acre/year	M.A.I. BF/acre/year
60	8.8	3196	9342	53.27	155.70
70	9.9	3418	10523	48.83	150.33
80	10.9	3394	11176	42.43	139.70
90	11.9	3275	11545	36.39	128.28
100	12.7	3168	11817	31.68	118.17
110	13.4	3141	12110	28.55	110.09
120	14.0	3217	12485	26.81	104.84
130	14.5	3382	12937	26.01	99.52

Appendix A.3

An Attempt to Determine Natural Regeneration Success

To determine the probability of natural regeneration success in stands which have been shelterwood cut, an attempt was first made to cross-reference the Timber Stand Improvement Needs Summary file (Reforestation Needs List) and The Stand Examination and Management Status Record (Stand Exam List; reference FSH 2411.15R1).

The Reforestation needs list was found to be totally inadequate however, since it identified natural regeneration failures on only the Seeley Lake and Superior Ranger Districts. Furthermore, only a small portion of the shelterwood cutting has been accomplished on these districts.

According to the Stand Exam List, 349 stands on the Lolo forest received a first entry shelterwood cutting during the period 1967 - 1977. However, there was no regeneration data on 240 (69 per cent) of these stands. Of the 109 stands on which data was available, the regeneration method used was:

1. Planting on 29 stands (perhaps as a result of natural regeneration failure?)
2. Natural regeneration on 89 stands
3. Direct seeding on one stand

According to the data only 16 or the 89 stands on which natural regeneration was attempted have become established. However, <u>none</u> of these stands were recorded as natural regeneration failures. There were several other obvious errors and inconsistencies in the data and a conclusion was reached that further analysis was meaningless.

APPENDIX B . 1

Separating Slash Disposal and Site Preparation Costs

The true costs of site preparation are extremely difficult to determine since site preparation and slash disposal are usually accomplished simultaneously. The separation of these costs is essential since site preparation is a regeneration (management)cost and slash disposal is a logging cost.

Slash disposal needs are determined when a timber sale is prepared. The purchaser is normally required to do some slash disposal work, but most is accomplished with so-called BD funds collected from the purchaser.

When the stumpage is appraised the purchaser receives credit for both his required work and the work to be done with the collected funds. This credit is given by calculating the total slash disposal costs on a per thousand board feet basis, then subtracting this amount from the appraised value of the stumpage. Since this directly reduces the appraised, and bid, value of stumpage, slash disposal is a normal logging cost.

Site preparation needs are also determined when a timber sale is prepared. This activity is normally paid for with Knutson-Vandenberg (KV) funds which are taken from the gross timber sale receipts. The collection of these funds does not reduce the bid value of the stumpage and site preparation is normally considered as a regeneration cost.

To determine the actual costs of site preparation (separate from slash disposal costs) data from completed projects was first reviewed. An assumption was made that the amount of BD and KV funds expended on each project would reflect the amount of slash disposal and site preparation work actually accomplished. This data, and information provided by foresters working in the field, showed an inconsistency in the use of BD and KV funds, however. In several instances activities such as slashing and fireline construction, which do not prepare the site, were paid for with KV funds. The proportion of the total cost of dozer-piling, paid for with BD and KV funds, respectively, varied considerably between districts and between projects. On some districts, 50% or more of the cost of dozer-piling was usually charged to KV, while other districts charged the entire amount to BD. Projects with essentially the same objectives would be charged entirely to KV in one instance and entirely to BD in another. After several days of frustration, it was concluded that the proportion of BD and KV funds spent on a project did not accurately reflect the amount of slash disposal and site preparation work accomplished.

The major reason for these inconsistencies is quite simple. The amount of BD funds collected has not been sufficient to accomplish the planned slash disposal work. As a consequence, a backlog of untreated slash has accumulated. In 1974, the Forest Service estimated that this backlog amounted to over 700,000 acres of untreated slash, that had built up in Region One since 1961.[1] To accomplish needed slash disposal work, foresters have thus been forced to expand either KV or appropriated funds. Weatherford gave some insight on this problem when stating that: "The manager may discover that the cost allowance made in the appraisal is

1. USDA Forest Service. 1974. Northern Region's slash disposal program, Final Environmental Statement R1-74-4. USDA Forest Service, Northern Region, Missoula, Montana.

inadequate to accomplish the brush disposal task because of changing treatments once the sale is completed or because it is simply difficult to estimate costs in the first place."[2]

It is especially difficult to estimate costs when they will be incurred more than five years into the future. The cost estimates for most of the slash disposal work being accomplished today (1978) on the Lolo Forest, were made prior to 1973. These estimates did not give adequate consideration to inflation and real cost increases.

To determine how unaccomplished slash disposal and site preparation work is being planned, 11 major timber sales sold during the period FY 1976-78 were analyzed. These sales were randomly selected and included examples from all 6 ranger districts on the Lolo National Forest. From the slash disposal and KV plans contained in these reports, and from consultation with Mr. Warren Buell of the Lolo National Forest Timber Management staff, the following observations were made:

1. Increases in costs due to inflation are now included in the cost estimates made for collecting BD and KV funds (a 6% per annum inflation rate is being used).
2. Since 1975, the timber sale purchaser has been required to do a greater proportion of the slash disposal work. In the 11 contracts surveyed, this included all of the projected fireline construction needs, 97% of the slashing needs, and 95% of the topping needs (percentages based on an area basis).

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[2].Weatherford, Donald J. 1976. Identifying and Evaluating Slash Treatment Alternatives (Review Draft). USDA Forest Service, Equipment Development Center, Missoula, Montana.

3. In all 11 sales, the burning of dozer-piles and broadcast burning is to be accomplished with BD funds.

4. Dozer-piling and scarification is charged either entirely to KV or entirely to BD. Dozer-piling is required in 7 of the sale contract areas. Two of these projects (both on the Plains Ranger District) will be paid for with KV funds. The other 5 projects will be paid for with BD funds (one small 30 acre area is to be piled by the purchaser).

5. All handpiling and burning is to be paid for with BD funds or accomplished by the purchaser.

From these observations, it was concluded that fireline construction, slashing, lopping, handpiling, and the burning of dozer piles, should all be treated as slash disposal (hence: logging) costs. This conclusion is based on the fact that these activities: 1) are now accomplished with BD funds or required of the purchaser; and 2) do not produce more than negligible site preparation benefits.

The question of how to treat dozer-piling and broadcast burning costs remained, however. The evidence indicates that the only logical means of separating these costs is to base the breakdown on the amount of slash disposal and site preparation work actually accomplished in an "average" project.

An assumption will thus be made that seventy (70) per cent of the cost of dozer-piling accomplishes slash disposal and must be treated as a logging cost. Thirty (30) per cent of the cost accomplishes site preparation and will be treated as a regeneration cost. This breakdown is based on this study and on a composite of expert opinions, made by foresters working on the Lolo forest.

Even though recent slash disposal plans indicate that all future broadcast burning is to be accomplished with BD funds, it would be inconsistent to say that there are no site proparation costs on these areas. Broadcast burning accomplishes site preparation and is normally conducted on steep slopes (greawter than 35 percent) where dozer piling is prohibited. The same cost breakdown, 70% slash disposal: 30% site preparation, will be made for sites which are broadcast burned.

APPENDIX B .2

Dozer-piling Contracts

1. Data Summary

year	contract number	stands treated	acres	cost/ acre	cost	total acres in contract	total cost of contract
1976	16-1617	11	367	50.00	18,250.00	376	18,350.00
"	16-1634	5	221	59.25	13,094.25	-	--
"	"	1	17	64.00	1,088.00	-	--
"	"	3	79	58.00	4,582.00	-	--
"	"	1	12	69.25	831.00	329	19,595.25
"	16-1652	4	110	65.00	7,150.00	-	--
"	"	1	18	69.00	1,242.00	128	8,392.00
"	16-1657	16	235.7	47.50	11,195.75	-	--
"	"	3	138	57.50	7,935.00	373.7	19,130.75
"	16-1674	8	211	55.00	11,605.00	211	11,605.00
"	16-1720	2	84	30.00	2,520.00	-	--
"	"	1	40	67.00	2,680.00	124	5,200.00
				TOTALS		1532.7 ac.	$82,273.00

Average Cost for 1976 $53.68/acre

year	contract number	stands treated	acres	cost/ acre	cost	total acres in contract	total cost of contract
1977	16-1848	2	51	58.00	2,958.00	51	2,958.00
"	16-1875	9	505	54.50	27,724.50	505	27,724.50
"	16-1887	3	142	34.76	4,935.92	142	4,935.92
"	16-1859	3	139	60.00	8,340.00	139	8,340.00
				TOTALS		837 acres	$43,958.42

Average Cost for 1977 $52.52/acre

year	contract number	stands treated	acres	cost/ acre	cost	total acres in contract	total cost of contract
1978	03R6-830	5	144.5	62.49	9,029.80	144.5	9,029.80
"	03R6-831	7	104	67.00	6,968.00	104	6,968.00
				TOTALS		248.5 ac.	$15,997.80

Average Cost for 1978 $64.38/acre

2. <u>Computation of the weighted average cost of Dozer-piling</u>

Year	Total Acres Treated	Total Cost	Inflation* Factor	Adjusted Cost (Total cost x inflation factor)
1976	1532.7	82,273.00	1.156	95,107.59
1977	837.0	43,958.00	1.090	47,914.22
1978	248.5	15,997.80	1.00	15,997.80
	2618.2			$159,019.61

Average Cost = $159,019.61/2618.2 acres
= $60.73/acre (1978 dollars)

*These inflation factors were determined from the "All Commodity Wholesale Price Index."

APPENDIX C . 1

A Discussion of Planting Cost Increases: 1976 - Present

The average per acre direct cost of contractual planting was $40.01 in 1976, and rose to $56.57 in 1977 and $71.45 in 1978. Only a minor portion of these cost increases can be attributed to inflation. Most is apparently the result of changes made in the contract specifications in 1976 and a steadily increasing demand for planters.

To clarify how contract specifications can influence planting costs, an explanation of the planting inspection procedure follows.

Each unit (stand) is inspected immediately after planting and given a percentage rating. If the rating falls below 90%, the contractor is penalized. Prior to 1976, the payment to the contractor was reduced 2% for every percentage below 90 received in an inspection. If a unit received a rating of 87%, a 6% penalty was thus assessed. In 1976, this penalty was increased from 2 to 3%. Concurrently, a "no payment clause" was incorporated into the contracts. This clause forbids payment to the contractor if a unit receives a rating below 80%. Since the contractor seldom has the opportunity of replanting an area which fails inspection, this clause greatly increased the risks of contracting.

Forest service personnel predicted that these contract changes would result in a large and immediate increase in planting costs.[1] This increase

[1] Ludwig, Steve. June, 1978. Personal communication.

failed to materialize in 1976, however. By 1977, the contractors were apparently more aware of the increased risks associated with these new contracts. This accounts in part for the large increase in planting costs in both 1977 and 1978.

The $3.73/hour basic wage specified in the 1976 contracts was raised to $4.86/hour in 1977 and remained at this higher level in 1978. This change undoubtedly contributed to the large increase in costs from 1976 to 1977.

