

United States
Department of
Agriculture

Forest
Service

Timber
Management
Washington, D.C.

PROCEEDINGS OF THE NATIONAL SILVICULTURE WORKSHOP

ECONOMICS OF SILVICULTURAL INVESTMENTS

Eugene, Oregon
May 16-20, 1983

Acknowledgement

The 1983 Silviculture Workshop was held in Eugene, Oregon, and the Willamette National Forest. The purpose of the workshop was to review and discuss the requirements by laws, regulations, and Forest Service policy of the need for and uses of economic analyses in silvicultural program planning and development.

The Washington Office Silviculture Group appreciates the efforts of our hosts from the Willamette National Forest, Weyerhaeuser Corporation and the Pacific Northwest Regional Office. We would also like to extend our thanks to all who made presentations and participated during the session.

Silviculture Group
Timber Management Staff
Washington, DC

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Theme: Economics of Silvicultural Investments

Division of Timber Management
USDA, Forest Service
Washington, D.C.

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AGENDA
1983 NATIONAL SILVICULTURE WORKSHOP
EUGENE, OREGON
May 16 through 20, 1983

THEME: Economics of Silvicultural Investments

PURPOSE OF MEETING: Discuss current silvicultural issues affecting all Regions. Review and discuss requirements in laws, regulations and policy concerning the need for and the use of economic analysis in silvicultural program planning and development. Develop an understanding of appropriate techniques in developing analyses and the use of economics in various decision situations.

May 16 (Indoors)

Moderator - Dick Fitzgerald, TM, WO

1:00 p.m.	Call to order (Introduction of Participants)	Dick Fitzgerald, WO
	Welcome	Region 6 & Willamette National Forest
	Purpose of Workshop	Dick Fitzgerald, WO

National Issues Related to Silviculture

1:45 p.m.	National Perspective of Silvicultural Programs and Budgets for FY 1983 and Future years.	Dick Fitzgerald, WO
2:15 p.m.	- National Review of TSI - Reforestation - TSI Needs and Program Planning. (Economics and lost production from delaying programs)	Dick Shaffer, WO
2:45 p.m.	Break	
3:00 p.m.	Contracting for Seedling Production. (Is a standard contract needed?)	Dick Miller, WO
	Equipment Development Needs (Identification of field level needs)	Dick Miller, WO w/Workshop participation)
5:00 p.m.	Break for Day	

May 17 (Indoors)

Moderator - Carl Puuri, TM, WO

8:00 a.m.	The National Scene - Silvicultural Challenges	George Leonard, WO
8:40 a.m.	Silvicultural Systems Reviews (Significant issues, strengths and weaknesses)	Carl Puuri, WO
	Growth and Yield Modeling (Planning for future development and implementation)	

May 17 cont'd

9:00 a.m.	Stocking Level Curve Standarization	Walt Knapp, R-6
9:15 a.m.	Open Discussion from Floor	
9:45 a.m.	Break	

TECHNICAL SESSION

Economic Concepts and Requirements

Moderator - Clark Row, FRER, WO

10:00 a.m.	Introduction to Forest Service Economics (terminology, concepts, and direction)	Charles Palmer, LMP, WO
11:00 a.m.	Legal Requirements 1. NEPA (EIS, EA) 2. NFMA 3. Legal Challenges	Clark Row, FRER, WO
12:00 p.m.	Lunch	
1:00 p.m.	Frameworks for Economic Analysis or Fitting the Problem at Hand	Tom Ortman, R-6
3:00 p.m.	Using Economics and Efficiency Analysis in Land Management Decisions and Activities	Larry Larson, R-1
4:00 p.m.	Improving Land Management Decisions through use of Economics	Lee Medema, University of Idaho
5:00 p.m.	Break for Day	

May 18 (Outdoors) - Day will be spent on the Willamette National Forest and industrial forest land with discussions of how economic evaluations are used. Ralph Jaszowski, Regional Silviculturist, R-6 will be tour leader and moderator. Willamette National Forest will host the field trip.

May 19 (Indoors)

Economics and Decision Making

Moderator - Linda Hagen, TM, WO

8:00 a.m.	How Should We Consider Other Resources?	Chris Hansen, R-6
8:45 a.m.	Interrelationships Among Biological, Financial, and Silvicultural Decisions in Forestry	Vernon Robinson and Will Fey, SE
9:45 a.m.	Break	

May 19 cont'd

10:00 a.m.	Generating Efficient Timber Prescriptions	Norm Johnson or Kathy Sleavin, CSU
11:00 a.m.	Trade-off Analyses	Roger Fight, PNW
12:00 p.m.	Lunch	
1:00 p.m.	Program Demonstration 1. R-1 CHEAPO 2. R-6 Hand Calculator Program 3. PNW Poster Presentation 4. Other Regions include appropriate examples and demonstrations	Lee Medema, University of Idaho and Regional Representative Regional Representative Roger Fight, PNW Regions Bring Examples
2:30 p.m.	Break	

Concurrent Sessions

Session A

Moderator - Dick Miller, TM, WO

2:45 p.m.	Forestry Incentives Program Economic Analysis (Investments, returns from reforestation & TSI)	Chris Risbrudt, S&P
3:30 p.m.	Analyzing Bids for Silvicultural Projects Promotes Fund Allocation Efficiency	Richard Guldin, SO
4:15 p.m.	Economics in R-8 Planning	Richard Greenhalgh, R-8

Session B

Moderator - Dick Shaffer, TM, WO

2:45 p.m.	Stratifying Sites Needing Site Preparation and Release	Mike Skinner and John Fiske, R-5
3:30 p.m.	Economics and Genetic Gains in Blister Rust Programs	George Howe, R-1
4:15 p.m.	Study on Costs of Silvicultural Treatments. Survey of project on N.F.'s	Tom Mills, PSW
5:00 p.m.	Break for Day (Both Sessions)	

May 20 (Indoors)

Moderator - Carl Puuri, TM, WO

7:30 a.m.	Using Economics in the Decision Process	John Beuter, Oregon State University
11:30 a.m.	Summary and Conclusion of Session	Dick Fitzgerald, WO

NATIONAL SILVICULTURE WORKSHOP

Workshop Attendees

R-1

Richard Deden
John Naumann
Allen Christopherson
P George Howe
P Larry Larson

R-2

Milo Larson
Jim Beavers

R-3

Tom Hentz
Dick Bassett
Stanley Randell
Jim Dick

R-4

Dave Iverson
Jerry Hamilton
Ed Harvey

R-5

Will Charter
Bill Beaufait
P John Fiske

R-6

Jack Usher
P Ralph Jazkowski
Bud Twombly
P Walt Knapp
Jim Edgren
P Tom Ortman
P Chris Hansen
Pete Stanger

R-8

Lee Cromley
Robert Kitchens
Dan Sims
P Richard Greenhalgh

R-9

Bob Blomquist
Kent Austin

R-10

Dennis Murphy
John Stanswick
Dale Heigh
Joe Mehrkens
Morris Huffman

S&P

Lloyd Casey (NA)

WO

P Director or Deputy Director (TM)
P Dick Fitzgerald (TM)
P Dick Shaffer (TM)
P Dick Miller (TM)
P Carl Puuri (TM)
P Charles Palmer (LMP)
P Linda Hagen (TM)
P Clark Row, FRER
P Chris Risbrudt (S&P)
Steve McDonald (S&P)
Dan Schroeder (FCCC)

Research

Wayne Shepperd (RM)
P Richard Guldin (SO)
Calvin Bey (Juneau)
Arland Harris (Juneau)
Dean DeBell (Olympia)
Donald Reukema (Olympia)
Robert Curtis (Olympia)
P Roger Fight (Portland)
Tom Adams (Portland)
Roy Silen (Corvallis)
Pat Cochran (Bend)
Ken Seidel (Bend)
P Tom Mills (PSW)
P Vernon Robinson (SE)
P Tom Brown (RM)
Bennee Swindell (SE)

P - Scheduled Speaker at workshop

NATIONAL SILVICULTURE WORKSHOP

Workshop Attendees Cont'd

Other

P Lee Medema, University of Idaho
P John Beuter, Oregon
State University
P Will Fey, Georgia Institute
of Technology
P Norman Johnson, Colorado
State University
Stan Detering, BLM
Chuck Frost, BLM (WO)
Tom Aufenthie, BLM
R. Michael Martin, BLM
Bob Sanders, Forest Silviculturist,
Willamette National Forest

LEGAL REQUIREMENTS FOR ECONOMIC ANALYSIS

Clark Row
Forest Resources Economic Analysis
UDSA Forest Service
Washington, DC

Summary

The legal requirements for economic analysis have been growing more stringent with the passage of NEPA and NFMA, and subsequent court decisions. So far, the major requirements affect the need for analysis, when the analysis should be done, and other procedural issues. The content of the analysis has only been prescribed in regulations, and has rarely been challenged in court. Analyses for National Forest plans, however, have not yet been involved in court cases.

A brief legal history of economics for federal decisionmaking
While extensive economic analyses were frequently made in the 1950's and 1960's, they were made for administrative reasons and not in response to legal requirements, or even regulations. At first the techniques and procedures used varied from one agency to another, or even between analysts. In the late 1950's the so-called "green book" was issued by an interagency committee created to establish more or less uniform procedures within the federal government. Later the role of coordination was taken over by the Water Resources Council, created by the Water Resources Planning Act of 1965. Ultimately the WRC issued a relatively elaborate set of economic analysis standards and procedures, which has been revised by the current administration.

The Water Resources Planning Act did not itself require economic analyses to be made, only that assessments be made, coordination be attempted, and that principles, standards, and procedures be developed. It was up to individual agencies to require the analyses, and the requirements could not be enforced effectively in court.

Part of the pressure for the coordination efforts in the 1950's and 1960's was the widespread perception by analysts and the public that many economic analyses were made only to justify projects after a decision has been made to undertake them. It was alleged that benefits were inflated and even double-counted, that direct costs were underestimated, and that indirect costs and effects were often ignored. Furthermore there were rarely opportunities for the public to comment on the plans or analyses.

Another push for economic analysis occurred during the enthusiasm for the Planning-Programming-Budgeting efforts associated with the Kennedy-Johnson administration in the 1960's. During this era and afterward many procedural advances were made, limitations of analysis were better recognized, and public acceptance for analysis gained. But still there were no legal requirements for economic analysis that could be enforced by litigation.

Legal requirements for analysis as we know them now stem from passage of

the National Environmental Protection Act in 1969. This Act, the most important and lasting impetus for economic analysis in federal decision-making, puts great stress, however, on only the procedural aspects of the decisionmaking. Among the many provisions of the Act are requirements for a defined procedure in planning and decisionmaking, publication of documents and provisions for public comment, development of alternatives, and disclosure and display of analysis procedures and results.

NEPA's emphasis is on analysis and disclosure of the external environmental effects of federal projects and programs, among which they included economic and social impacts. Unlike the previous efforts to encourage economic analysis by the WRC, the PPB movement, and various agencies, NEPA did not emphasize economic efficiency in federal resource investments.

Most of the court litigation and opinions concerning economic analysis requirements concern NEPA. The volume of litigation continues to rise and nearly all issues covered by the Act now have court interpretations. But to repeat, nearly all those issues relating to economics concern procedural aspects and not analytical content.

The Forest Service, alone among major federal resource management agencies, is now going through another revolution in analysis for decision-making. The Renewable Resources Planning Act of 1974, and the amending National Forest Planning Act of 1976 have had the effect of requiring extensive economic analysis, both for agency-wide assessments and programs (called for by RPA), and National Forest Plans (called for by NFMA). While not directly saying so, they imply that among the issues that must be addressed are economic efficiency and economic and social impacts. The NFMA also called for separate guidelines for economic analysis. These were not directly addressed by the regulations to implement NFPA (CFR 219), but were deferred to a separate document to be developed by the Forest Service. These guidelines were published in the Federal Register in provisional form in April 1980, and in final form in May 1981. They are now sections 1970, 1971, 1972, and 1973 of the Forest Service manual. These FSM sections have the force of law according to Forest Service attorneys.