The total acreage planted in the northwestern states (Idaho, Montana, Oregon, and Washington) increased steadily from approximately 240,000 acres in 1971 to 387,000 acres in 1976.[2] Due to drought conditions, there was a slight decline in acreage planted in 1977. The number of acres planted apparently increased again in 1978, however. This increased demand for planters or shortage of entrepreneurs willing to organize planting crews has apparently resulted in real increases in planting costs.[3]

2. USDA Forest Service. 1971-1977 reports. Forest Planting, Seeding, and Silvical Treatments in the United States.

3. Laird, Pete. USFS Region 1 Reforestation Specialist. Nov. 1978. personal communication.

APPENDIX C.2

Problems Associated with the 1976 Planting Data

An inspection of the 1976 planting data revealed an unusually large amount of variation in cost. When compared to the 1977 and 1978 data, the stands planted in 1976 were atypical. Twenty per cent (6 of 33) had not been site-prepared within 10 years. This was true for only one stand planted in 1977 or 1978. Only 15 per cent of the stands planted in 1976 were dozer-piled. This compares with 33 and 30 percent of the stands planted in 1977 and 1978, respectively. Since recent site preparation and dozer-piling both reduce the cost of planting, the increase in costs from 1976 to 1978 was actually greater than the 1.786 factor indicates (n.b., this factor was derived by dividing the average per acre cost for 1976 into the per acre cost for 1978). An appropriate corrective factor could not be determined. This necessitated the removal of the 1976 stands from the data base.

APPENDIX C · 3

Further Statistical Information: Initial Planting Cost Equation

The following statistical tables apply to the regression equation predicting initial planting costs. In each table:

x_1 = habitat group (0 = groups E & F; 1 = groups B,C, and D)

x_2 = slope·site preparation method (0 =dozer-piled sites; 1 = broadcast burned sites)

x_3 = natural log of the bid item size

y = cost/acre (1978 dollars)

TABLE 1

REGRESSION EQUATION

VAR.	BETA COEFFICIENT	STD.DEV.	T-RATIO
CONSTANT	108.954		.
X_1	8.93147	4.04661	2.20715
X_2	0.217474	5.00719E-2	4.34323
X_3	-7.98531	2.11465	-3.77619
STANDARD ERROR OF Y		10.4598	

UNADJUSTED VALUES	R = 0.690817	R SQUARED = 0.477228
ADJUSTED VALUES	R = 0.67464	R SQUARED = 0.455139

TABLE 2

CORRELATION COEFFICIENTS

X_1	X_2	X_3	Y
1	0.14	-0.47	0.45
	1	-0.18	0.48
		1	-0.54
			1

TABLE 3

AUTOCORRELATION

DURBIN-WATSON D = 1.57724

1. Testing for Statistical Significance

The critical value of t, at the 95% confidence level, is 1.645. As can be seen from Table 1, all variables in the model are significant. Variables x_2 and x_3, in addition are significant at the 99% confidence level.

2. Multicollinearity

Multicollinearity is a phenomenon that occurs when two independent variables are strongly correlated. This has a tendency of increasing the standard error.[1] In developing this regression equation, care was taken to select independent variables which were not strongly correlated. The correlation coefficient table shows that the multicollinearity between all independent variables is relatively weak.

3. Autocorrelation

The Durbin-Watson test statistic is used to determine if the error terms for each sample are independent of one another. When the error terms are not random, a situation called autocorrelation exists. Autocorrelation is frequently the result of the omission of a significant variable from the regression model. In the regression equation, the error term may

[1] Hu, Tuh-wei. 1973. Econometrics: An Introductory Analysis, University Park Press, Baltimore, p. 75.

represent the influence of the omitted variable.[2]

The Durbin-Watson test for this equation was inconclusive. Autocorrelation may thus exist. It is suspected that the equation would be improved, and the doubts about autocorrelation could be removed, if a variable expressing competition between bidders was included. This was not attempted since the level of competition cannot be predicted or controlled.

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2. Ibid. p. 77.

APPENDIX C.4

Further Statistical Information: Interplanting Cost Equation

The following two tables apply to the regression equation predicting interplanting costs. In each table:

x_1 = site preparation method (0 = dozer-piled sites; 1 = broadcast burned sites.

x_2 = years since site preparation

x_3 = bid item size (acres)

Y = cost/acre (1978 dollars)

TABLE 1

Regression Equation

Var.	Beta Coefficient	Standard Deviance	T-Ratio
Constant	111.3560		
x_1	9.6318	2.54105	3.79047
x_2	1.8791	0.55537	3.38353
x_3	-8.6739	1.78148	-4.86895
Standard Error of Y		11.73680	

Unadjusted values	R = 0.617671	R^2 = 0.381517
Adjusted values	R = 0.602616	R^2 = 0.363146

TABLE 2

Correlation Coefficients

x_1	x_2	x_3	Y
1	0.26	-0.007	0.41
	1	-0.002	0.36
		1	-0.41
			1

1. Testing for statistical significance

The critical value of t at the 99% confidence level is 2.576. As can be seen, all independent variables are statistically significant at this level.

2. Multicollinearity

The correlation between all independent variables is weak. The highest degree of correlation expressed was .26 between variables x_1 and x_2.

3. Autocorrelation

The Durbin-Watson test for this equation is inconclusive (DW = 1.737).

APPENDIX C . 5

Determining Planting Success

1. Introduction

All planting attempts on the Lolo Forest are not successful. When failure occurs stands are generally replanted. A major portion of the variability in planting costs may thus depend on the probability of having an initially successful planting.

As a result of the National Forest Management Act of 1976, strong emphasis has been placed on identifying past planting failures on the Lolo Forest. Deficiencies in the data base still make an analysis of past planting success difficult and somewhat dubious, however. Some of the major problems with the data base are as follows:

1. The number of seedlings that were planted on each site is difficult, if not impossible, to determine.
2. There is no data on the number of planted seedlings which have survived on each site (many of the seedlings now present on these sites have regenerated naturally).
3. There is no information on the quality of the stock planted on each site.

In general, sites have been classified as planting failures if there are less than 300 desirable or acceptable seedlings per acre now present. The objective of this analysis was to identify the variables which influence planting success or failure, based on this acceptable stocking level.

2. Method

It was initially hypothesized that planting success is a function of habitat group, site preparation method, aspect, harvest method, and the delay period between site preparation and planting. A z test for comparing proportions was used to test the significance (95% confidence level) of these variables (see explanation in section 6 of this appendix).

Data was utilized from two Forest Service files. The Stand Examination and Management Status Record (Stand Exam list; reference FSH 2411.15R1) contains data on all inventoried stands on the forest and was used to identify those stands which had been planted. The Timber Stand Improvement Needs Summary file (Reforestation needs list) contains information on all current TSI needs and was used to identify stands currently understocked due to planting failures.

An initial comparison of these two files produced discouraging results. On the Missoula, Plains, and Superior Ranger Districts 35 per cent or more of the planting failures were not recorded as having been planted in the Stand Exam list. These discrepancies were apparently the result of several factors which could not be easily corrected. The data from these three districts was therefore excluded from the analysis.

On the other 3 districts (Ninemile, Seeley Lake, and Thompson Falls) approximately 15% of the planting failures were not recorded as having been planted. Assuming a failure to record the same number of planting attempts, these planting failures were removed from the data base.

A determination of success or failure has not been made on stands initially planted after 1975. The historical record of stands planted prior to 1966 is generally incomplete. For these reasons only those stands planted during the period 1966 to 1975 were analyzed.

Before the analysis of these stands could be made, another major problem had to be solved. Each entry made in the Stand Exam list erases the previous entry. This file is thus not a complete historical record and could not be used to identify planting failures which have been successfully replanted. A list of "suspected" (but unrecorded) failures was compiled by identifying those stands with a time lag between harvesting and planting of 4 years or more. The historical record of these stands was then determined by foresters working on the respective ranger districts

The final data base consisted of 271 planting sites all of which had been either clearcut or shelterwood cut. Initial planting failure occurred on 116 of these sites.

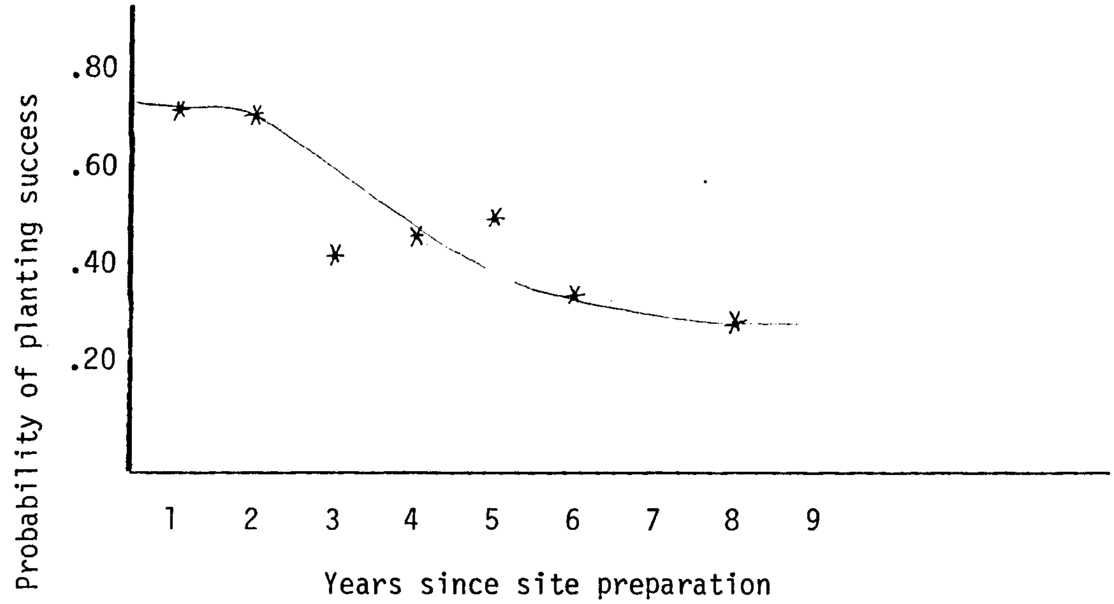
3. Results

These data do not support the hypothesis that aspect, habitat type group, harvest method, and site preparation method significantly affect planting success (see section 6b of this Appendix). However, the lack of significance of these variables may be due to the poor method used to measure planting success. If the planted seedling survival rate could be determined for each planted site, regression analysis could be used to give a better estimate of the effect of these variables on seedling survival.

The delay period between site preparation and planting was found to be significant. Planting success decreases sharply as this delay period increases. For instance, the success rate for plantings done within two years of site preparation was 71 per cent, while only 41 per cent of the plantings done after a delay period of 3 or more years were successful. This relationship is shown graphically in Figure 1.

FIGURE 1

Planting success as a function of years since site preparation



4. Discussion

These data suggest that the planting success rate on initial plantings is approximately 70 per cent. However, to reduce planting failures major changes in the planting contract specifications were made in 1976. Since these changes resulted in a substantial increase in per acre planting costs, it is reasonable to assume that they have also increased the probability of planting success.

To determine the effect of these contract changes on planting success, Dr. Pete Laird, USFS Region 1 reforestation specialist, was consulted. After reviewing the results of this study's analysis, Dr. Laird estimated that initial plantings are now successful on 90 per cent of the sites planted (within an average delay period of 5 years).[1] He attributes this higher success rate to both changes made in the contract specifications and an increase in the quality of planting stock. In this study interplantings, i.e. plantings done after regeneration failure, are assumed to be 75 percent successful, within average delay periods of 5 years.

5. Calculation of Additional Cost Incurred due to Planting Failures

The estimates of a 90 per cent initial planting success rate and a 75 per cent interplanting success rate are used to determine the additional cost incurred on each site due to the possibility of a planting failure.

The average stocking level on sites classified as planting failures was determined from the Reforestation Needs file and is 116 trees per acre. Assuming that these sites will be interplanted to a density of 436 trees per acre, an average of 320 trees per acre will be planted on each site. The average material cost incurred on each site, assuming bare root stock, is thus $27.18 per acre (.32 · $85.94/1000 seedlings).

In chapter 4 it was determined that the direct and administrative cost of interplantings are $104.30 per acre on dozer-piled sites and $113.93 per acre on broadcast burned sites. The total per acre interplanting cost is the sum of the direct, administrative, and material costs or $131.48 on dozer-piled sites and $141.11 on broadcast burned sites.

With an initial planting success rate of 90 per cent, and subsequen- interplanting success rates of 75 per cent, initial planting failures will require interplanting one and one-third times. The additional prorated cost incurred on each site due to planting is $18.05 per acre on dozer-piled sites and $19.34 per acre on broadcast burned sites. This cost is slightly

[1]This does not mean that 90% of the planted seedlings survive. Planting is normally done at a density of 436 trees per acre. Plantings are considered successful of 300 or more seedlings per acre become establish.

in excess of .133 times average interplanting costs, since it has been compounded using a 5 per cent discount rate, to the year in which initial planting failures are expected to be successfully regenerated.

6. Addenda

a. Explanation of the z test.

In this analysis the z test for comparing proportions was used to test the statistical significance of each variable. In this test:

$$z = \frac{p_1 - p_2}{\sqrt{\hat{p}\,\hat{q}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

Where:

p_1 = The proportion of planting successes in population 1

p_2 = The proportion of planting successes in population 2

$\hat{p}$ = The proportion of planting successes in the combined population

$\hat{q}$ = The proportion of planting failures in the combined population

n_1 = The size of population 1

n_2 = The size of population 2

If the size of both populations is greater than 30, the z value which corresponds to a statistical difference at the 95 per cent confidence level is 1.96 or greater.

b. Variable Testing Results

(1) Habitat Type Group

The proportion of planting successes on habitat type groups B, C-D, E, and F was .60 (15/25), .62 (53/85), .55 (51/86), and .55 (40/73) respectively. These differences are not statistically significant.

(2) Site preparation method

In the 271 stands sampled, the proportion of planting successes was .64 (95/148) on sites which were broadcast burned and .55 (59/108) on dozer-piled sites. This difference is not statistically significant. It is probably explained by the fact that while 66 per cent of the broadcast burned sites were planted within 2 years of site preparation, only 50 per cent of the dozer-piled sites were.

(3) Aspect

Planting success on south, south-west, south-east, and westerly aspects was not significantly less than on other aspects. On stands site prepared within 2 years of planting, success was 70 per cent (55/79) on these exposed aspects and 73 per cent (77/106) on other aspects. Other combinations of aspect were tested and none were found to be significant.

(4) Harvest Method

Sixty-one per cent (150/246) of the plantings done on clearcut sites were successful while only 47 per cent (22/47) of the plantings on shelterwood sites were successful.

The average time lag between site preparation and planting has been much greater in shelterwood units however. In areas planted within two years of site preparation, success was achieved on 71 per cent (113/159) of the clearcut units planted and 73 per cent (19/26) of the shelterwood units planted. The differences are not statistically significant.

APPENDIX D.1

Further Statistical Information: Precommercial Thinning Cost Equation

The following two tables apply to the regression equation predicting precommercial thinning costs. In each table:

x_1 = thinning stand area (acres)

x_2 = slope in percent

x_3 = number of leave trees per acre

x_4 = height specification (0 = 24 inches; 1 = 6 inches)

Y = cost/acre (1977 dollars)

TABLE 1

Regression Equation

Var.	Coefficient	Std. Dev.	T-Ratio
Constant	306.0940		
x_1	-22.8492	4.22937	-5.40249
x_2	0.5790	0.17418	3.32394
x_3	-34.7342	7.43764	-4.67006
x_4	14.4816	5.24845	2.75922

Standard error of Y 14.215

Unadjusted Values	R =	R^2 =
Adjusted values	R =	R^2 =

TABLE 2

Correlation Coefficients

x_1	x_2	x_3	x_4	Y
1	0.21	-0.08	-0.29	-0.39
	1	-0.01	-0.19	0.23
		1	-0.20	-0.51
			1	0.46
				1

1. Testing for Statistical Significance

The critical value of t at the 99 percent confidence level is 2.576. All independent variables are thus significant at this level.

2. Multicollinearity

Care was taken to select independent variables which were not inter-correlated. The highest degree of correlation expressed was -.29 between variables x_1 and x_4. This is probably inconsequential.

3. Autocorrelation

The Durbin-Watson test statistic was inconclusive (DW = 1.371). The predictive accuracy of this model could probably be improved if competition was included as an independent variable. This would not serve the purposes of this study, however.

APPENDIX D.2

Calculating Precommercial Thinning Costs

Assuming a median thinning stand area of 40 acres, the equation for predicting precommercial thinning costs is:

$$Y = 221.81 + .5790x_2 - 34.734\ell n x_3 + 14.48x_4$$

Where:

Y = cost/acre (1977 dollars)

x_2 = slope in per cent

x_3 = number of leave trees/acre

x_4 = the height specification variable (0 for 24 inches, 1 for 6 inches)

With 302 leave trees per acre, 0 per cent slope, and a 24 inch height specification, this equation is:

$$Y = 221.81 + 0 - 34.734(\ell n\ (302)) + 0$$
$$= 221.81 \quad - 198.35$$
$$= 23.46$$

To convert to 1978 dollars, the wholesale price index factor of 9 per cent was used. Only 90 per cent of the sites actually require thinning, however. The predicted cost of thinning on level sites is thus:

$$23.46(1.09)(.90) = \$23.01/\text{acre}$$

For every 10 per cent increase in slope, the additional cost is:

$$.5790(10)(1.09)(.90) = \$5.68/\text{acre}$$

APPENDIX E.1

Annual Costs

Road Maintenance Costs

Since this is a study on the economics of second-growth timber management, it is assumed that the primary and secondary road systems are in place and paid for. A portion of the cost of maintaining these roads is considered as an annual cost to timber production, however.

The actual cost of road maintenance in Fiscal Year (F.Y.) 1978 was $427,803. In constant, i.e. uninflated, dollars, this cost is projected to increase to $583,000 in F.Y. 1979 and $736,495 in F.Y. 1982.[1] Only a minor portion of this projected cost increase is due to new road construction. Most results from the fact that roads have been inadequately maintained in the past.[2] To meet RPA goals, it is estimated that over $1MM must be spent on road maintenance in F.Y. 1982.

Because of the large road maintenance cost increase, which will occur in the near future, the annual per acre cost chargeable to timber production is determined from the F.Y. 1982 projections. There are presently 713, 579 acres of commercial forest land in the allowable cut base, in the roaded portions of the forest. Assuming that 70 percent of the total road maintenance cost should be charged to timber production,[3]

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[1]These cost figures were obtained from budget records and Advent Reports, maintained in the Forest Supervisor's Office.

[2]Bob Willis, Lolo N.F. Engineering Staff, Personal discussion, Feb., 1979. There are presently 3,900 miles of maintained roads on the forest. Approximately 200 miles of new roads are projected to be built through F.Y. 1982.

[3]This estimate was provided by Jack Luzinski and Bob Willis, of the Lolo N.F. Supervisor's staff. It is based on expert opinion, not actual survey data, and is thus subject to change.

and that 5 percent more land will be roaded by F.Y. 1982, the per acre cost of road maintenance is .70($736,495)/713,579(1.05), or $0.688/acre per year.

The proportion of the road maintenance cost that should be charged to timber management is highly debatable. Although 70 percent may seem excessive to some individuals, this percentage was chosen with consideration that major road reconstruction is often required prior to second-growth harvesting.

2. Fire Management Costs

The reasons for not including fire management costs as an annual cost to timber production are included in this section.

Most of the fire management money allocated to the Lolo forest is spent on wildfire detection, suppression, prevention, and planning. The control of wildfire protects many resources besides timber and is done on all roaded lands regardless of their classification. There is also little evidence to indicate that wildfire management costs more on lands that are managed for timber production. In the long-run it may actually cost less to control fire on managed lands, since fuels are reduced with harvesting and slash disposal, and managed areas are generally more accessible to fire attack crews.

Slash treatment and fuels treatment costs are normally paid for with brush disposal (BD) funds collected from timber sale purchasers. They are thus a cost of logging and are also not charged as an annual cost.[4]

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[4]The portion of these costs paid for with KV and appropriated funds are included in the timber sale prep. and admin. costs (see Appendix E.2).

3. Miscellaneous Timber Management Costs

Costs that are not charged in this study to either timber sale or contract preparation and administration are included in this miscellaneous annual cost category. These costs were determined from budget projections contained in the Advent Report (current: F.Y. 1980) and are in 1978 dollars.

MISCELLANEOUS COSTS

ACTIVITY	SOURCE OF COST	COST (DOLLARS)
Tree improvement	districts	27,720
Seed collection	districts	14,785
Overhead (Planting, site prep., regent, surveys, etc.)	S.O.	11,760
Insect and disease control	S.O.	52,844
TSI and reforestation planning & coordination	S.O.	4,858
TSI general	S.O.	1,856
YCC manpower	S.O.	63,000
TOTAL		$176,883

Note: Insect and disease control is paid for out of special funds. A cost of only $800 was projected for F.Y. 1980. The amount shown ($52,844) is the F.Y. 1977 actual cost, inflated to 1978 dollars.

There are 1,321,843 acres of commercial forestland in the allowable cut base on the forest. The per acre cost due to these miscellaneous expenditures is thus $176,883/1,321,843 acres, or $0.134 annually.

4. Timber Management Overhead Costs

Charlie Fudge, of the Lolo National Forest Timber Management Office, has just completed a study on timber managment overhead costs. According to this study, overhead costs average $5.41/m.b.f. when 125 million board feet are harvested annually.[5]

[5] It is somewhat discretionary to decide how these costs should be charged. Mr. Fudge charges them to timber sale preparation and administrative. In this study they are considered as annual costs.

There are three components which make up these costs: These are:

1. General Administration Costs (salaries, clerical support, etc.)
2. Program Management Costs (operation of timber management office, etc.)
3. Land Management Planning Costs (the portion of the land management planning cost attributable to timber production).

With an annual harvest of 125 million board feet, the annual overhead cost would be \$5.41/m.b.f. x 125,000 m.b.f. or \$676,250. The per acre overhead cost of \$0.512 was computed by dividing this annual cost by the number of acres of commercial forestland in the allowable cut base (1,321,843 acres).

APPENDIX E.2

Timber Sale Preparation and Administrative Costs

Charlie Fudge, of the Lolo National Forest, has determined these costs on a per m.b.f. basis, based on a projected annual harvest of 125 million board feet. The costs, shown in the following table, are in 1978 dollars.

PROJECT COSTS FOR TIMBER SALE PREP. AND ADMIN.

ACTIVITY	COST/M.B.F.
Timber Management (sales prep. and admin.)	$9.64
Timber Management Planning	.33
Stand Exams	1.30
Engineering (includes preconstruction and construction engineering and admin., right-of-way and cost-share agreement activities, geometronics, and landline location)	12.69
Resources Support	
Archaeology	.15
Recreation	.11
Visual	.22
Fish and Wildlife	.49
Fuel Management	.20
Fuel Exams	.23
Soil	.15
Water	.33
Geology	.19
Minerals	.07
Range	.04
Special uses	.02
TOTAL	$26.16/m.b.f.
Overhead*	20.69%(5.41/mbf)

*In this study overhead costs are treated as annual costs.