The emphasis of FSM 1970 is on general requirements and coordination of all economic and social analysis; FSM 1971 treats economic efficiency requirements; and FSM 1972 and 1973 treat economic and social impacts respectively. Handbook procedures for all sections are now in draft stage.

Procedural requirement for economic analysis

As mentioned, the absolute requirements that economic and social analyses be made rest mostly on requirements of NFPA, its implementing regulations, and on the Forest Service manual. They are required by NEPA only - if economic effects are identified as a major issue or concern for the project or program. However, if an economic analysis is conducted, whether required by NEPA or not, then many of the NEPA procedural details must be followed.

Chief among these procedural requirements are:

* The economics of the situation must be considered in the formation of each alternative by the interdisciplinary team, rather than be analyzed only after the alternatives are formed on biological, physical, or engineering considerations. An even worse procedural flaw would occur if the economic analysis were to be conducted after the recommended alternative has been selected or the decision made.

* All alternatives to be actively considered for a decision, including a mandatory "no action" or base alternative, require the same type and degree of economic and social analysis. (So-called "benchmark" alternatives developed only to illustrate or to display an extreme emphasis on an output or resolution of an issue, do not need the full analysis.)

As the California vs. Block decision on the RARE II analysis and decision pointed out, failure to analyze each alternative in the same way can be a fatal procedural flaw. Among the issues in that case was the lack of the same type of economic analysis for the "wilderness uses" alternatives as was given to the "non-wilderness uses" alternatives.

* If an economic or social analysis is made, it must be reported and displayed, even though it turns out it would not have an important bearing on the decision made. For example, reporting in the published documents only the economic efficiency analyses, and not the economic impact analysis (if made) would be a serious flaw.

* All of the major assumptions, information collected, procedures used, results obtained, and literature employed should be documented, whether in the primary Draft Environmental Impact Statement or in other available documents. If taken to the ultimate, an analyst couldn't throw any paper away, but good judgment should be used.

(There exists some spirited disagreement on how much analytical results should be edited in draft and final economic impact statements. One school believes that the primary purpose is to inform the public, and this takes heavy editing and rewriting to make it understandable to average citizens. Another school can point to court cases in which one or more issues involved material in statements so edited that it omitted important facts and qualifications, or was misleading in terms of the circumstances.)

Another procedural aspect is that the guidelines for making analyses as well as the analyses themselves must be made public. This is the primary reason for the publication of FSM 1970 in the Federal Register, which is unusual for a section of the Forest Service manual.

Requirements for content of economic analysis

Remarkably little in the legal history of economic analysis of federal programs or projects, chiefly under NEPA, concerns the content or proce-

dures of the analysis itself.

There are a number of court cases where very obvious goofs were made in the analysis, and subsequently become issues in the decisions. But in general courts have accepted the assumptions, data, procedures, and results as long as they were reasonably professional and no element of fraud or intentional bias were perceived. Courts are loath to place themselves as arbiters of what is professionally adequate professional analysis.

Several cases have dealt with issues related with assumptions of analysis. In litigation not involving the Forest Service, the courts have ruled on the reasonableness of discount rates used, whether costs have been representative, and the assumptions used in determining values. But in general the cases have been sporadic and no general guidelines from either law or court cases could probably be made.

However, the courts have yet to deal with cases that arise from requirements that economic analysis consider the economic efficiency of federal programs or projects, such as the NFMA does. None of the National Forest Plans being developed have been issued as final decisions or final environmental impact statements, and so could be brought to court. But from the range of comments a wide range of issues related to the economic analysis might be attacked in various plans. These may include:

- * The discount rate of 4 percent prescribed in FSM 1970 for long-range Forest Service planning. This is substantially lower than those used for other federal agencies, though based on substantial economic rationale.

- * The role of the economic analysis of the suitability of lands, and the use of that information in development of alternatives.

- * The degree to which the economic information on costs and output values are specific to individual analysis areas, especially in comparison to the site-specificity of the biological and physical information.

- * Whether the economic analysis is hiding any alledged subsidies of one type of output to another function, particularly whether timber harvest is being subsidized.

These may be just a few of the issues that might be raised. But in the coming few years the courts may substantially influence the way the Forest Service conducts its economic analysis, both in field units and in central planning.

THE ROLE OF ECONOMICS IN NATIONAL FOREST PLANNING

Charles Palmer, Clark Row, Robert M. Randall

Introduction

Since the National Forest Management Act (NFMA) was passed, economic analysis has been integrated into the land management planning process. The Forest Service has adopted a unique framework for economic analysis to deal with the difficult problems the law forces us to face:

- * Production processes that are technically complex and specific to numerous on-the-ground conditions.

- * Varied outputs and effects that must be recognized include those that (a) have market values, (b) could have market values if they were marketed, and (3) provide no basis for market-like values.

- * Large comparative advantages among analysis areas within National Forests, and among Forests and Regions, that require mathematical programming techniques to identify the most efficient alternatives.

The limits of state-of-the-art of economic methodology prohibits computation of a single comprehensive measure of economic worth and thus the identification of an "optimum" management alternative. The analyses we are attempting to develop measures of economic effectiveness and economic impact that, along with other criteria, help decisionmakers select alternatives that will produce the highest "net public benefit" as the NFMA law directs.

The economic analysis also helps focus the debate over management policies and alternatives on those elements of the planning process that are most uncertain--the relative values of the outputs and effects that each alternative management plan would produce.

The Guiding Laws

RPA and NFMA

The Forest and Rangeland Renewable Resources Planning Act (RPA) as amended by The National Forest Management Act (NFMA) states in Section 3(d)(1) that "It is the policy of the Congress that all forested lands in the National Forest System shall be maintained . . . to secure the maximum benefits of multiple use sustained yield management in accordance with land management plans." To fulfill this policy the Act requires the Forest Service to "develop . . . (1) . . . one integrated plan for each unit of the National Forest System" (NFMA, Sec 6(f)) and "In developing, maintaining, and revising plans for units of the National Forest System . . . the Secretary shall assure that such plans--(1) provide for multiple use and sustained yield of the products and services obtained therefrom . . . in particular, include coordination of outdoor recreation, range, timber, watershed, wildlife and fish, and wilderness . . ." (NFMA, Sec.6(e)).

The regulations published in the Federal Register September 30, 1982 interprets NFMA to require the Forest Service to develop a planning process in which ". . . the resulting plans shall provide for multiple use and sustained yield of goods and services from the National Forest System in a way that maximizes long term net public benefits in an environmentally sound manner (36 CFR Part 219.1)."

Net public benefit is defined to be "the overall value to the Nation of all outputs and positive effects (benefits) less all associated inputs and negative effects (costs) whether they can be quantitatively valued or not. Net public benefits are measured by both quantitative and qualitative criteria rather than a single measure or index. The maximization of net public benefits to be derived from management of units of the National Forest System is consistent with the principles of multiple use and sustained yield (36 CFR Part 219.3)."

Interpreting the law in economic analysis.

Although the regulations are not specific, the overall intent and the definition of "net public benefits" interprets RPA and NFMA as direction to manage the National Forests in accordance with the "principle of maximum social gain." Robert H. Haveman (1976) defined this principle as: "The public sector, in undertaking any activity, should choose that alternative for which the gains to society exceed the costs by the greatest amount and should refrain from any activity if its benefits do not exceed the costs."

The simplicity of this principle is that if gains to society only equal the costs, public expenditure adds nothing on balance to the Nation's welfare, but if the gains are less than the costs it detracts from economic well-being. Of course, net public benefits are explicitly defined to include all gains to society and not just those assigned a monetary value.

Congress, in passing NFMA, delegated certain decisionmaking authority to the Secretary of Agriculture, who in turn has passed the authority to Forest Service line officers. In doing so, Congress put constraints on decision makers by establishing three necessary conditions that must exist in every forest management plan (36 CFR 219.1(b)):

1. Maintenance of Long-run productivity of the land. This means the land must be maintained in a condition that will not impair its capacity to produce future outputs of goods and services (36 CFR 219.1(b)).
2. Coordination and integration of planning activities for multiple-use management. This requires each resource be considered equally in the planning process. At a minimum, no resource is emphasized to the exclusion or violation of the minimum or threshold management requirements of other resources (36 CFR 219.12)(Clawson, 1975)(Mealey and Horn, 1981).
3. Management sensitive to economic efficiency. This means that each alternative shall be the most cost-efficient combination of management prescriptions examined that meets the objectives of the alternative management plan (36 CFR 219.12).

The definition of "net public benefits" and the current state-of-the-art methodology in economics and all other disciplines rules out the possibility of a single value or index to represent net public benefit. Instead, the entire analysis process should simultaneously analyze and display all outputs, inputs and effects. Then, decisionmakers must weigh all of the values identified by markets, preferences, and trade-offs to determine the allocation of resources that, in their judgment, comes nearest to the greatest long-run net public benefits.

Economic analysis and political bargaining.

Some argue that the political and administrative bargaining process by which public spending decisions are made embodies a kind of "invisible hand"--at least if it is working effectively. They feel this automatic guidance system insures that the full range of interests and tastes is heard through the public involvement process in identifying public issues, management concerns and opportunities, and commenting on the alternatives. Social values are thus represented when public decisionmakers pursue what they perceive is the public interest. (And if they do not perceive correctly, they may find they no longer make decisions.)

If these assertions are true, what is the role of analysis in the public spending process? If total benefits and total costs are automatically taken into account in the public involvement process, why should the impacts be specifically estimated and analyzed?

Although the public involvement and political processes are important, the analysis of public spending alternatives is a crucial step in securing efficient budget allocation decisions and in the bargaining process itself. The main role of analysis is in giving decisionmakers sufficient knowledge to judge and balance the competing claims. Certain costs and gains may not be accounted for in the bargaining process because they are not perceived and because certain interests, particularly those of diverse and unorganized groups of people, are not adequately presented. Decisionmakers and even beneficiaries may not be aware of certain kinds of gains or losses or may misjudge their size.

A second role of analysis is forcing all parties to focus on and debate the same set of issues. If inputs of alternatives are spelled out, the resource responses and the values (whether explicitly displayed or shown by a trade-off) attached to them can be clearly debated. It is especially the values on which individual judgments may differ. A good analysis forces the debate to focus on these valuation issues, instead of on matters not pertinent to the public interest.

Economic analysis in the decision process

For all major planning efforts, the economic analysis includes both an efficiency analysis and an equity or distributive analysis. Efficiency is calculated using costs and benefits and is displayed by the resulting "present net value" of the alternative. Equity is currently determined by analyzing the impacts or effects on affected economies and societies, and measured primarily by changes in employment and income; though both efficiency and distribution must be recognized in the decision process. If there were some means to evaluate society's preference for distribution of income and determine interpersonal values, the two might be included in the same calculus. But this is impossible now and in the foreseeable future. Present methodology requires that they remain two separate analyses. The decisionmaker must weigh the measures from each analysis along with all other outputs and measures, and consider them separately and not as a single decision criterion.

Efficiency analysis requires both a detailed consideration of the forest and grassland production processes and values for both inputs (costs of activities) and outputs. Both present major problems and limit the measures of efficiency that can be computed.

Efficiency of production processes

Efficiency is the relationship between the quantities of inputs and amounts of resulting outputs. The more of the output resulting per unit of input, the greater the efficiency. In forest management, inputs include combinations of labor and capital (or management activities) applied to a parcel of forest or grassland (analysis area) to provide a number of different outputs simultaneously. The physical input-output relationships identify technical efficiency. The monetary input-output relationship determine economic efficiency.

To measure either type of efficiency, the technical input-output relationships must be known. Three types of relationships between inputs and outputs are required to develop efficient management prescriptions for an analysis area.

1. Input-input relationships. These are, in practical terms, the feasible combinations of inputs (labor, equipment and supplies) that can be used together. The Forest planning process identifies all possible management practices (MIH activities) that when applied to the analysis area are compatible with each other and will achieve the forest condition and produce the desired outputs and effects. Technical efficiency is achieved when the least amount of activity or combination of activities brings about the desired forest condition and yields.

Input-input relationships are often "joint"--the use of one input affects one or more other inputs. There are four types of joint relationships:

a. Technical joint relationships occur when one activity cannot occur physically or biologically without the other. An example: harvesting trees for timber requires access roads to get the logs out to a mill.

b. Legally joint relationships are activities that the law or regulations require to occur together. For example: timber harvest requires all activities necessary to maintain water quality at the State's specified quality standards.

c. Economic joint relationships occur when activities can technically or legally be conducted separately, but when done together cost less to achieve given output levels. For example: It is often less expensive to get both timber and wildlife outputs when timber is harvested in such a way that wildlife habitat is enhanced. The National Forest Management Act regulations require economic joint relationships be analyzed extensively when developing management prescriptions.

d. "Artificial joint relationships" result if analysts or agencies erroneously and arbitrarily require two or more activities be performed together and never consider doing one without others. An example might be a high standard road and a timber sale. Timber sales may be harvested with a lower standard road but the agency wants high standard roads for other purposes. Efficiency is obtained if only the necessary activities to meet the objectives are included in the prescription, eliminating any extraneous or extravagant activities.

2. Input-output relationships. These specify how much output will result from a specified forest condition and the management activity or combination of activities required to achieve that Forest condition. The input/output relationships for an analysis area identify a production process. In forest planning these relationships must be translated into the physical coefficients (such as are recorded in FORPLAN yield tables). Good analysis practice requires a number of prescriptions for each analysis area. When the objectives of diverse alternatives are specified, a realistic and feasible prescription that emphasizes those objectives for each analysis area, must be available for application.

3. Output-output relationships. These are specific technical relationships that exist between the outputs of a production process--often called trade-offs. Technical efficiency, in output-output relationships, requires determining how outputs interact with each other. In forest planning this requires the knowledge of output trade-offs for different forest conditions--such as the different combinations of timber and forage that can be obtained by thinning timber to different standards.

There are three types of output-output relationships:

a. Complementary (or joint outputs). That is, when one output is produced, another or the joint output is also produced, even if it may be desirable not to have the joint output produced. The first three kinds of joint relationships occur with output-output complementary relationships as with input-input relationships. Examples of these relationships in Forest planning are numerous--they include such things as timber harvest causing a change in the quantity and quality of water.

b. Supplementary or independent. Relationships in which the production of one output has no effect on another output. In Forest management these types of relationships are hard to find.

c. Competitive relationships. One output can only be produced or increased by decreasing another output. An example is the incompatibility of wilderness recreation and timber harvest, since one excludes the other.

Values and Costs

Though determining various technical relationships among inputs and outputs in a production process is difficult and occupies a large share of a planning team's time, determining values of inputs and outputs presents even greater methodology questions and uncertainties.

Direct costs of activities: In Forest Service planning direct costs include all the costs of producing or developing the output up to the point where the output is valued or the environmental or social consequences are realized. These costs are accounted by Management Information Handbook (MIH) activity or activity type codes. Many managers would like to know which cost or activity produces which output, or to allocate all costs to outputs within an alternative. Since the forest and grasslands are to be managed for multiple uses, most outputs are joint. Therefore, all procedures available to allocate direct costs to outputs are purely arbitrary and do not present accurate information since outputs cannot be achieved with just the allocated costs but require the total cost of the prescription or project. A better procedure to compare costs of joint production processes is to develop full alternatives emphasizing the different outputs or forest conditions and then compare the total costs between the alternatives. Total direct costs for prescriptions or projects are the sum of the costs of each activity required to meet the objective of the prescription or project.

From an application's side one cannot include all costs. Though direct costs (labor, supplies and equipment) of activities can be determined, indirect or external costs of the process present numerous difficulties. Indirect costs, often called externalities or costs to third parties, include such effect as the cost of polluted water to downstream users or costs in wasted time because of overcrowding. Economic theory overcomes this problem by "internalizing" the externalities. Empirically, this has not been well developed.

Types of values. The most significant problem is determining output values that represent society's preferences. Values set in markets where both buyers and sellers are free to bargain are the most available measures. However, subsidies, price supports, regulations, and non-competitive situations often distort the values, so they do not represent society's true preferences. When such conditions prevail, analysts must make appropriate adjustments before the values can be used. This often can require an experienced analyst, careful research, and perhaps divine guidance.

The outputs not exchanged in markets present even more difficult problems. For many years economists have been developing methods to impute values that represents society's preferences for non-market outputs. Acceptable methods have been developed for many outputs, especially those that could be exchanged in the market place but are not because of government policy. Examples in Forest planning include recreation, range and water. There are other outputs called public goods, for which economists have not found acceptable valuation methods. Public goods are those outputs that when provided to one individual must be provided to all. Examples of public goods are national defense, fire protection, and police protection. In forest management, clean air, scenic beauty and just knowing the forest exists are outputs that have values to society but no empirical method of determination. Because of all these problems, a holistic economic efficiency analysis that will not only determine the most efficient method to achieve different objectives, but which alternative best meets society's preferences, cannot be developed.

There is always a question as to which outputs should be valued and which should be specified by the physical amounts to be produced. It seems preferable to have the amounts of each output that requires resources to be allocated to its production set on its own merits (value to society) rather than to be forced into production through arbitrary standards or guidelines. Hence, it is the policy of the Forest Service (FSM 1971.63) to value all outputs that are sold or could potentially be sold. That is, all outputs for which reasonable values can currently be imputed are produced up to the point where its value is greater than the costs and produces a greater return than a competing output value. FSM 1971.63 requires the following outputs to be valued: timber, recreation, range, water, wildlife and fish, minerals and energy. No attempt is made to value scenic beauty, threatened or endangered species or any other output or forest condition that no market exists for their exchange.

All output values are measured to similar standards to insure their comparability.

* Values are expressed in real dollar values (net of general inflation). It is not necessary to estimate inflation rates in future years. Base year values are used for the entire time horizon unless relative real changes in values can be estimated for values for future years.

* All values are based on the same point in the production process. In forest planning the point is where and when the output is removed from the Forest or Grassland. On-site uses are valued at the point and time of use.

Values for specific outputs:

* Timber outputs are volumes harvested by time period. Values can be calculated two ways: (1) As conversion surplus values--the price of lumber and other processed products minus costs for manufacturing and logging, or (2) As comparative values--statistically estimated from high bids (but including the road costs and other costs from previous sales.)

* Range outputs are the amounts of forage permitted to be grazed, measured by the number of animal unit months (AUMs). AUM values are calculated by the value of the marginal product of an AUM in the production of a marketable animal. The preferred analysis technique is the ranch budget approach. Returns from all ranch products are determined, then all costs of production are subtracted, the remaining returns plus the cost of the forest permits becomes the residual value of the AUM. The residual AUM value in ranch livestock production is comparable to conversion surplus timber values. The current grazing permit fee level should not be used as the value of an AUM.

* Water outputs are incremental water flows produced in addition to the flows that would occur naturally under the minimum management alternative. (The naturally occurring flows are not an output resulting from management activities.) Water values are residual values to users minus the cost of maintaining transport channels from the forest boundary to the point of use. Generally the value will be the marginal user's value since transport costs are negligible. In some areas watershed activities produce high quality water for municipal and industrial uses and thus have higher values.

* Wildlife and fish outputs include habitat for game and non-game fish and wildlife associated with recreation visitor days (RVD's). As with water, these RVD's are only changes from levels that would occur under the minimum management alternative. They are limited by the amounts estimated to be used by time period. The analysis should recognize that forests and grasslands only produce habitat for fish and wildlife. Production of the "animals" is someone else's responsibility, but the RVD's would not exist were it not for the habitat on the forest or grassland. The value for fish and wildlife habitat is the value of the additional RVD's minus the cost of other agencies providing and managing the animals. Such residual values are consistent with range and timber.

* Commercial fishing values are calculated using the same method as for range. Their value is the marginal product of the habitat in the production of the fish. Calculating commercial fish values requires budget analyses of the fishing industry as done for range values. After subtracting all costs, the residual value represents the value of the marginal product.

* Recreation outputs include all the recreation visitor days (RVD's) in addition to those from the minimum management alternative, but limited to the amount projected to be used each time period. Values for recreation activities occurring on the forest or grassland should be the users' willingness to pay at points of use. Values for those activities that require a concessionaire to provide services should only include portions of willingness to pay that can be attributed to the land. The analysis in such cases involves concession budget analysis as in range and commercial fish.

* Minerals outputs are the tons of ore and common minerals, and the oil and gas estimated to be extracted by time period. The value analysis requires the expected outputs to be multiplied by the probabilities that the areas would be developed. If only one area out of 10 that are explored is developed, then the output is only 1/10 of the output that would come from a developed area. Mineral values are only values of the marginal product, or the contribution of the land in mineral production. Free market royalties seem comparable to values of the other forest and grassland outputs. These royalties are not those administratively determined by the government.

Ways to Measure Efficiency

Technical efficiency measures how much output is produced per unit of input. Since the direct inputs can generally be reduced to two; acres of land and dollars of budgeted funds, the measures are generally calculated on those two bases. Generally, outputs per acre are computed and displayed in plans. But while informative, they have limited decisionmaking value.

One technical efficiency measure is the basis for a standard required by NFMA. Timber rotations cannot be shorter than the one with the highest mean annual increment per acre.

Cost effectiveness measures how well inputs (activities) in a production process are used to produce a fixed set of outputs. A cost effective analysis requires the amount of all relevant outputs and effects to be specified. Analysis computes the costs of each alternative set of activities and determines the least cost method of achieving those outputs. There are no alternative cost effective methods, since only one alternative is the least costly way to achieve a specific set of outputs. In forest planning, a management prescription for an analysis area is cost effective when the least costly way to produce all relevant outputs, uses and effects at specified levels is identified. A prescription that is not cost effective would achieve the same results but would cost more than the least cost prescription.

Economic efficiency measures how well inputs are used to achieve outputs when all inputs (activities) and all outputs (including market and non-market) are identified and valued. All costs to society are included just as they are in the cost effectiveness analysis. However, amounts of each output are not specified but are produced according to their contribution to society's value of the alternative. Economic efficiency is then a comparison of costs and value. The larger the value per unit of cost, the greater the economic efficiency of the process.

Ideally, economic efficiency, with all the costs identified and all outputs valued at society's preference rates, could define a situation in which all productive resources were allocated among alternative uses such that any reshuffling from this pattern could not improve any individual's position and still have all other individuals as well off as before. With the assumption that the distribution of income as given by the efficiency analysis is acceptable, "ideal" resource decision could be calculated. Because of the problems identified, the Forest Service does not pretend to be able to calculate a completely "economic efficient" alternative.

Why these traditional measures are not appropriate. The distinction between "cost effectiveness" and "economic efficiency" is not as clear in the economic literature as in the above definitions. Some writers argue that even if several outputs are produced at levels determined by market or estimated values it is still a cost effective analysis. Other writers claim that it does not matter whether all outputs are not valued in an economic efficiency analysis as long as specified amount are produced. However, without the distinction identified above, one cannot readily distinguish a difference between a cost-effectiveness or an economic-efficiency analysis. The reader must study the analysis to understand what the numbers mean. If "cost effectiveness" can have some outputs valued and "economic efficiency" does not require all outputs to be produced according to their values, the analysis procedures become essentially the same. The resulting "present net values" can have extremely different meaning, depending upon how many and which outputs were entered as specified amounts and which are produced according to their value.