APPENDIX F

Contract Preparation and Administrative Cost Estimates

1. District Level Costs

These estimates are based on the average number of man-days spent preparing and administering contracts. The average man-day cost of a GS-4,5,7, and 9 employee are $38.72, $48.44, $60.00, and $70.72 respectively. Each vehicle day costs the Forest Service an estimated $10.00. All cost estimates are in 1978 dollars.

a. Dozer-piling and Scarification Contracts

1. Jerry Miller, Seeley Lake R.D. (Estimate based on a 609 acre contract completed in 1977).

Activity	man-days	grade	labor cost	vehicle days	vehicle cost	total cost
writing contract	4	GS-7	240.00	-	-	240.00
show-me trip	1	GS-7	60.00	1	10.00	70.00
traversing, marking boundaries	20	GS-4	774.40	10	100.00	874.40
prework conference }	10	GS-7	600.00	-	-	600.00
inspection, close-out }	50	GS-4	1936.00	50	500.00	2436.00
TOTAL						$4220.40

Per Acre cost = $4220.40/609 = $6.93/acre.

2. Bruce Hartford, Plains R.D. (estimate based on hypothetical 100 acre contract).

Activity	man days	grade	labor cost	vehicle days	vehicle cost	total cost
writing contract	1	GS-7	60.00	-	-	60.00
show-me trip	1	GS-7	60.00	1	10.00	70.00
traversing, marking boundaries	5	GS-4	193.60	2	20.00	213.60
prework conference } inspection, close out	9	GS-7	540.00	9	90.00	630.00
	TOTAL					$973.60

Per acre cost = $973.60/100 = $9.74/acre

3. Cliff McCluskey, Thompson Falls R.D. (estimate based on 1977 average costs adjusted to 1978).

Activity	Cost
traversing, marking boundaries	1.52/acre
writing contract, show-me trip	1.00/acre
inspection	5.00/acre
TOTAL	$7.52/acre

b. Planting Contracts

Steve Ludwig, Superior R.D.

1. Preparation costs (estimate based on four 25 acre units in a larger planting contract).

Activity	man days	grade	labor cost	vehicle days	vehicle cost	total cost
Writing contract, office work	2	GS-7	120.00	-	-	120.00
Traversing, marking boundaries	2	GS-5	96.88	3.5	35.00	131.88
	2	GS-4	77.44	-	-	77.44
Supervision	2	GS-9	141.44	-	-	141.44
Supplies	-	-	-	-	-	20.00
	TOTAL					$490.76

per acre costs = $490.76/100 = $4.91/acre

2. Administrative Costs (estimate based on time charges for 680 acre contract completed in 1978).

Activity	Cost
Inspection	$20.21/acre

3. Total Preparation and Administrative costs.

Due to unusual problems with the planting contractor, the cost of administering the planting contract this year was much higher than normal. Steve Ludwig estimates that the average cost of administration is about $15.00 per acre. The cost estimate for preparing and administering planting contracts used in this study is:

$4.91 + 15.00 = $19.91/acre

c. Pre-commercial Thinning Contracts.

1. Jerry Miller, Seeley Lake R.D. (estimate based on 60 acre contract).

Activity	man days	grade	labor cost	vehicle days	vehicle cost	total cost
writing contract	1	GS-7	60.00	-	-	60.00
traversing, marking boundaries	2	GS-5	96.88	1	10.00	106.88
map work, review	1	GS-5	48.44	-	-	48.44
prework conference, show-me trip	1	GS-7	60.00	1	10.00	70.00
inspection	5	GS-5	242.20	10	100.00	342.20
final inspection, close out	1	GS-7	60.00	1	10.00	70.00
		TOTAL				$697.52

Per acre cost = 697.52/60 = $11.63/acre

2. Merlin Lemmer, Ninemile R.D. (estimate based on 60 acre contract).

Activity	man days	grade	labor cost	vehicle days	vehicle cost	total cost
writing contract	1	GS-7	60.00	-	-	60.00
traversing/boundary marking	1	GS-7	60.00	1	10.00	70.00
	2	GS-5	96.88	-	-	96.88
mapwork	1	GS-7	60.00	-	-	60.00
review with staff & s.o.	1	GS-7	60.00	-	-	60.00
prework conference, show-me trip	1	GS-7	60.00	1	10.00	70.00
Inspection	5	GS-5	242.20	5	50.00	292.20
final inspection, close-out	1	GS-5	48.44	1	10.00	58.44
	1	GS-7	60.00	-	-	60.00
	TOTAL					$827.52

Per acre cost = 827.52/60 = $13.79/acre

3. Bruce Hartford, Plains R.D. (estimate based on 40 acre contract unit).

Activity	man days	grade	labor cost	vehicle days	vehicle cost	total cost
writing contract	1	GS-7	60.00	-	-	60.00
traversing, marking boundaries	3	GS-4	116.16	1	10.00	126.16
show-me trip	.5	GS-7	30.00	1	10.00	40.00
inspection, prework conference }	3	GS-7	180.00	3	30.00	210.00
close out }	1	GS-4	38.72	1	10.00	48.72
	TOTAL					$484.88

Per acre cost = 484.88/40 = $12.12/acre

2. <u>Forest Level Costs</u>

The forest level costs are based on the following estimations of Fred Olness, Lolo National Forest Contracting Officer.

1. All contracts, regardless of size, require five GS-11 man-days, four GS-5 man-days, and one GS-4 man day.

2. The cost of preparing and administering a contract is a function of its size in dollars paid to the contractor. For every $5000 over a

$5000 base, an extra GS-5 man-day is required.

3. The vehicle cost for each contract is approximately $22.50. This is based on the assumption that one 150 mile trip is required for each contract (.15/mile).

a. Dozer-piling and Scarification Contracts

average contract size (acres)	214
average contract size (dollars)	$12,000

5 days GS-11	@	88.84	444.20
5 days GS-5	@	48.44	242.20
1 day GS-4	@	38.72	38.72
vehicle costs			22.50
TOTAL			$747.62

per acre cost = 747.62/214 = $3.50 per acre

b. Planting Contracts

average contract size (acres)	350
average contract size (dollars)	$25,000

5 days GS-11	@	88.84	444.20
8 days GS-5	@	48.44	387.52
1 day GS-4	@	38.72	38.72
vehicle costs			22.50
TOTAL			$892.94

per acre cost = $892.94/350 = $2.55 per acre

c. Precommercial Thinning Contracts

average contract size (acres)	94
average contract size (dollars)	$5640

5 days GS-11	@	88.84	444.20
4 days GS-5	@	48.44	193.96
1 day GS-4	@	38.72	38.72
vehicle cost			22.50
TOTAL			$697.18

per acre cost = $697.18/94 = $7.42 per acre

APPENDIX G

Problems Associated with the Regression Analysis of Contractual Data

There are major problems which make regression analysis of contractual cost data difficult. Firstly, some of the contractors do not submit their bids on a stand by stand basis. Instead, they determine their total bid then divide this total by the number of acres in the bid item. As a consequence of this procedure, 24 of the stands in the initial planting file were all planted at an adjusted cost of either $76.20/acre or $76.34/acre. The experience and expertise of the contractors also varies considerably. The larger bid items tend to attract the larger and more experienced contractors who have developed a firm rationale for estimating costs. The smaller bid items attract the amateurs, however, and much of the variability in costs on these items cannot be rationally explained.

Two basic problems that were encountered are associated with the data itself.

Since 1969, three different numbering systems have been used to code habitat types on the Lolo forest. When these numbering systems changed there was an apparent failure to correct the habitat codes in the Stand Exam list. As a consequence, this file now contains a mixture of both old and new habitat numbers. This is a major problem since some of the codes in the current system have a different meaning in the older systems. The number 35, for instance, referred to an Alpine fir habitat type in 1969, but now refers to a Douglas-fir type. Examination of stand data, maintained at the district offices, was required to determine the actual habitat type of many of the sample stands. Some stands were actually deleted from the planting and precommercial thinning files since the correct habitat type could not be determined.

On several of the contracts that were analyzed, the contract units were not identified according to their stand numbers. Several tedious days were spent comparing maps to obtain these numbers. This was necessary since many of the site specific variables such as habitat type are not shown in the contracts and can only be obtained from the Stand Exam list.

APPENDIX H

Lumber Price and Production Cost Projections

The projections of Adams and Haynes (1979) for the Rocky Mountain region are tabulated below. The costs are "stumpage-to-car," that is, logging plus milling. The costs do not include a margin for profit and risk. Both costs and prices are deflated by the all commodity wholesale price index and are thus in 1978 dollars. The cost and price for the base year (1978) were calculated by assuming constant cost and price growth rates from 1978 to 1990.

	Production Cost ($/mbf,lumber tally)	Proportion of 1978 cost	Lumber Price ($/mbf, lumber tally)	Proportion of 1978 price
1978	$88.64	1.0000	131.78	1.0000
1980	92.70	1.0458	137.80	1.0457
1990	115.90	1.3075	172.30	1.3075
2000	138.20	1.5569	198.20	1.5040
2010	141.60	1.5975	220.00	1.6694
2020	144.80	1.6336	239.60	1.8182
2030	147.90	1.6685	257.10	1.9510

APPENDIX I

Economic Comparison of Clearcutting Regimes With and Without Commercial Thinning

Land expectation values with and without commercial thinnings, for area classes CD-1, E-1, F-1, are illustrated in graphs 1(a) through 3(b). The "a" graphs compare management regimes using a 5.0 per cent discount rate, while the "b" graphs are for a 3.5 per cent rate. The current regeneration strategy, i.e. immediate planting following harvesting, is assumed in these six graphs.

Graphs 4(a) and 4(b) are for area class E-3. They are presented to illustrate that slope has no significant effect on the ranking of harvest regimes. Likewise, graphs 5(a) and 5(b) show that the regeneration method chosen does not influence the optimal harvest regime.

The following key applies to all 10 graphs:

________________clearcutting without commercial thinning

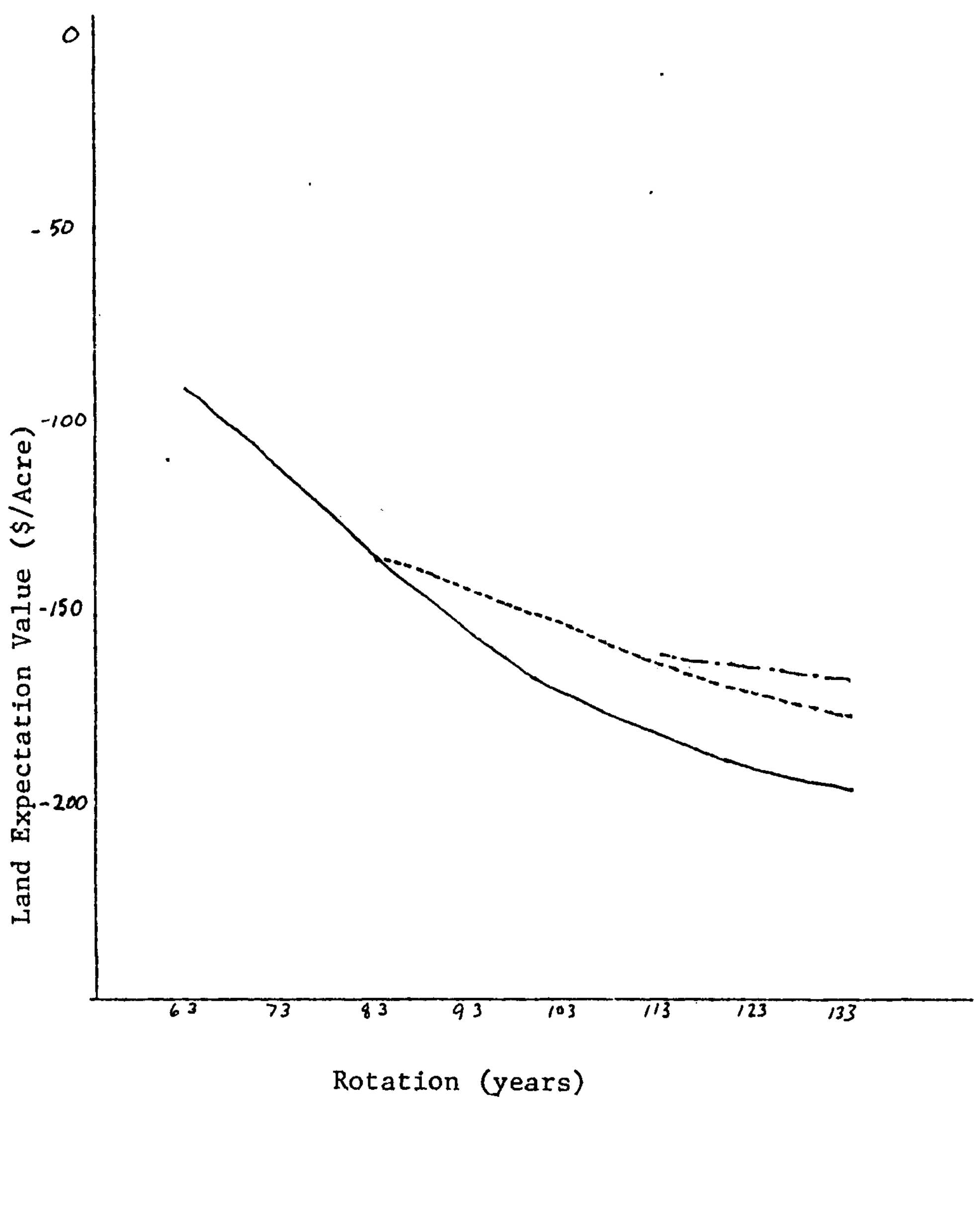
.................one commercial thinning at age 70

_ ._ . _ . _ . _ .two commercial thinnings at ages 70 & 100

To prevent the graphs from becoming too cluttered, the land expectation values produced with one commercial thinning at age 80 are not shown. In general, this regime is less efficient than one thinning at age 70.

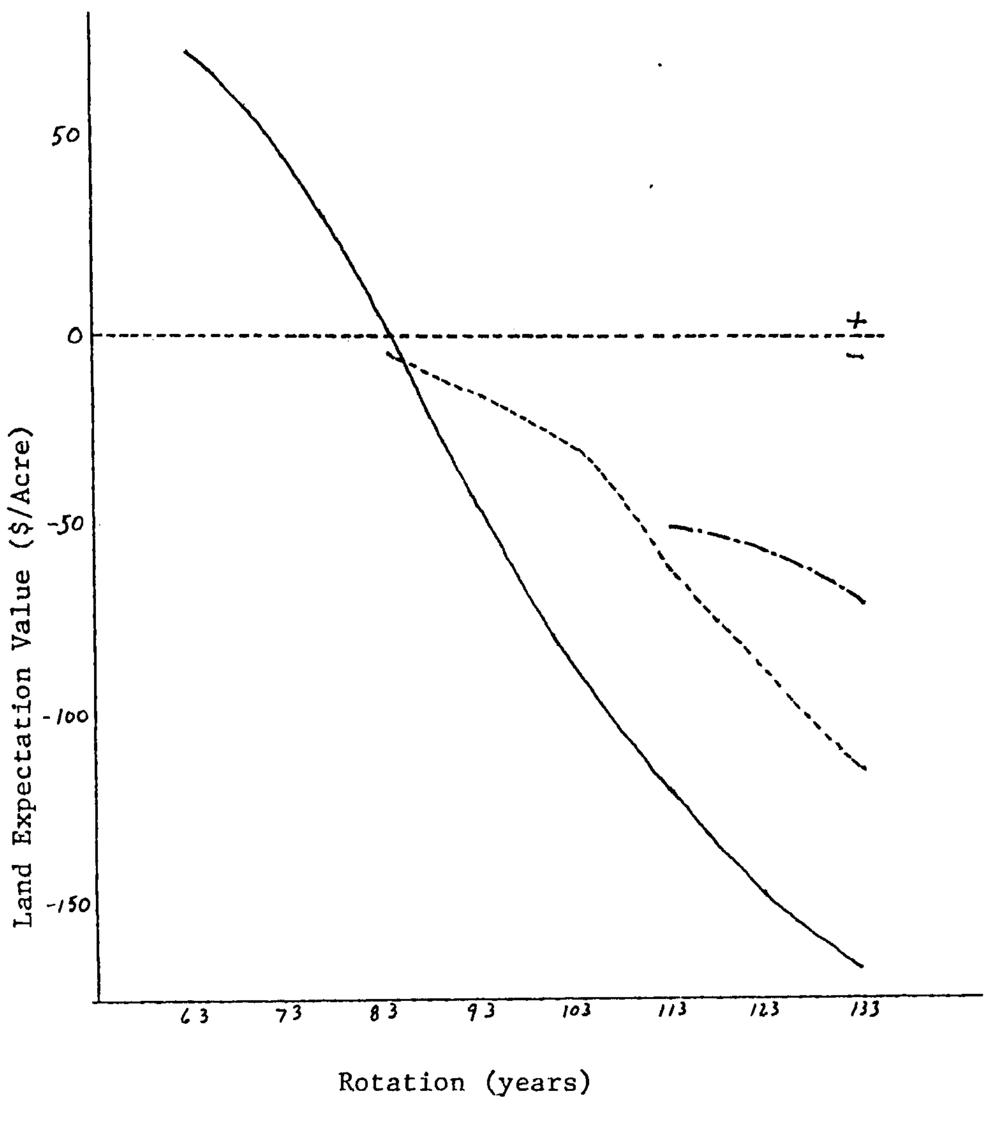
Graph 1(a)

Habitat Type Group: CD
Slope Class: (0 - 20%)
Regeneration Method: Planting
Discount Rate: 5.0%



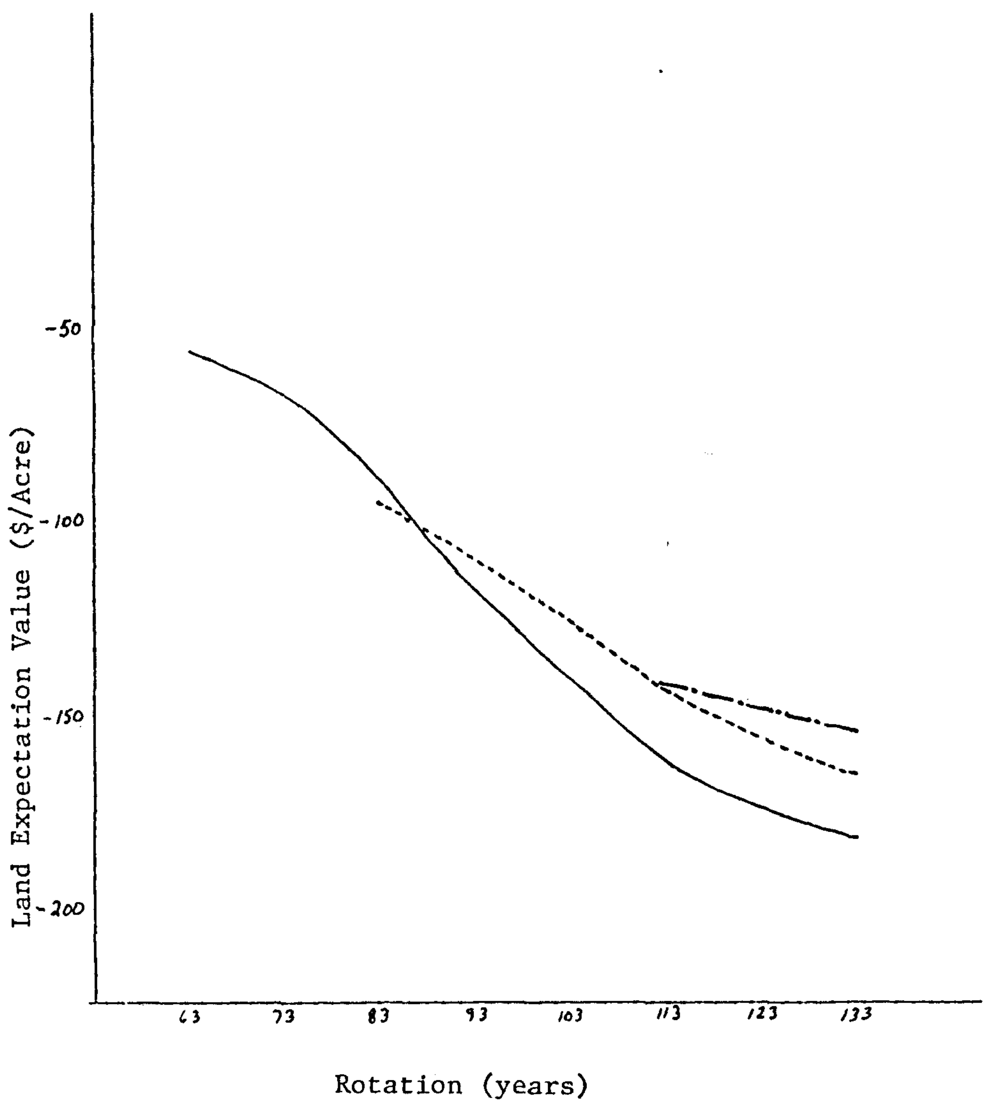
Graph 1(b)

Habitat Type Group: CD
Slope Class: (0 - 20%)
Regeneration Method: Planting
Discount Rate: 3.5%



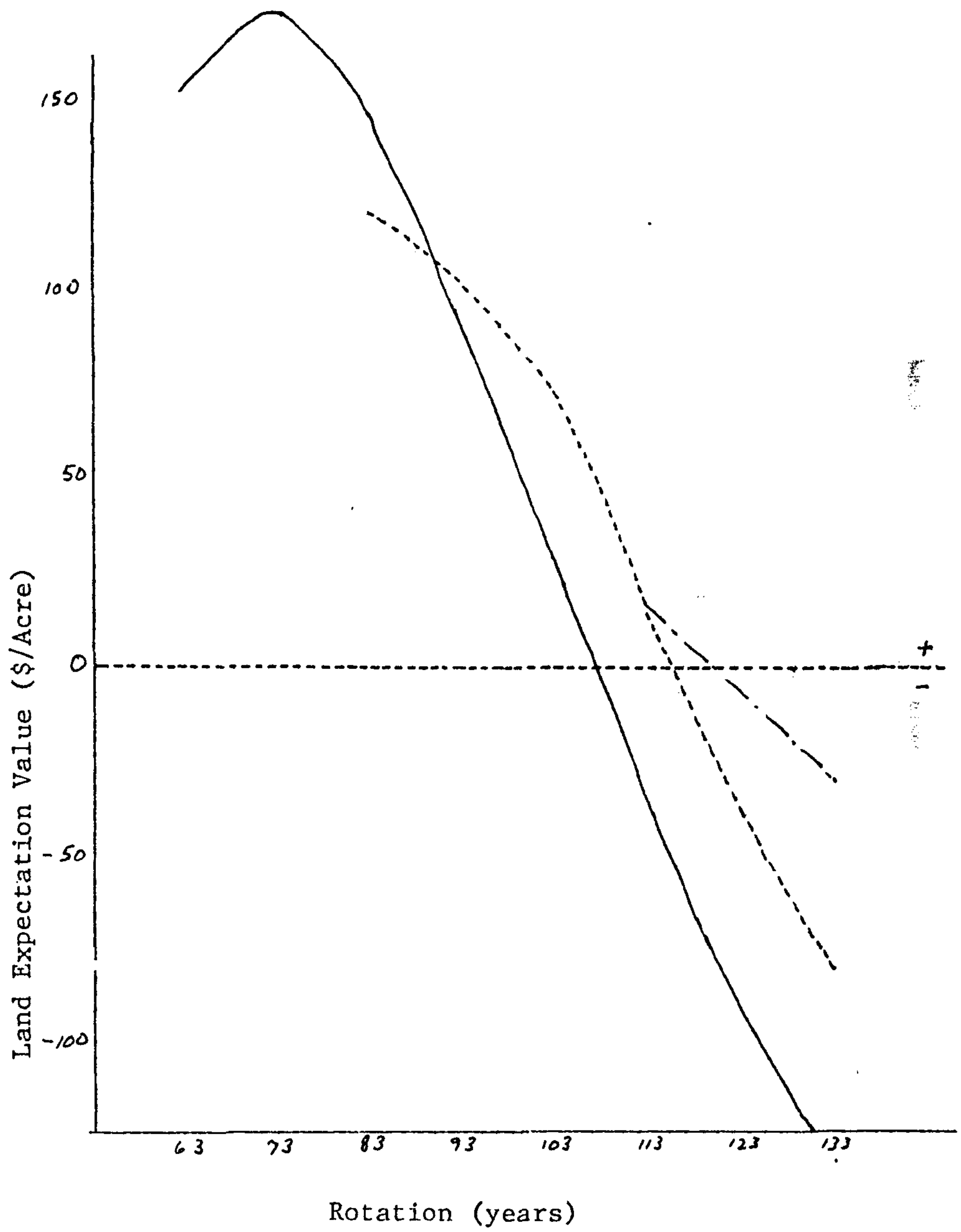
Graph 2(a)