If the Forest Service were to use a purely cost effective analysis the value of outputs would not be considered in the resource allocation process. Thus, a board foot of timber would be a board foot of timber regardless of species or diameter of the tree. When the value of some species are several times greater than the value of others, and in some cases a larger diameter tree is worth several times as much as a smaller tree. A cost effective analysis would not provide much help in these and many other situations to allocate resources. An economic efficiency analysis could solve these problems, however, as previously discussed there are many outputs in which no monetary value is acceptable. Thus in many of these cases, neither a pure cost effective nor an economic efficiency analysis is acceptable or feasible.

"Cost Efficiency" The Forest Service uses the term "cost efficiency" to describe an analysis in which some outputs are produced according to their value and others are produced at specified levels and achieved in the least cost manner. "Cost efficiency" comes from combining "cost" from "cost effectiveness" and "efficiency" from "economic efficiency" to emphasize that it is a combination of the two traditional analyses.

The definition of the net public benefits required by NFMA to be maximized, states that all outputs and positive effects must be considered in the benefit calculation and all inputs and negative effects must be considered in the cost calculations. With the definition of "cost efficiency", the Forest Service can ensure that every alternative is the most cost efficient method of achieving the objectives of the alternative. This means that the largest

"present net value" resulting from a cost efficiency analysis is not necessarily the alternative that maximizes "net public benefits." It does mean that "present net value" is just one, but an important and comprehensive one, of the decision criteria that must be weighed by the decisionmaker in selecting the preferred alternative.

The economic analysis process

Management prescriptions for analysis areas.

In forest management, a management prescription includes:

1. Goal, or the ultimate condition of the land, that the project is to achieve,
2. Set of objectives, or outputs that will result from the project,
3. Schedule of management practices or MIH activities required to develop the desired conditions required to meet the goal, and to produce the outputs that will achieve the specified objectives,
4. Time horizon specifying when the project will be completed.

An economic analysis of a prescription must include costs of the management activities and values of the outputs. These costs and values are to be applied to the management practices and outputs at the time they occur. Thus, costs and values are not single variables but become a stream of costs and values that must be discounted to the present to make them comparable as to time and dollar value (Row, Kaiser, and Sessions, 1981).

Projects may include one or more specific areas of land that have relatively similar capabilities and responses to treatments. A National Forest plan is like a project in that it may cover hundreds of analysis areas.

In designing an efficient project, the objectives of the project must be well defined, identifying those outputs that have values and those outputs that must be specified. Technical relationships, including "input-input", "input-output", "output-output", and costs and values are used to determine the most efficient combination of management practices to achieve the objectives and goals. The analysis must select that alternative that will achieve the greatest value per dollar spent for those outputs that have values, and the specified nonvalue outputs at the least cost.

Several computer programs are available to help select the most cost efficient combination of management practices to achieve the project's objectives. If MIH activities, with their costs and the outputs, and their values by time periods, are entered, these models can calculate the present net value, for each alternative way of achieving the set of objectives. The analyst can then select the most cost efficient project by comparing the present net values. The programs also compute benefit-cost ratios and rates of return which can be used to compare alternatives, especially when their size and costs are extremely different..

Development of alternative prescriptions

A management prescription may include as few as one activity or many. When designing a prescription, the goal and a set of objectives must be developed specifically for the "analysis area" (parcel of land) to be managed. Several alternative prescriptions should be designed to achieve the desired results, ~~since "a-priori" one cannot tell which alternative will be most cost efficient.~~

When a prescription is selected as the method of management for an analysis area, the manager must know exactly what is to be done and when to do it. If the prescription does not contain sufficient specificity, so as to identify inputs, outputs, costs, and values, misallocation may result.

Comparative advantages among areas

The process of developing alternatives that include management prescriptions for a number of analysis areas is quite complex. It would be simple if only one output were to be produced or if just one simple measure or rule could be used to rank or order areas. But some areas are often best at producing several outputs, and it is often more efficient to use less than the best land to produce even high-valued outputs because the best land can often satisfy the standards or markets for complementary outputs. This is the effect of the principle of comparative advantage, which says an input should be used where it has the greatest relative and not absolute advantage.

Alternative resource allocation

To determine an allocation of resources that will achieve a given set of objectives and meet long-range goals in the most cost efficient manner requires a method of selection that can systematically compare the relative advantages of each area. It can then choose among all available analysis area-prescription combinations and select a prescription for each analysis area that can best meet those objectives and goals. With several hundred analysis areas and as many as a dozen prescriptions for each, selecting the most cost efficient prescription for each analysis area would be impossible to do without a computer.

Linear programming (LP) models, however, quickly and easily sort through all possible combinations and make the "optimum" selection. Thus, "cost efficiency" and linear programming are very compatible. All costs and values of outputs are incorporated into the objective function. The other outputs and conditions necessary to meet the objectives of the alternative can be entered at specified levels (constraints). For outputs that are valued, the value is entered as a positive number. Costs go into the objective function as negative values. The smaller the negative or the less the cost, the greater the positive total of the objective function. Therefore, with all costs in the model, the prescription that meets the specified outputs and forest conditions with the smallest negative will be the least cost solution. With all values, for outputs that can be valued, in the model the prescription with the greatest net value (positive difference between values and costs) will be selected. The solution will then be the most cost efficient method of meeting the goals and objectives of the alternative.

When using an LP model, the outputs entered by specified amounts will override the outputs entered by values. The model will satisfy the constraints first, then maximize the net values (values less the costs). Outputs entered as constraints are assumed to have implicit values equal to or greater than the costs of their production plus the value of any output they replace in the solution.

To maximize the objective function the analysis looks for the activities that have the greatest positive difference between values and costs. The model will continue to introduce activities as long as the net value of the outputs exceed the activities' cost, or until some resource is constraining, such as land or capital (budget). But if the value is less than the cost, the model will not produce any of that output, since it would detract from amount of the objective function.

For every set of constraints, the solution of the LP program by definition will be cost efficient. Cost efficiency does not specify which or how many outputs should be valued, only that some outputs are valued and some are entered by specified amounts. However, for every output entered by a specified amount, a sensitivity analysis must be developed to provide the decisionmaker an estimate of its implicit value, or the value that the output would be required to have in order to be called into the solution by a value rather than being forced in by a constraint. Otherwise, the decisionmaker would not know the real tradeoff occurring as a result of the constraints or identify the implicit values of the outputs forced into solution.

The purpose of the analysis is to provide information to the decisionmaker. The assumption is that the decisionmaker will make the proper decision given sufficient knowledge. As discussed earlier in this paper, an economic analysis should force the debate concerning the selection of the preferred alternative to be focused on the values of all outputs. Thus, the analysis should make these values specific and explicit. This does not preclude the values of those outputs that come from the minimum standards, Congress has mandated these to be worth what ever is necessary to achieve them. Congress generally imposes the minimum standards without benefit of an analysis which make explicit the values. Perhaps, if the values are made known, Congress may decide to alter the standards.

Forest Service Land Management Planning process.

The planning process developed by the Forest Service's Land Management Planning Staff is designed to specifically provide all the information required for the decisionmaker to make a reasonable decision. The benchmark analysis should identify the values of the minimum standards imposed by Congress. The prescriptions should identify the range of possible combinations of outputs that can come from an analysis area, so that any feasible goal or set of objectives can be achieved. The values of those outputs that are valued and the specified amounts of those outputs that cannot be valued will bring into solution the proper amounts of each output to meet the goals and objectives of the alternatives. The LP model will select the proper prescription for each analysis area to achieve the alternative's objectives in the most cost efficient manner. The decisionmaker will have sufficient information to make the proper decision.

Equity problems, or economic and social impacts:

The efficiency analysis discussed thus far in this paper assumes that the distribution of income, or who pays and who gets the benefits, as given by the efficiency analysis is the way society prefers. However, in many cases efficiency does not distribute income the way society desires. Social laws have been purposely designed to redistribute income. The concept of "take from those that have and give to those that have less" is expressed in American society by laws that created the progressive income tax, numerous tax incentives, welfare assistance, and numerous grant and aid programs.

The distribution of income from the Forest Service actions is different than most other social programs. The distribution of income is less associated with income groups, but more associated with geographic location, specific interest groups, or industry sectors. For example: the efficiency analysis may allocate most resources to timber production, when the public desires salmon fishing. In another area where timber growing is inefficient, an efficiency analysis may not allocate any resources to timber production but there is an industry and a community depending on that timber for their livelihood. In these cases the distribution of income as provided by the efficiency analysis is not acceptable. Thus the allocation must be constrained to get the desired distribution of income even though it may not be as efficient as other alternatives.

Response coefficients can be developed for any output that comes from a forest or grassland using the IMPLAN (the Forest Service nation wide Interindustry model system) model for any county or combination of counties in the United States (Palmer).

Economic impacts resulting from forests or grasslands management comes from outputs being sold in markets and users of the forests and grasslands spending their incomes. IMPLAN breaks the impacts into three components:

1. Direct impacts are the amount of income or number of jobs generated from the production and marketing outputs and uses on the forest or grassland.
2. Indirect impacts result from the activities of supporting industries, i.e., those industries that can produce and sell their products to the directly impacted industries.
3. Induced impacts come from the income expenditures of employees and owners, of the direct and indirectly impacted industries, in the local economies. All three impact components are included in the response coefficients, thus, total impact can be included in the LP model.

As discussed earlier, efficiency analyses and impact or distribution analyses must be conducted separately, however, one can constrain the other. The preferred method to modify the distribution of income that results from an efficiency analysis is to include response coefficients (jobs or income per unit of output) in the LP model. The model can then be constrained to achieve specified employment or income in selected groups.

To use response coefficients in the LP model to achieve a specified income distribution or employment in a geographic area or industry, requires conducting the IMPLAN analysis before the FORPLAN (Linear programming model) resource allocation. Response coefficients would be used as part of the LP problem, and would have to be calculated for every output that generates jobs or income.

In summary then, efficiency analysis and impact analysis cannot be included in the same calculus. Each can and should affect the other. Each can and should change the answers from the other analysis, but they must remain separate analyses and be used as separate components and criteria in the decision process.

Implementing the forest plan

What kind of economics is required to implement the forest plan? If the forest plan is developed according to the concepts in this paper there would be no economics, nor even any analysis needed to implement the forest plan. All projects (at least those to be undertaken for the first five years) would be scheduled, by analysis area and by year for the first five years, in the five year action plan. Since each project would be identified in the plan, through the prescription development, and the plan has gone through the NEPA process, no environmental impact statement nor even an environmental assessment need be made, the public already knows what is going to be done. The managers can now go about getting the jobs done, and meeting the objectives of the plan.

Conclusions

Congress, through certain laws, requires the National Forest and Grasslands be managed in such a way that net public benefits are maximized. Regulations, written to interpret and implement the laws, define net public benefits to be: An expression used to signify the overall long-term value to the nation of all outputs and positive effects (benefits) less all associated inputs and negative effects (costs) whether they can be quantitatively valued or not. Net public benefits are measured by both quantitative and qualitative criteria rather than a single measure or index....(36CFR 219.3).

Since net public benefits cannot be quantitatively calculated or represented by a single index, the Forest Service has developed a planning and decision making process in which the decisionmaker (certain line officers), using information from public involvement, management concerns and opportunities developed from physical, biological, economic and social analysis, makes an informed judgment that identifies the alternative that comes nearest to maximizing net public benefits. Economic efficiency and equity measures are used in the trade-off analysis, not as overriding criteria, but as two important components of the decision making process.

The economic analysis developed in the Forest Service planning and decision process does not make the decision, however, it does focus the debate in decision making on the value of the outputs to be achieved. These values include market values, imputed non-market values, and the implicit values of outputs and effects that monetary values cannot be assigned. Armed with such values the decision maker can make an informed, defensible decision consistent with the public desires and preferences, indeed a decision that maximizes net public benefits.