Habitat Type Group: E
Slope Class: (0 - 20%)
Regeneration Method: Planting
Discount Rate: 5.0%



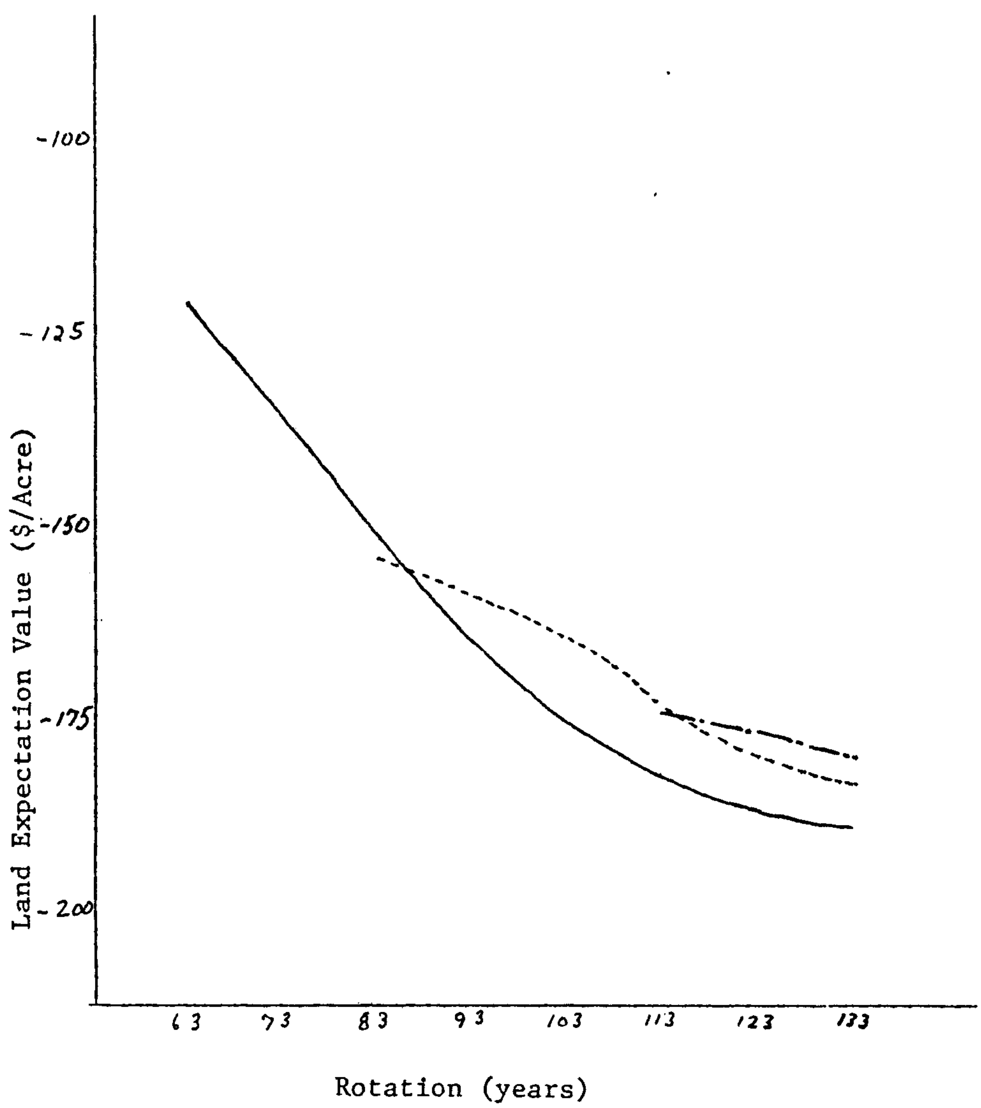
Graph 2(b)

Habitat Type Group: E
Slope Class: (0 - 20%)
Regeneration Method: Planting
Discount Rate: 3.5%



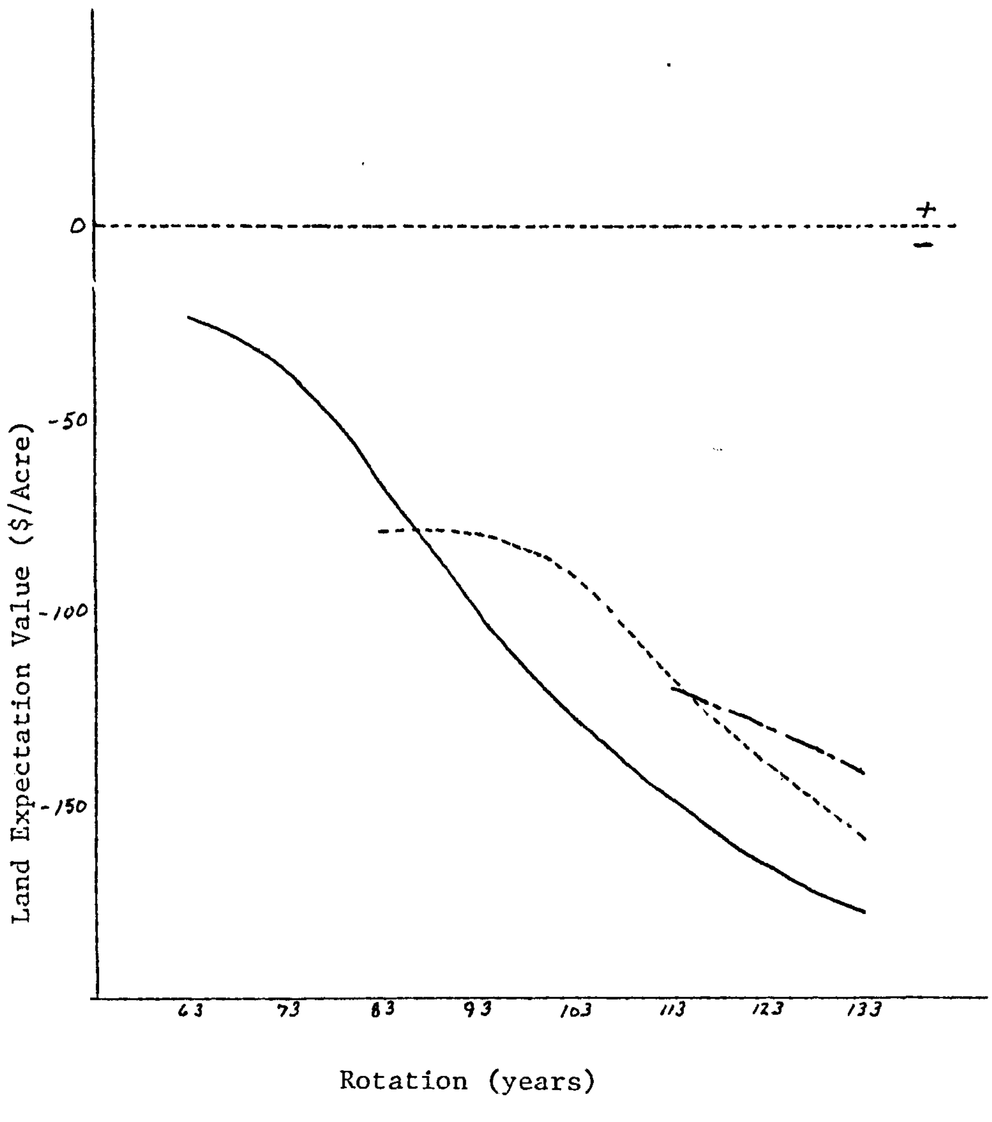
Graph 3(a)

Habitat Type Group: F
Slope Class: (0 - 20%)
Regeneration Method: Planting
Discount Rate: 5.0%



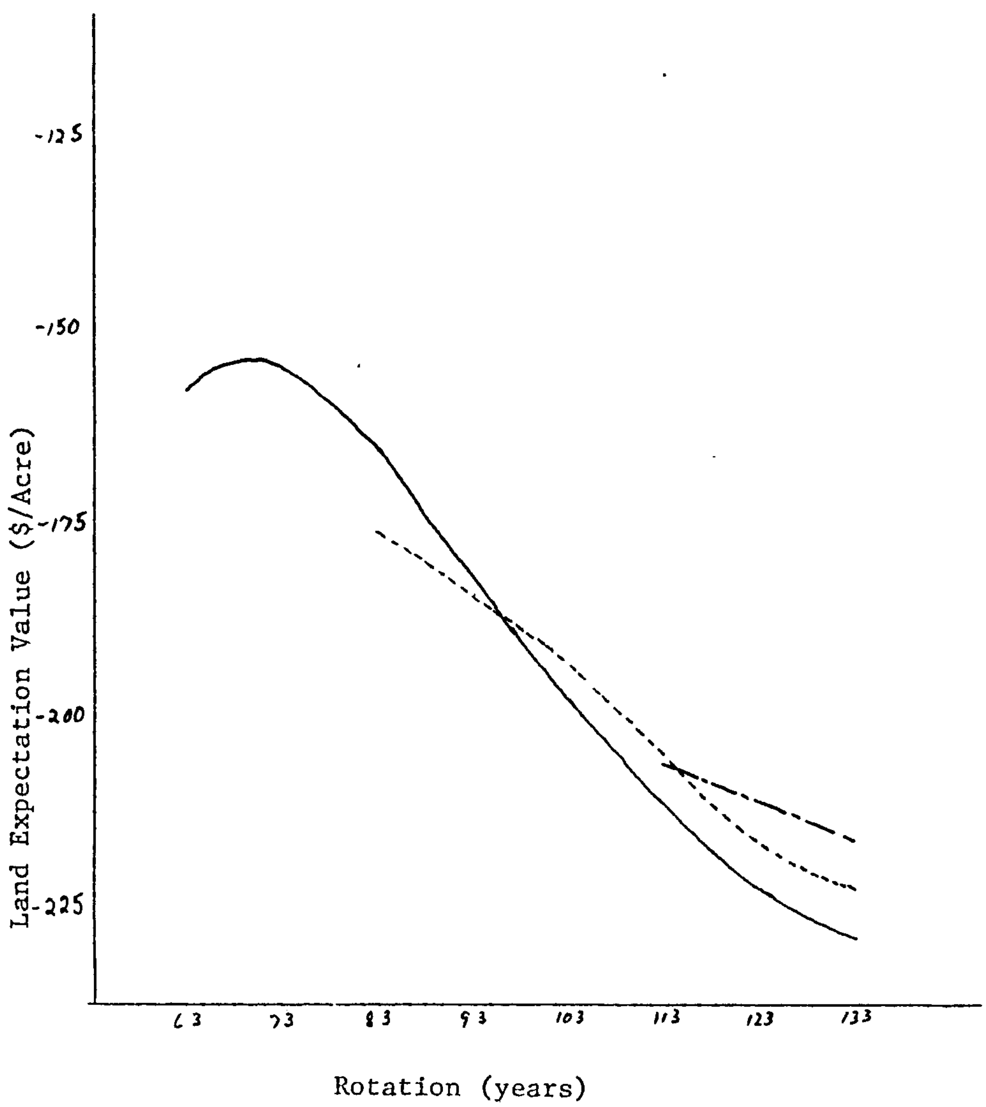
Graph 3(b)