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THE FRAMEWORK FOR EXAMINING SILVICULTURAL OPTIONS
IN FOREST PLANNING

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Region Six

The Framework for Examining Silvicultural Options in Forest Planning

The arrival of large land management planning models has given Forest managers the capability to calculate allowable cutting rates efficiently. At the same time effects on other resources can be predicted and land allocations made. In conjunction with this planning effort, a framework has been constructed at the National, Regional and Forest level that defines the silvicultural options available to the field.

To begin this discussion, let's examine how we got to Forest planning and how planning tools have developed. The evolution of a linear program with planning applications began when the United States Forest Service began to harvest timber on National Forests and calculate an "allowable cut". The allowable cut was calculated for a working circle which was generally a National Forest or part thereof. The formulation for this calculation on Western old-growth Forests was Hanzlik's: Allowable Cut (AC) = $\frac{V_m}{R} + I$ where

V_m = The volume of mature timber

R = The rotation or conversion period

I = The mean annual increment of immature timber.

The subdividing of a National Forest into multiple-use zones during the 1960's made allowable cut calculations more complex since the National Forests were divided into different management emphasis areas. In areas like a water or travel influence zones, yield estimates had to incorporate longer rotations and scheduling requirements.

The 1970's ushered in a decade of unit planning on part of the National Forests and the introduction of the Resources Allocation Model, or RAM, to calculate an allowable cut or potential yield. Not only could this linear program handle variable rotation lengths, but variable timber management intensities as well. The silviculturist was given a good tool to test various management strategies on a working circle basis.

When implementing the Timber Management Plans, Forest staffs and District Rangers found conflicts between the functional timber plan and the unit plans. The unit plans allocated the Forest to different uses, but were completed at different points in time, often after the Timber Management Plan. In addition, other functional plans, also done at different times, tended to pull the field people in different directions.

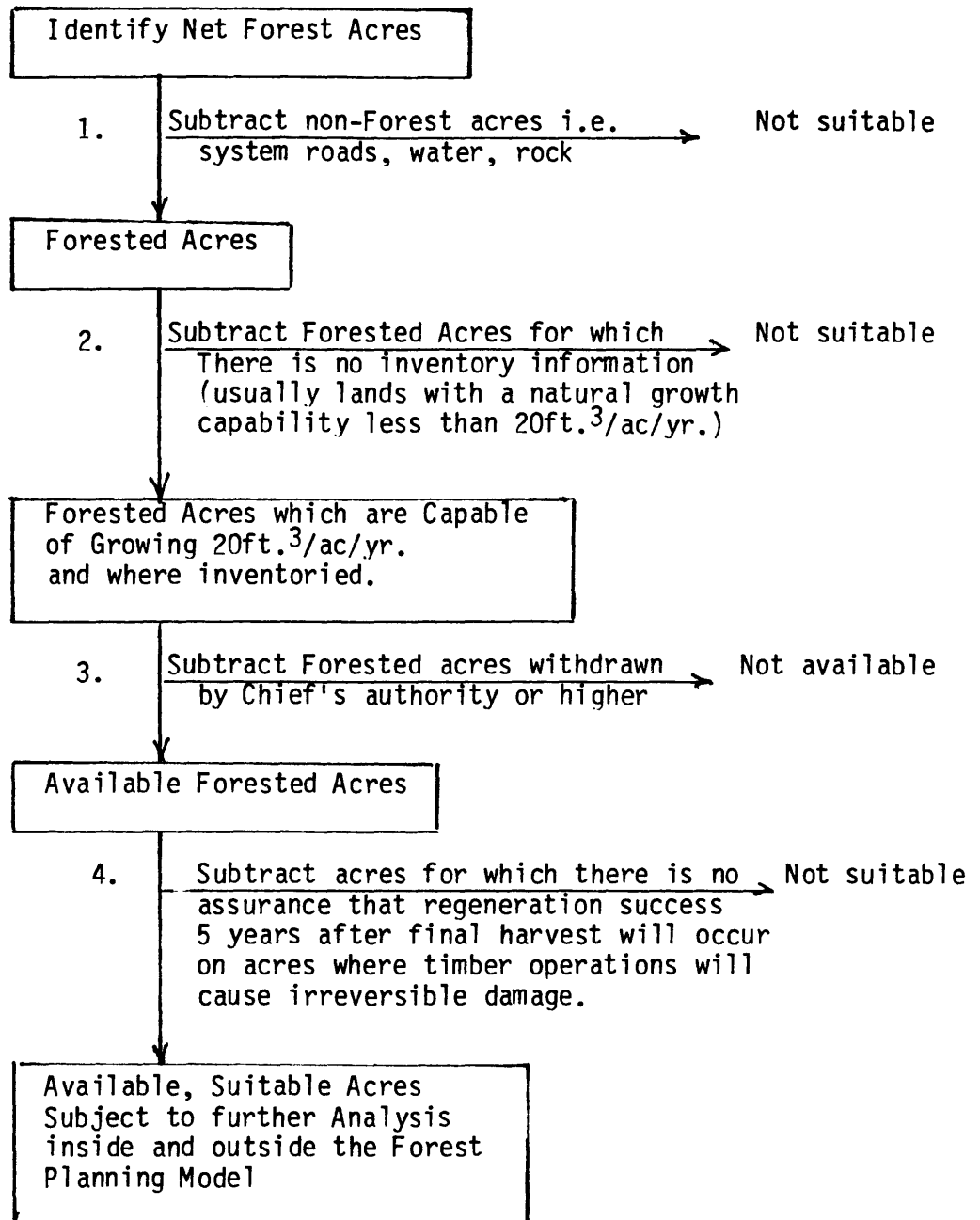
Out of the National Forest Management Act of 1967 and the inevitable conflicts during implementation that arose when different groups of planners working at different points in time planned for the same acre, came the current Forest planning effort.

At this time a linear program called FORPLAN is being used to calculate the allowable cut or allowable sale quantity as it is now called. FORPLAN has the capability to both allocate land and schedule outputs at the same time. Computer model size limitations have prevented doing all the allocation and scheduling with the model, but for the first time allocating and scheduling are being done at the same time and place by the same group of people.

It is important to note that the Forest Plan alternatives developed with FORPLAN have as an objective function "maximize present net value". This is different from RAM models which maximized timber output. The objective function in FORPLAN implies that costs and values will be attached to yield coefficients which are attached to particular acres.

Building the Framework

The first phase of analysis that involves looking at silvicultural options that occurs early in the planning process is the identification of lands suitable of timber production. This process is done outside the model and is illustrated by the following process:



A point here is that in two steps, number 2 and number 4, silvicultural options have been examined and selected at a Regional level.

With step 2, a long standing inventory definition of commercial forest land i.e., lands capable of producing 20ft.³ or greater/acre/year was used to determine which part of the National Forest was inventoried. Only the growth rates of natural stands were considered. This decision was not subjected to a rigorous economic analysis as the Forest Service critics are quick to point out.

In step 4, the 5-year regeneration requirement spawned several decisions at the Regional Office level. Some decisions involved management on harsh sites. Forests were instructed that they would not have to consider importing soil or irrigation when making this determination. The idea was simply that both of these practices, while certainly feasible, have such a high cost that neither public or private foresters have used them to any large degree. Other practices using current technology such as brush control, shading and reliance on natural regeneration on rocky sites, were considered.

In these two steps examining suitable lands, then, we find decisions that have become the framework of the silvicultural and economic analysis to be done in the planning process.

In the next phase the Forest planners analyze the available and suitable acres passing the first screens. As each Forest Plan data base is put together, the Forest is carved up into smaller pieces called analysis areas. These analysis areas are defined by similar attributes like geographic area, soil groups, timber working groups and condition classes like sawtimber, poles, seedlings and saplings, etc. With all the different disciplines represented on the planning team trying to build a model to analyze and address issues concerning their area of interest, the probabilities are good for building a model with a great number of analysis areas. The version of FORPLAN most Region 6 Forests are using is limited to about 1000 analysis areas and 1000 prescriptions. Therefore, on Forests with nearly 1000 analysis areas, only one prescription can be considered for each area. On Forests with 500 analysis areas an average of two prescriptions per analysis area may be considered. This means that of the many silvicultural options or prescriptions that could be chosen the set given to the model will be greatly reduced.

Some actual examples illustrate the process used on two Forests in Region 6.

On the Colville National Forest a total range of 90 plus possible prescriptions was subjected to some criteria to screen out all but the 24 most likely or most efficient. They include the following:

1. Prescriptions that included a precommercial thin (PCT) would only be considered. (This is because most current acres are overstocked in the natural state.)

2. A commercial thinning would have to have a positive value.

3. In some silvicultural working groups natural regeneration was not considered.

On the Umatilla National Forest the following table illustrates that out of 20 possible prescriptions for the South associated species working group, only four will be carried forward into the model as choices on full yield timber management acres. On less than full yield acres found where timber management is not the emphasis, such as in an area with a visual quality objective of retention, a fewer number of prescriptions choices may be placed in the model.

Ideally there will be enough prescriptions choices for the model to make on each allocation to allow an optimization within each alternative. In reality most Forests are screening or preselecting prescriptions before entering the Forest model. Then when the analyst assigns a set of goals for a particular alternative such as "meet or exceed an RPA timber target of 200 MMCF/decade", the model will allocate land and choose prescriptions to maximize the present net value while meeting that goal.

Here we have another part of the framework built at the Forest level. Note that we are using Forest-wide economic coefficients and yield tables at this analysis point.

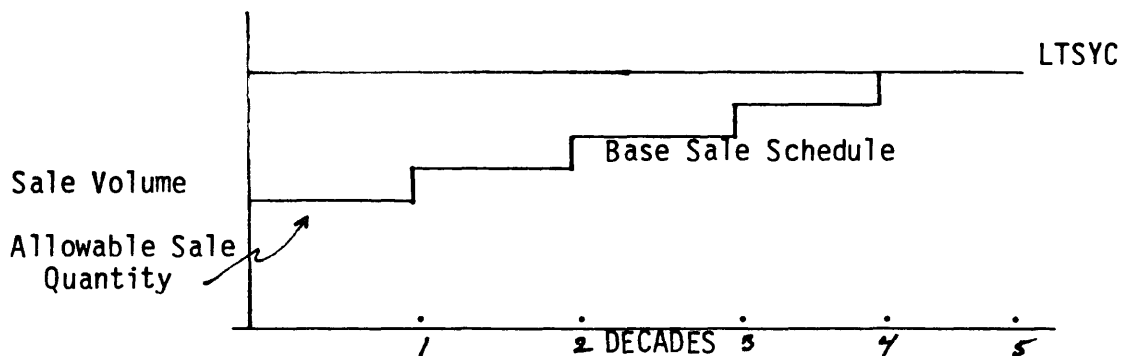
Implication of Working Circle (Forest Level) Economic Decisions with Non-declining Even Flow Constraints.

Many Forests in the West have an uneven-age class distribution which runs heavy to the older age classes. To introduce the vocabulary associated with the current planning effort, reference is made to the following graph where:

Allowable Sale Quantity (ASQ) is defined as the amount of timber chargeable to the Plan that can be sold in a decade or if divided by 10, annually.

Base Sale Schedule is a planned sale schedule where the sale volume in future decades is greater than or equal to the current decade volume.

Long-term Sustained Yield Capacity is the amount of timber sale volume that can be sustained through time consistent with the management intensity and multiple use objectives of a particular alternative.



With non-declining even flow constraints, the amount of first decade timber than can be sold is often held down by the amount of timber available for harvest in future decades as the forest condition is converted to a managed state. More specifically this occurs as the old-growth is nearly converted, but the second growth is not ready for final harvest. So to schedule a sale volume equal to or greater than the previous decade, the model will schedule commercial thinnings, even in some cases when a per acre analysis would not indicate that commercial thinning is a good economic choice. What this does is allow a higher ASQ in the first decade while the model discounts the higher logging costs from a future decade. The result is a higher present net value. At the Forest level what we have here is an economic analysis for commercial thinning that on some acres might not be attractive looking at a project level analysis. But from the standpoint of an entire National Forest analysis, the commercial thinning operation represents a good choice.

Other Characteristics of Forest Level Analysis

Another aspect of Forest level analysis is the tendency to schedule expensive operations on existing stands far into the future. Under the maximize present net value objective function this occurs because costs discounted over long periods are small while the real price increases plus growth make holding the timber an attractive choice. For example, on the Wallowa-Whitman National Forest, ponderosa pine on helicopter logging sites is increasing in value at a rate of 8 percent while the discount rate is 4 percent. Therefore, the Forest model chose to delay all helicopter and long span logging as long as it could. The Forest then made a conscious decision to prorate the advanced logging systems operation over all decades beginning with the first.

So here we have additional framework for analysis at the Forest level. Both in the case of the commercial thinning schedules and the scheduling of advance logging systems for timber harvesting, this framework definition at the Forest level will influence the degree of economic and silvicultural analysis done at project level work.

The direction contained in the Forest Plan will define the framework established at the National, Regional and Forest levels for examining silvicultural options in operations level planning.

We can get an idea of what this framework looks like by turning to a few excerpts for the Wallowa-Whitman National Forest Plan.

Under Management Direction the Forest has listed several control statements one of which reads:

4. When cumulative changes in the harvest sell volume vary more than ± 10 percent from the planned schedule by timber working group or land class, the allowable sale quantity will be recomputed. The first check will be in 3 years and will include the planned harvest of the succeeding 5 years. In calculating harvest sell volumes no substitution will be made between regulated and unregulated components.

Table 4.3 from the same Forest gives the timber sale planners volume and acre goals by harvest method. Region 6 has suggested that Forests fit specific silvicultural prescriptions to specific sites. These goals however, were derived using Forest-wide averages. Therefore changing a regeneration activity from a clearcut to a shelterwood, would still be within the framework established in the Plan. Forgoing a commercial thinning opportunity and substituting regeneration harvest volume is not.

Table 5.1 gives volume targets by silvicultural working group and logging system. With Forest-wide averages used in the model there is some flexibility allowed in the control section. However the intent is clear that the Forest intends to implement a schedule which will sell lodgepole pine and introduce advance logging systems this decade. The framework has again been defined and the project level planner need not analyze the economic merits of substituting ponderosa pine volume for lodgepole pine volume or the economic advantages of delaying the harvest of timber by advance logging systems. He need not analyze the allocation decisions made in the Forest Plan.

The monitoring and control language stated in the Plan provide a key to determining how accurate the Forest-wide average yields and costs used in building the Plan were. This section will state the appropriate adjustments to the ASQ, during the life of the Plan.

Summary

The framework for examining silvicultural options in Forest Planning has been built at the National, Regional and Forest levels. This framework will be stated in the Forest Plan and will define limits within which project level analysis can occur.

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TABLE 4.3
ANNUAL ALLOWABLE SALE QUANTITY (ASQ) AND PROGRAMMED SALE STATEMENT

Total Program Component and Activity	Annual Allowable Sale Quantity 10/1/84 - 9/30/93				Programmed Sale Statement Fiscal Year 1984						Products		Total Volume	
	Area Acres	Large Roundwood (ST) MBF	MCF	Products MCF	Total Volume MCF	Area Acres	Large Roundwood (ST) MBF	MCF	Products MCF	MBF	MCF	MBF	MCF	Total Volume MCF
FULL YIELD														
Clearcut	7,246	44.7	13.1	-	12.9	4,863	49.9	16.9	-	-	-	-	16.9	49.9
Seed Out	4,217	40.5	7.1	1.3	8.6	3,838	28.0	5.2	-	-	-	-	5.2	28.0
Selection	5,000	10.0	1.9	1.2	3.1	2,265	8.1	2.1	-	-	-	-	2.1	8.1
Removal	5,995	36.6	6.7	1.2	7.9	10,345	50.4	9.2	-	-	-	-	9.2	50.4
Commercial Thin	3,137	7.1	1.4	-	1.4	8,732	25.0	4.8	-	-	-	-	4.8	25.0
Small Green Sales	3,000	6.0	1.3	4.4	5.7	1,800	5.0	1.3	3.6	15.3	-	-	6.2	25.3
Total ASQ	28,595	144.9	31.5	8.1	39.6	31,843	166.4	39.5	3.6	15.3	-	-	44.4	186.7
Programmed Nonchargeable														
							5.0	1.3	3.6	15.3			4.0	

PROGRAMMED FROM UNSUITABLE LANDS - NONE

TABLE 5.1

ANNUAL ALLOWABLE SALE QUANTITY AND NPA TARGET STATEMENT, 1984-1993

Program Components - 2/					Annual NPA Target Statement											
Working Groups/Land Class/Silvicultural Treatments	Total Acres Available	Annual Allowable Sale Quantity			1984		1985		1986		1987		1988		1989- 1993	
		Sale Acres	MCF	MBF	MCF	MBF	MCF	MBF	MCF	MBF	MCF	MBF	MCF	MBF		
<u>Regulated Components - (Chargeable Program) 3/</u>																
CD/G/REF	4,262	0	0	0												
CD/G/PCT	5,449	0	0	0												
CD/G/FE-EX	32,129	3,182	3.37	18.38												
CD/G/INT	53,020	1,350	.47	2.45												
CD/G/REG	28,157	986	1.35	7.69												
CD/S/REF	6,517	0	0	0												
CD/S/PCT	3,854	0	0	0												
CD/S/FE-EX	25,521	2,428	2.81	15.30												
CD/S/INT	39,178	0	0	0												
CD/S/REG	20,420	269	.34	1.91												
CD/H/FE-EX	3,602	0	0	0												
CD/H/REG	16,654	120	.15	.87												
NPA TARGETS ASSIGNED BY																
PROGRAM TOTAL ONLY																
CM/G/REF	7,868	0	0	0												
CM/G/PCT	17,859	0	0	0												
CM/G/FE-EX	1,418	142	.19	1.06												
CM/G/INT	35,123	1,788	.89	4.66												
CM/G/REG	139,868	3,576	6.75	37.87												
CM/S/REF	13,544	0	0	0												
CM/S/PCT	19,799	0	0	0												
CM/S/FE-EX	2,437	244	.33	1.82												
CM/S/INT	29,205	0	0	0												
CM/S/REG	119,272	740	1.41	7.89												
CM/H/REG	32,098	397	.74	4.17												
LFP/G/PCT	13,377	0	0	0												
LFP/G/REG	94,704	5,200	9.18	23.78												
LFP/S/PCT	8,231	0	0	0												
LFP/S/REG	24,458	92	.17	.45												
COB/S/REG	2,146	15	.02	.13												
COB/H/FE-EX	2,542	0	0	0												
COB/H/REG	8,641	68	.07	.42												
Subtotal	811,353	20,597	28.24	128.85												
Riparian	(15,986) 1/	1,500	.58	3.00												
NRA-Dispersed Res/ Timber Mgt/Selection Harvest	58,885	3,500	1.32	7.00												
Small Green Sales		1,500	1.30	6.00												
Total Allowable Sale Quantity	870,238	27,097	31.44	144.85												
<u>Unregulated Components - (Nonchargeable Program) 4/</u>																
Mortality Salvage from Suitable Lands		1,500	1.30	6.00												
Convertible Products- Chippable Cull Logs		1/	3.70	20.00												
Small Diameter LFP		1/	3.10	8.00												
Total	870,238	28,597	39.6	178.8	40.4	217	41.0	220	41.0	220	41.0	220	41.0	220	41.0	220

1/ Acres included in other component categories above.

2/ CD = Conifer Douglas-fir/ponderosa pine working group

CM = Conifer Douglas-fir/white fir/Engelmann spruce working group

LFP = Lodgepole pine

COB = Brushfield Competition

G = Ground based (tractor) yarding

S = Skyline Cable (0-2,500') yarding

H = Skyline Cable (2,000' and over) and helicopter yarding

FE-EX = Final Entry (overcut removal)

3/ Timber included in the current inventory and in the calculations of the Allowable Sale Quantity.

4/ Timber and products in the unregulated component including: volume from experimental forests, administrative sales, and noncommercial forest land. It includes entire insect killed timber, cull material, and windward size trees. If funding and markets permit this, unregulated component will supplement the Annual Allowable Sale Quantity as part of the program sale statement.

INT = Intermediate Entry (commercial thinning)

REG = Regeneration Harvest

REF = Reforestation

PCT = Precommercial Thinning

INTEGRATING FOREST PLANNING WITH
REGIONAL PLANNING AND MANAGMENT

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May 17, 1983

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INTRODUCTION

Traditionally Regional timber budgets have been disbursed to the Forests largely on the basis of geographic and temporal equity (1) (2). There is a strong belief within the agency that every unit, regardless of size or location, should receive its "fair" portion of dollars. Funds are therefore distributed more on the basis of "acres of CFL" or "potential yield" than on economic factors. Temporal equity is maintained by not allowing a unit's budget to deviate by more than a small fixed percentage rate from year to year. Because of these two factors a large proportion of the annual budget is actually fixed and not subject to economic review (2).

The one economic tool that has been frequently used in Region 1 in the budgeting process is a comparison of unit costs, e.g., costs/acre or costs/mbf. Managers have intuitively selected or were forced to select, the lowest cost option for meeting targeted output levels. The cumulative effects of using unit costs as a budgeting tool are:

- (1) There has been a steady increase in costs as Forests have been forced to extend management into more marginal lands, and
- (2) Economic efficiency has been sacrificed for shortrun cost minimization.

Inefficiency results from using unit costs, since neither present nor future benefits are considered. For instance on many Forests timber receipts are required to cover all or a large portion of the road construction costs. By comparing timber sales which construct varying amounts of road, without considering both the present and the future benefits to be derived from those roads, we often end up with an ill-designed road network that is not equipped to meet future needs.

In Forest planning, management prescriptions are selected and applied to individual units of land (Analysis Areas), based on an objective of maximizing net public benefits. A dichotomy thus exists between the current budgeting and the long-run planning processes. In Forest planning prescriptions are selected on the basis of maximizing net benefits, while the current budgeting process seeks to promote stability and to minimize short-term costs. Due in part to this dichotomy the plans that have been completed to date show large and immediate increases in costs without commensurate increases in outputs. This paper discusses a proposal for using the cost and output data from the Forest plans, to allocate budgets on the basis of both economic and physical criteria. By identifying the cost and benefit relationships at the management prescription and analysis area level, this system will enable efficient allocations both within a Forest and for the Region as a whole.

OBJECTIVES

The objectives of this study are to:

- (1) Develop a procedure for allocating the Regional budget, based on both physical and economic criteria, using the prescription by analysis area data generated by the Forest plans. The primary physical criterion

to be considered is the maximization of resource output levels (e.g., timber, range, and wildlife) for a given budget. Economic criteria include maximization of present net value and maximization of short-term net benefits.

(2) Check the economic data used in Forest planning for logical consistency and develop a means of continually upgrading and improving the methods by which data is stratified.

(3) Analyze timber management costs as a function of time. When significant increases in costs are observed analyze the effect that this will have on the implementation of the Forest plans.

BACKGROUND

A logical means of insuring that future budgets will be allocated efficiently between Forests is to require some reasonable degree of economic analysis within each Forest plan. In the selected alternative for each plan there is a requirement that "net public benefits" be maximized. These public benefits are defined on the basis of both the priced and non-priced outputs and costs. The present net value (PNV), in contrast, is the discounted sum of the priced benefits and costs only. To maximize net public benefits the effect that various output levels or constraints have on PNV must be examined at the margin. For instance, by incrementally changing the production level of an output (e.g., timber, wildlife security cover, etc.) and comparing the change in net non-priced benefits with the resultant change in PNV, the optimal production level of that output can be estimated. In all alternatives economics should be considered a constraint on management. It makes no sense to calculate the most cost efficient means of meeting output goals when those goals have no economic foundation.