Habitat Type Group: F
Slope Class: (0 - 20%)
Regeneration Method: Planting
Discount Rate: 3.5%



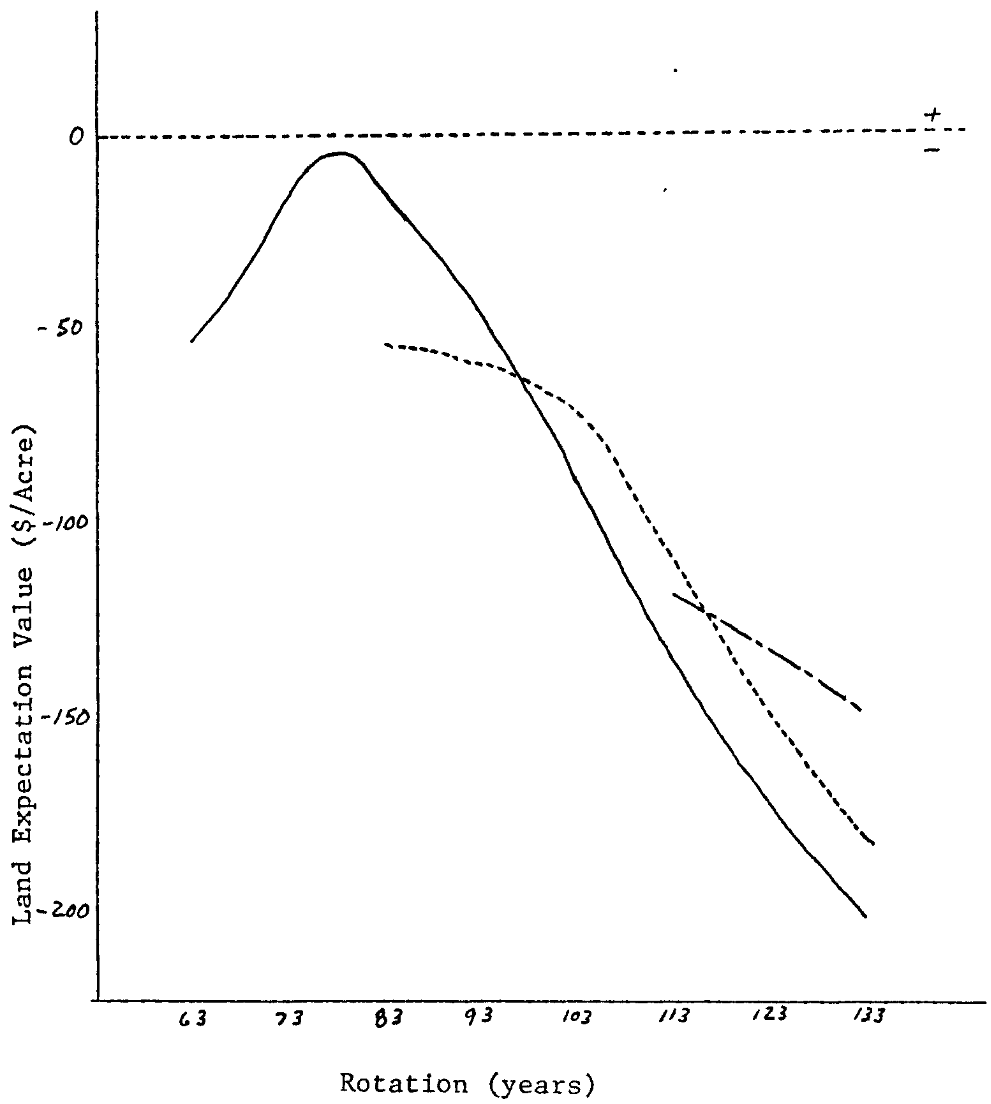
Graph 4(a)

Habitat Type Group: E
Slope Class: (40 - 60%)
Regeneration Method: Planting
Discount Rate: 5.0%



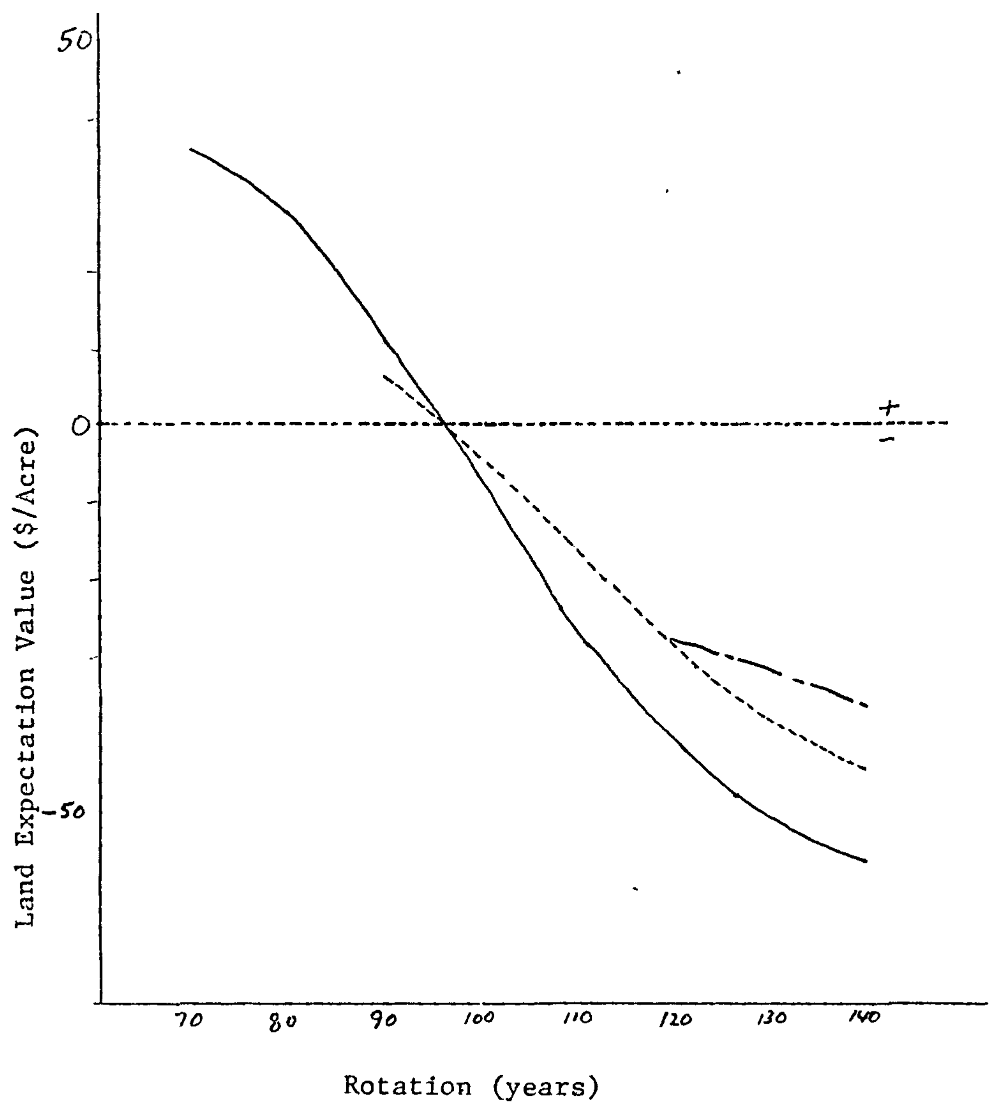
Graph 4(b)

Habitat Type Group: E
Slope Class: (40 - 60%)
Regeneration Method: Planting
Discount Rate: 3.5%



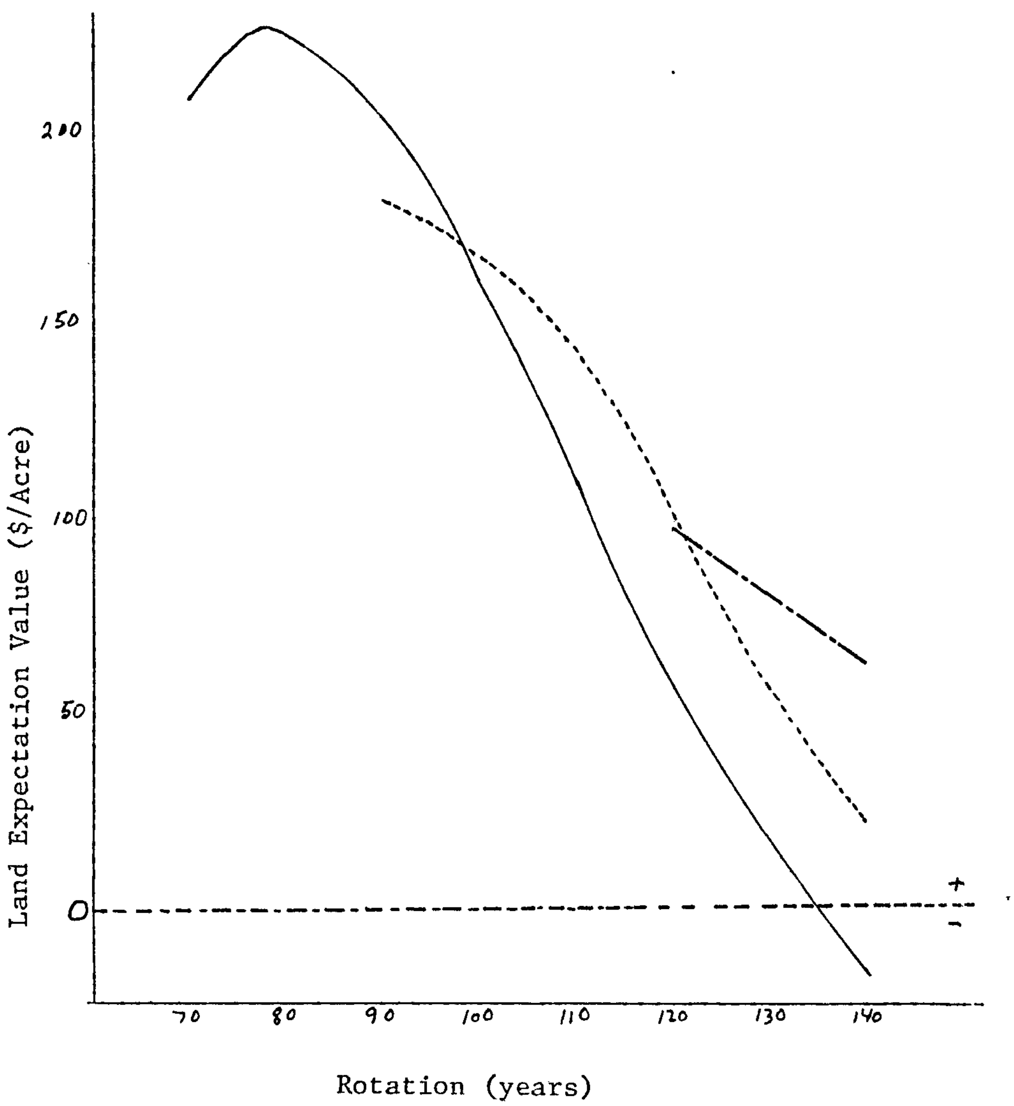
Graph 5(a)

Habitat Type Group: E
Slope Class: (0 - 20%)
Regeneration Method: Natural with 10 years average delay
Discount Rate: 5.0%



Graph 5(b)

Habitat Type Group: E
Slope Class: (0 - 20%)
Regeneration Method: Natural with 10 years average delay
Discount Rate: 3.5%



APPENDIX J

Ranking of Area Classes by Land Expectation Value (Clearcutting and Shelterwood Cutting Without Commercial Thinning)

Tables 1 - 3 in this appendix are for the clearcutting regimes, while tables 4 - 6 are for the shelterwood cutting cutting regimes. In each table:

FV = future (non-discounted) value

PV_R = present value of the revenues/acre

PV_C = present value of the costs/acre

LEV = land expectation value (PV_R - PV_C)

In the shelterwood regime tables, the ten-year difference between the rotation age and the stand age at initial entry is due to an average regeneration delay period of ten years. This average delay period on planted clearcut sites (Tables 1 - 3) is three years.