To make valid economic comparisons between Forests, standardized means of estimating costs and benefits must be developed. Forest (or Zone) multiple regression equations, which predict stumpage price as a function of species mix, average d.b.h., volume per acre harvested, and logging method employed, were developed in Region 1 to value timber in Forest planning (i.e., the FORPLAN model) (5). Timber values thus vary according to the same criteria on all Forests. Because a systematic approach was used to display these data in FORPLAN, values can also be easily changed when better data becomes available. Conversely, the timber management costs that are used in FORPLAN are often Forest-wide averages and a major purpose of this study is to determine how these costs have and should be stratified.

The methods used to define both the management prescriptions and the analysis areas must also be consistent across Forests in the Region. As a minimum analysis areas were defined on the basis of logging suitability (i.e., tractor, skyline, or helicopter) timber type, condition class (ssap, pole, sawtimber, etc.), and existing level of development. The degree to which analysis areas are stratified by economic factors varies significantly between Forests however, and this analysis will

attempt to set Regional standards. In addition all of the management prescriptions in the Forest plans have been classified into a set of Regional prescriptions. This will enable us to compare like areas, being managed for similar objectives, on different Forests.

A question that is critical to answer is "How far should this analysis deviate from the Forest plans?" If the Clearwater National Forest's plan proposed a harvest level of 200 mmbf in period 1 and the total Regional PNV (or total timber output under a budget constraint) would be maximized if they harvested 230 mmbf, would we consider transferring funds from a less efficient Forest? For the present we are limiting the analysis to the decisions bracketed by each Forests' preferred and max present net value alternatives. In the future we will examine possible modifications of the Forest plans when these plans do not coincide with Regional objectives. Because this is a budget allocation problem we may also require each Forest to develop preferred and/or max PNV alternatives under various budget constraints.

METHODS

For each prescription (RX) applied to each analysis area (AA) in each Forest plan, all costs and benefits associated with timber harvesting will be isolated. Initially the analysis will be limited to those prescriptions which implement timber harvesting in decades 1 to 5. At a minimum the following data will be collected:

- (1) Cost/MCF for decade of implementation (including sale prep and administration, site preparation, reforestation and resource support)
- (2) Revenue/MCF for decade of implementation
- (3) Volume/acre in initial harvest
- (4) PNV/acre for the total management prescription, and
- (5) Average volume produced (MAI) for regenerated stands

The data will be stored in a file that can be sorted by any parameter such that both short- and long-run budget and output objectives can be met. The data may also be used with a simple linear programming model such that either timber output levels or PNV could be maximized under a budget constraint, while minimal harvest constraints are applied to each Forest.

The timber output and price data will be extracted from the FORPLAN "complete results file," where data is stored on each prescription and analysis area allocated in a FORPLAN run. The timber management cost data will be collected from the "RPA economic tables." These tables, which were developed in Region 1 to bridge the gap between FORPLAN and RPA, contain costs classified down to the MIH component and subcomponent level.

The second objective of this study is to develop a quality control for each Forest's data. To accomplish this the prescription and analysis area data will be stratified according to physical and administrative variables such as (1) harvest method (e.g., clearcut, shelterwood, or

selection); (2) logging suitability; (3) management emphasis (e.g., high intensity timber, timber-wildlife, visual corridor, etc.); and (4) existing level of development. By making comparisons of like areas with similar prescriptions on different Forests, we will be able to determine where cost discrepancies exist and where costs or benefits should be further stratified. These comparisons could also be used to develop minimum standards for stratifying physical data (i.e. analysis areas and timber yield tables) based on economic criteria.

Only those outputs that result from management will be considered when comparing prescriptions. For example if a commercial forest area produces three livestock AUMS/acre/year when managed in a natural state, but produces six AUMS when managed for timber, the benefit attributable to timber management is three, not six AUMS. If background production levels are not identified when making comparisons across Forests, those Forests which currently support the greatest number of livestock AUM's, etc., may incorrectly appear to produce the highest returns with management.

The last objective of this study is to compare costs as a function of time and to determine the management implications. It may make economic sense to defer management in some high cost areas. In fact real stumpage price projections that are built into the FORPLAN model encourage this since many management practices that are currently uneconomic are forecasted to produce a positive return in the future. The major temporal concern will be whether the proposed action is implementable from both a budgeting and physical standpoint. Because of spatial considerations it is usually impossible to harvest only the best (or worse) timber areas in any one decade. Plans that do not consider this through access control or other constraints are inadequate. Similarly a timber prescription that has a negative stumpage price associated with it is possible in FORPLAN but difficult to sell on the ground. If many of these prescriptions are coming into solution in any one decade (e.g., via the allowable cut effect) the plan will not be implementable.

OTHER CONSIDERATIONS

A linear programming model such as FORPLAN assigns prescriptions to analysis areas on the basis of their contribution to the total present net value, while simultaneously satisfying a large set of management constraints (e.g., sustained yield, watershed protection, etc.). Because of these constraints, the prescription that maximizes the PNV of an individual area may not be the prescription that contributes most to the total net value. This leads to a host of conceptual problems associated with disaggregating the FORPLAN data. The general problems associated with this analysis are discussed below.

(1) There are many opportunity costs associated with producing timber, as measured by the PNV "foregone" which are not calculable from the prescription by analysis area data. For example, many Forests place vegetation cover constraints on commercial Forest areas to maintain or enhance wildlife habitat. The opportunity cost of these constraints is the net

loss in PNV associated with going to a less efficient harvest method, harvest schedule, or rotation age. In most instances the benefit that results is not picked up by the analysis area that bears the cost. The true PNV associated with managing these areas is thus understated.

Similarly in most Forest plans constraints were placed on timber harvesting and road development to help maintain a "quality" recreational experience, a non-priced component of net public benefits. Since these constraints do not produce a larger quantity of recreational visitor days (RVD's), and only one price is allowed for valuing a given unit of recreation, their actual benefit cannot be shown in FORPLAN. To partially correct for these situations the management emphasis will be matched when making comparisons of prescriptions between Forests. In addition we will determine if consistent logic has been used to develop constraints on all Forests.

(2) Some outputs that are produced across the entire Forest may be attributed to a small minority of the analysis areas. On the Deerlodge National Forest, for example, big game hunter-visitor days are outputs of winter range forage areas only. To insure that adequate habitat is maintained for the entire year, constraints are also placed on the amount of summer range forage allocated to wildlife. If you were to analyze the Deerlodge data without understanding this relationship the conclusion would be that investments in winter range areas are economically efficient while those in non-winter range areas are not.

(3) In some instances the production functions which define an output have not been adequately defined. For example, some plans assume that total dispersed recreation use will increase as roadless areas are developed, while other plans assume a decrease in use due to a diminishing supply of primitive recreation opportunities, while still other plans assume that increased development will only result in more dispersal of use. Although each of these assumptions may be valid under the right circumstance they have not been applied consistently in the Forest planning process. This analysis will compare recreational costs and benefits across Forests to attempt some standardization of methods, but will not use these data to calculate the net costs or benefits associated with timber management.

(4) A basic tenet of this analysis is that future budgets will be insufficient to carry out all of the programs proposed in the Forest plans, and that a means of allocating budgets to maximize PNV or physical output using the Forest planning data must be developed. If budget allocations are in fact made in this manner, insufficient consideration may be given to prescriptions which produce intangible benefits. Care must be taken to separate out the truly uneconomic prescriptions from those that are designed to produce non-timber benefits.

(5) The allocation decisions in FORPLAN are based on analysis areas while the actual scheduling of practices will be by management area.*

*A management area is a contiguous unit of land managed for one emphasis, i.e., timber production, and is normally made up of portions of several analysis areas.

Because of spatial considerations that can be considered in a management area, but were not considered in FORPLAN, the harvest schedule produced by the model can never be matched on the ground. The implication that this has on the analysis remains unclear.

(6) One of the major budget decisions to be made is the amount of appropriated dollars for roads that should be allocated to each Forest. Unfortunately, there are now 13 methodologies being used to link road costs with timber scheduling in FORPLAN. To insure consistency in a Regional analysis we need to analyze these methods and develop one procedure for use on a Region-wide basis.

(7) In FORPLAN most timber management and overhead costs are modeled as being linear (e.g., a 10 percent increase in annual harvest volume is predicted to require a 10 percent increase in budget). Because of the effect of scale economies, the relationship between costs and output may be non-linear however, particularly on the smaller Forests. On the Gallatin National Forest, for example, a 10 percent decrease in the annual harvest volume (i.e., from 20 to 18 mmbf), would probably result in a much smaller decrease in costs. This is due to the fact that approximately the same facilities and personnel would be required to function at both harvest levels. A purpose of this analysis may be to determine the minimum size program that is needed to efficiently retain timber management expertise on all Forests.

(8) In some cases uneconomic treatments (e.g., precommercial thinning) may be buried in an otherwise economically efficient prescription. This means that we may have to analyze each Forests' prescriptions outside of FORPLAN to insure that they were developed on a sound economic basis.

SUMMARY AND CONCLUSIONS

Presently a management gap exists between long-range Forest planning and the day-to-day activities of the Forest Service. This study proposes a method of bridging that gap by linking Forest planning to short-term budgeting. By disaggregating the data from each Forest's plan to the management prescription and analysis area (land unit) level, and pooling it into a Regional data base, budgets can be allocated efficiently both within and between Forests. Whereas historical precedence and cost minimization are the major budgeting tools used today, this study proposes that economic efficiency be the main criterion in the future. Although there are many problems associated with interpreting each Forests' data and establishing this linkage, methods must be developed if the Forest plans are to be effectively implemented.

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Genetic Gains Realizable in Rust Resistance
Programs--What Are We Buying? 1/

by

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INTRODUCTION

Jerry Franc, in an earlier paper described the breeding program generating the western white pine orchard seed we use in our operational reforestation program. The present paper focuses on describing the benefits of using this blister rust resistant seed in operational reforestation in the Northern Region. This description will exemplify how resistant material perhaps ought to be viewed. The view is from the perspective of folks who have been planting resistant white pine for nearly a decade now.

In a later section, we compare alternative management regimes for two stands on the Wallace Ranger District of the Idaho Panhandle National Forests.. In these comparisons, we exemplify benefits of predictable stocking control and species diversity discussed in other sections, considering no white pine, susceptible white pine and moderately resistant white pine alternatives.

Resistance Levels

Nine sources of white pine seed ranging from 25 percent to 60 percent resistant are approved for planting in the Northern Region (Table 1), but, to date, virtually all resistant white pine stock emanated from three seed orchards (Sources 1, 2 & 3 in Table 1). This paper describes the benefits of using this orchard seed. The principal purpose for developing sources displaying lower levels of resistance is to permit the matching of resistance level to site hazard (for rust infection). (We are working now with IFRES to implement a hazard rating scheme for planting sites.)

The resistance level of two of the seed orchard sources described in this paper is 60 percent, and the third is 35 percent (Table 1). By this we mean that 60 percent or 35 percent, respectively, of the white pine trees planted will be able to survive blister rust and grow normally to rotation age, under moderately severe infection conditions; conditions in which about 10 percent of native wild trees would survive (this is the survival level we call "susceptible" in this paper). Some surviving resistant trees will be infected and display symptoms.

Demand vs. Supply

The Regional Forester banned the planting of western white pine in operational reforestation in the Northern Region from 1964 through 1973. Managers of white pine had concluded that susceptible white pine in plantations would create more problems than it was worth, principally in stocking control (more on this later).

In 1974, the first operational rust-resistant white pine stock in the Region's history was planted on the Palouse Ranger District of the Clearwater National Forest. The plantation was dedicated to Dick Bingham.