TABLE 1

Clearcutting: 5% Discount Rate
(Values are in 1978 Dollars)

Area Class	Rot. Age	Harv. Age	Harv. Vol. (mbf/acre)	Harv. d.b.h. (inches)	Price (FV/mbf)	MAI (bf)	PV_R	PV_C	LEV
E-1	63	60	10.530	10.5	$307.69	167	$157.10	$213.87	$- 56.77
E-2	63	60	10.530	10.5	307.69	167	157.10	218.82	- 61.72
CD-1	63	60	8.444	9.9	315.08	134	129.01	220.36	- 91.35
CD-2	63	60	8.444	9.9	315.08	134	129.01	225.31	- 96.30
F-1	63	60	9.342	8.8	200.77	148	90.94	212.73	-121.78
F-2	63	60	9.342	8.8	200.77	148	90.94	217.68	-126.73
E-3	73	70	13.905	11.9	238.82	190	97.04	252.09	-155.05
CD-3	63	60	8.444	9.9	203.66	134	83.38	242.24	-158.86
E-4	73	70	13.905	11.9	238.82	190	97.04	261.06	-163.97
CD-4	63	60	8.444	9.9	203.66	134	83.38	251.33	-167.95
F-3	73	70	9.342	9.9	121.01	144	37.21	250.13	-212.92
F-4	73	70	9.342	9.9	121.01	144	37.21	259.15	-221.84

TABLE 2

Clearcutting: 3.5% Discount Rate
(Values are in 1978 Dollars

Area Class	Rot. Age	Harv. Age	Harv. Vol. (mbf/acre)	Harv. d.b.h. (inches)	Price (FV/mbf)	MAI (bf)	PV_R	PV_C	LEV
E-1	73	70	13.905	11.9	$350.25	190	$430.19	$258.39	$ 171.80
E-2	73	70	13.905	11.9	350.25	190	430.19	265.05	165.14
CD-1	63	60	8.444	9.9	315.08	134	343.98	272.48	71.50
CD-2	63	60	8.444	9.9	315.08	134	343.98	279.39	64.59
E-3	73	70	13.905	11.9	238.82	190	293.33	308.26	- 14.93
F-1	63	60	9.342	8.8	200.77	148	242.50	265.36	- 22.87
E-4	73	70	13.905	11.9	238.82	190	293.33	319.34	- 26.01
F-2	63	60	9.342	8.8	200.77	148	242.33	272.27	- 29.78
CD-3	63	60	8.444	9.9	203.66	134	222.34	299.68	- 77.35
CD-4	63	60	8.444	9.9	203.66	134	222.34	311.17	- 88.84
F-3	73	70	10.523	9.9	121.01	144	112.48	302.35	-189.87
F-4	73	70	10.523	9.9	121.01	144	112.48	313.40	-200.94

TABLE 3

Clearcutting: 6.5% Discount Rate
(Values are in 1978 Dollars)

Area Class	Rot. Age	Harv. Age	Harv. Vol. (mbf/acre)	Harv. d.b.h. (inches)	Price (FV/mbf)	MAI (bf)	PV_R	PV_C	LEV
E-1	63	60	10.530	10.5	$307.69	167	$ 62.49	$187.10	$-124.61
E-2	63	60	10.530	10.5	307.69	167	62.49	190.83	-128.34
CD-1	63	60	8.444	9.9	315.08	134	51.31	194.33	-143.02
CD-2	63	60	8.444	9.9	315.08	134	51.31	198.06	-146.74
F-1	63	60	9.342	8.8	200.77	148	36.18	185.65	-150.47
F-2	63	60	9.342	8.8	200.77	148	36.18	190.38	-154.20
CD-3	63	60	8.444	9.9	203.66	134	33.17	213.04	-179.87
E-3	63	60	10.530	10.5	196.26	167	39.86	227.35	-187.49
CD-4	63	60	8.444	9.9	203.66	134	33.17	220.68	-187.51
E-4	63	60	10.530	10.5	196.26	167	39.86	234.80	-195.12
F-3	73	70	10.523	9.9	121.01	144	12.97	223.63	-210.67
F-4	73	70	10.523	9.9	121.01	144	12.97	231.20	-218.23

TABLE 4

Shelterwood Cutting: 5.0% Discount Rate

(Values are in 1978 Dollars)

Area Class	Rot. Age	Stand Age In.Ent.	In. Ent. Harv. Vol. (mbf/acre)	Harv. d.b.h. (inches)	Price (FV/mbf)	Over.Rem. (yrs foll. In.Ent.)	Over.Rem. Harv.Vol. (mbf/acre)	Harv. d.b.h. (inches)	Price (FV/mbf)	MAI (bf)	PV_R	PV_C	LEV
E-1	80	70	9.038	11.9	$238.96	10	6.243	13.1	$339.82	191	$ 71.29	$122.04	$- 50.74
E-2	80	70	9.038	11.9	238.96	10	6.243	13.1	339.82	191	71.29	125.46	- 54.17
CD-1	80	70	6.393	11.3	245.61	10	4.283	12.7	354.05	133	51.50	120.47	- 68.96
CD-2	80	70	6.393	11.3	245.61	10	4.283	12.7	354.05	133	51.50	123.89	- 72.39
F-1	80	70	6.840	9.9	126.12	10	4.588	11.1	233.42	143	31.30	120.73	- 89.42
F-2	80	70	6.840	9.9	126.12	10	4.588	11.1	233.42	143	31.30	124.15	- 92.85
CD-3	80	70	6.393	11.3	134.19	10	4.283	12.7	242.62	133	30.80	131.42	-100.62
CD-4	80	70	6.393	11.3	134.19	10	4.283	12.7	242.62	133	30.80	134.85	-104.04
E-3	80	70	9.038	11.9	127.53	10	6.243	13.1	228.39	191	41.76	154.86	-113.10
E-4	80	70	9.038	11.9	127.53	10	6.243	13.1	228.39	191	41.76	158.29	-116.52
F-3	80	70	6.840	9.9	14.70	10	4.588	11.1	122.00	143	9.15	153.55	-144.40
F-4	80	70	6.840	9.9	14.70	10	4.588	11.1	122.00	143	9.15	156.97	-147.83

TABLE 5

Shelterwood Cutting: 3.5% Discount Rate

(Values are in 1978 Dollars)

Area Class	Rot. Age	Stand Age In.Ent.	In.Ent. Harv.Vol. (mbf.acre)	Harv. d.b.h. (inches)	Price (FV/mbf)	Over.Rem. (yrs.foll. In.Ent.)	Over.Rem. Harv.Vol. (mbf/acre)	Harv. d.b.h. (inches)	Price (FV/mbf)	MAI (bf)	PV_R	PV_C	LEV
E-1	80	70	9.038	11.9	$238.96	10	6.243	13.1	$339.82	191	$249.64	$169.29	$ 80.36
E-2	80	70	9.038	11.9	238.96	10	6.243	13.1	339.82	191	249.64	174.42	75.22
CD-1	80	70	6.393	11.3	245.61	10	4.283	12.7	354.05	133	180.24	163.84	16.40
CD-2	80	70	6.393	11.3	245.61	10	4.283	12.7	354.05	133	180.24	168.97	11.27
F-1	80	70	6.840	9.9	126.12	10	3.683	11.1	233.42	143	110.52	164.73	- 54.22
F-2	80	70	6.840	9.9	126.12	10	3.683	11.1	233.42	143	110.52	169.87	- 59.35
E-3	90	80	10.995	12.9	154.05	10	7.348	14.1	249.72	204	141.84	201.94	- 60.10
E-4	90	80	10.995	12.9	154.05	10	7.348	14.1	249.72	204	141.84	206.97	- 65.13
CD-3	80	70	6.393	11.3	134.19	10	4.283	12.7	242.62	133	108.65	179.19	- 70.54
CD-4	80	70	6.393	11.3	134.19	10	4.283	12.7	242.62	133	108.65	184.33	- 75.67
F-3	90	80	7.264	11.4	48.46	20	5.991	13.0	163.71	135	40.02	196.37	-156.35
F-4	90	80	7.264	11.4	48.46	20	5.991	13.0	163.71	135	40.02	201.41	-161.39

TABLE 6

Shelterwood Cutting: 6.5% Discount Rate

(Values are in 1978 Dollars)

Area Class	Rot. Age	Stand Age In.Ent.	In.Ent. Harv.Vol. (mbf/acre)	Harv. d.b.h. (inches)	Price (FV/mbf)	Over.Rem. (yrs.foll. In.Ent.)	Over Rem. Harv.Vol. (mbf/acre)	Harv. d.b.h. (inches)	Price (FV/mbf)	MAI (bf)	PV_R	PV_C	LEV
E-1	80	70	9.038	11.9	$238.96	10	6.243	13.1	$339.82	191	$ 21.48	$ 97.37	$- 75.89
E-2	80	70	9.038	11.9	238.96	10	6.243	13.1	339.82	191	21.48	99.74	- 78.25
CD-1	80	70	6.393	11.3	245.61	10	4.283	12.7	354.05	133	15.53	96.89	- 81.37
CD-2	80	70	6.393	11.3	245.61	10	4.283	12.7	354.05	133	15.53	99.26	- 83.74
F-1	80	70	6.840	9.9	126.12	10	4.588	11.1	233.42	143	9.36	96.97	- 87.61
F-2	80	70	6.840	9.9	126.12	10	4.588	11.1	233.42	143	9.36	99.34	- 89.98
CD-3	80	70	6.393	11.3	134.19	10	4.283	12.7	242.62	133	9.22	105.08	- 95.87
CD-4	80	70	6.393	11.3	134.19	10	4.283	12.7	242.62	133	9.22	107.45	- 98.23
E-3	80	70	9.038	11.9	127.53	10	6.243	13.1	228.39	191	12.49	126.82	-114.34
E-4	80	70	9.038	11.9	127.53	10	6.243	13.1	228.39	191	12.49	129.19	-116.71
F-3	80	70	6.840	9.9	14.70	10	4.588	11.1	122.00	143	2.60	126.43	-123.82
F-4	80	70	6.840	9.9	14.70	10	4.588	11.1	122.00	143	2.60	128.79	-126.19

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