TABLE 1

Approved Sources of Operational

Western White Pine Seed

Name of Orchard, Plantation or Stand	Estimated Resistance (%)*	Location		Collected by
		Forest	District	
1. Cd'A Nursery Orchard	60	IPNF's	Nursery	Nursery
2. Sandpoint Orchard	35	IPNF's	Sandpoint	Sandpoint RD
3. Moscow Arboretum	60	IFRES	-	R-1 Selective Breeding Specialist (SBS)
4. Canyon Creek Test Plantation	40	IPNF's	PREF	IPNF's (or R-1 SBS)
5. Merry Creek Test Plantation	40	IPNF's	St. Maries	IPNF's (or R-1 SBS)
6. Elk River Test Plantation	28	CLW	Palouse	CLW (or R-1 SBS)
7. Fernwood Test Plantation	28	IPNF's	St. Maries	IPNF's (or R-1 SBS)
8. Natural Selection SPA	25	Specify	Specify	Forest (or R-1 SBS)
9. Phase 2 Plus Trees	25	Specify	Specify	Forest (or R-1 SBS)

* Genetics Project Leader, IFRES Moscow, will provide research publications, on request, confirming these estimates.

In 9 years, now, 3,249,340 seedlings have been planted in operational reforestation projects on six National Forests. This planting program represents about 8,100 acres.

For 1974 and 1975, the supply of seed (Table 2) exceeded the demand, primarily because "the word wasn't out yet." Then, until 1981 when the bank was inflated by a bumper 1980 seed crop, the demand exceeded the supply, in some years enormously. Clearly, silviculturists on white pine Forests were convinced white pine was beneficial, even though not immune and sometimes only 35 percent resistant.

WHITE PINE MANAGEMENT

The Desirability of Western White Pine

Western white pine is favored over alternative species for the same site for several reasons. The first are its faster growth rate and higher stumpage value (more on this later). White pine is less damaged by insects and diseases (except for blister rust) than are other species, and it often proves surprisingly free of animal damage--e.g. browsing or rodents--when other species in the stand are devastated. White pine is more plantable than other species, and because of lower planting shock white pine "takes off" quicker and suffers less mortality.

On south and southeast facing slopes the availability of white pine planting stock offers the opportunity for a three-species mix in stands which would have been stocked with only two species (e.g. DF and PP) during the 10 years of the white pine planting moratorium. In a worst-case scenario--total destruction of one species from insects or disease during the rotation--the stand could more nearly maintain full stocking if one of three rather than one of two species were lost.

Moreover, for many insects (e.g. bark beetles) and some diseases, (e.g. dwarf mistletoe or root rots) proximity of host trees influences the severity of the damage. The more widely spaced the trees--as in a 3-species stand vs. a 2-species stand--the less severe the total damage from the pest.

Because white pine grows faster in its early years than other species on the site, sites planted with white pine recover visually and hydrologically faster than they would if alternative species are chosen. This rapid early growth is also important for capturing highly productive sites from competing vegetation, e.g. Ceanothus, willow, maple or menziesia.

Objectives, Opportunities and Constraints

The typical white pine site managed for timber is highly productive--frequently exceeding 120 cu. ft/A/yr. and virtually always exceeding 80 cu. ft/A/yr. Ergo, timber optimization is often the goal.

Because of the moderate environment of the typical white pine site and the successional status of the species favored for this site, clear-cutting and planting is most frequently the regeneration system chosen.

TABLE 2

WHITE PINE SEED ADDED TO INVENTORY

<u>Year</u>	<u>Quantity Added (Lbs.)</u>
1974	42.75
1975	90.25
1976	58.75
1977	38.25
1978	57.20
1979	433.20
1980	1.70
1981	564.00
1982	149.20
TOTAL	1435.30

Indeed, sites needing shelterwood treatment will be too dry for western white pine, even if it were planted under the shelterwood.

Another goal for these stands is a mixture of species. At least two species, and on north-facing sites, three or more species are desirable. Were white pine planting stock not available, many clearcut sites might end up with only one commercially desirable species. Based on the composition of natural stands, the need for species diversity, and economics, the manager wants at least 25 percent (by volume) white pine in the stand at the end of the 80- to 110-year rotation. This goal ought to be reasonably achievable by planting 300 white pine trees per acre plus one or two other species, followed by a precommercial thinning at about 25 or 30 years of age and a commercial thinning at age 50 to 60 years. The schedule of planting and thinnings should create a stand neither severely over- or understocked.

On north-facing sites, this treatment sequence was unable reliably to create the target stand when only susceptible white pine was available. North-facing sites often were either severely overstocked at an intermediate entry or nearly devoid of a white pine component at rotation, depending on the vagaries of blister rust disease development. The overstocking problem could easily have been compounded by planting white pine on sites later occupied by several hundred or several thousand more volunteers of white pine and/or other species.

On south-facing sites, even knowing the site would seed in naturally, the silviculturist often chose to prescribe planting anyway, to ensure a white pine component at the end of the rotation. If severe infection were to kill 90 percent of the white pines in the stand, and if the manager wanted 25 white pine trees per acre at rotation, then the stand had to start with at least 250 trees per acre. Natural seeding couldn't always be counted on to provide 250 trees per acre.

Indeed, on south and southeast-facing clearcuts, white pine could rarely be expected to seed in sufficiently to offer a manageable well distributed component. Only planting could ensure that component, and if it were susceptible stock, the white pine stocking, again, would be determined more by the whims of blister rust disease development than by a predetermined schedule of stocking control treatments. But understocking, at least in the white pine component, was far more likely than overstocking.

The reliability of creating the target stand, with an affordable treatment sequence, was so low that planting white pine was abandoned for a decade. It was as unreliable for north-facing sites as for south-facing, but for different reasons.

BENEFITS

The faster growth rate of white pine persists through the rotation, so yields are increased if white pine is a significant component of the stand. Receipts are also inflated from the higher stumpage value of white pine.

Stumpage value differences between white pine and other species have historically been enormous. While many have predicted for 10 years or more that gap

would narrow, it hasn't yet. White pine (and ponderosa pine) is typically selling for about \$220/MBF while Douglas-fir rarely exceeds \$70 in current sales on the Wallace Ranger District. Other species are lower yet. Stumpage revenue from harvesting stands devoid of white pine (because of blister rust) clearly is reduced, compared to comparable stands with a white pine component. The trend is likely to continue.

Perhaps the greatest benefits for using rust resistant white pine are in reliable stocking control and reduced mortality rates. Here's how those factors reduce stand management costs.

On south-facing sites, if the silviculturist were to plant susceptible white pine, he might prescribe 1,000 WP trees per acre to ensure adequate stocking of white pine after blister rust takes its toll throughout the rotation. (On north-facing sites he wouldn't prescribe planting susceptible white pine, because he'd get all the naturals of that resistance level he'd want.) With resistant stock he may prescribe only 400 white pine trees per acre, so he has reduced his stock costs and variable planting costs by 60 percent (for the WP component of the planting mix). Benefit/cost ratios can be influenced.

Higher initial densities of white pine may result in higher precommercial thinning costs as well. Blister rust infection may be too poorly developed by precommercial thinning age to have killed many trees, so they have to be thinned to avoid overstocking. If the site is planted at lower densities and blister rust develops strongly, the stand will end up with an insignificant WP component and perhaps understocking.

The higher the susceptibility of white pine, the less likely is any one thinning to maintain its stocking goal. The phenomenon extends to all thinnings in the rotation. With susceptible white pine, the fewer the thinnings the less likely is the stand to achieve its stocking goals. Thinnings later in the rotation, however, will be less affected than early thinnings, because infected large trees are less likely to perish than infected young trees, and have fewer years to survive to the end of the rotation.

The economic consequence of overstocking or understocking is reduced yield. If the white pine component of the stand is 60 (or 35) percent resistant, rather than 8 percent or 10 percent, then stocking controlled at a given level of predictability may be achieved with fewer thinnings. Or, if we can afford only two thinnings in the rotation, we are more likely to attain projected stocking if the white pine component is 60 (or 35) percent resistant than if it is 8 percent or 10 percent.

COSTS

To portray the added costs of using rust resistant white pine, we scrutinized seed, seedling and stand management operations.

Seed and Seedling Costs

All the added costs for producing seed orchard seed are reflected in the price of orchard seed in the WCF inventory, versus nursery-run seed. Orchard seed is carried at \$485/lb. vs. \$75/lb. for nursery-run seed of white pine and other species.

Forests, however, don't care about white pine seed costs, because Forests never buy white pine seed, only seedlings. Bareroot seedlings of all species are priced the same--\$128 per thousand. Container seedlings are all \$163 per thousand (in Pine Cells). The white pine program, then, is subsidized by the programs in other species. (Had the added cost of seed (\$410/lb.) been included in the subsequent analyses, the undiscounted amount would have been \$18.22/A. This discounted at 4 percent for 90 years is \$0.53.)

Most white pine, however, is grown in containers, while the majority of stock in other species is grown bareroot. A Forest choosing to plant white pine therefore may be incurring an added cost of \$35 per thousand, which is a 28 percent increase, but this is not a consistent added cost on Wallace.

Cultural Treatment Costs

We looked at possible differences in costs of tending (on the same site) stands with rust resistant versus susceptible versus no white pine. Differences, if they exist, will be so trivial as to influence economic analyses very little.

ECONOMIC CAMPARISON OF ALTERNATIVES

To illustrate the benefits of using rust resistant white pine in the Northern Region, we identified two sites on the Wallace Ranger District harvested and planted within the last 6 years. Three alternative prescriptions were written for the south-facing site, and three for the north-facing site. Each carried the stand through to rotation. Costs and benefits were compared. The alternative chosen for implementation for each site illustrates the benefits discussed in preceding sections of this paper.

The South-facing Site

This 25-acre site lies in the Ulm Creek drainage on the Wallace Ranger District on a southeast-facing slope of about 60 percent. Its productivity is about 100 cubic feet per acre per year (MAI). The Habitat Type is grand fir/Pachistima. The elevation is 4200'. The soil is angular, gravelly subsoil over highly fractured metamorphic bedrock and overlain with a loess cap of variable depth.

The site was clearcut and regenerated in 1978. We compare and contrast the existing stand with two other alternatives which realistically might have been chosen. Each alternative is projected to rotation, using the IFRES Prognosis Model. Economic comparisons employed the model CHEAPO (Computerized Help for the Economic Analysis of Prognosis-model Outputs, Appendix 1) which is tied to the Prognosis. Assumptions common to all three alternatives were:

..... The stand is commercially thinned to 100 trees/A at age 64 years.

..... The stand is clearcut harvested and regenerated 100 years from now (culmination of MAI).

..... The cost of site preparation and planting were included in the Economic Analysis and entered as a "special cost" at year of final harvest (2082).

..... The real value of stumpage increases at the rate of 2 percent per year over the next 100 years.

..... Discount rate = 4 percent.

..... Specifications on three tree product categories; large sawtimber, small sawtimber, and poles. By specifying a difference in size classes, value revenues could be determined for each species by tree size.

..... Minimum removal volume of 2.5 MBF/acre to be considered a commercial operation.

..... Specified stumpage revenue values by tree product category and species. These stumpage values were obtained using the Idaho Panhandle National Forest's Stumpage Valuation Equation (Appendix 1). This equation was developed by regression analysis using data from 65 major timber sales sold on the Idaho Panhandle National Forests.

Alternative 1--plant 60 percent resistant white pine, Douglas-fir, and ponderosa pine. This is the existing stand. About 300 trees per acre of white pine (60 percent resistant), ponderosa pine, and Douglas-fir were planted. Volunteers, mostly of grand fir, have brought the stocking level up to 480 trees/A today, 44 percent Douglas-fir, 25 percent grand fir, 19 percent white pine, and 13 percent ponderosa pine. The Prognosis Model shows no need for a precommercial thinning because natural mortality is expected to reduce stocking to about optimum level until age 64 years. Our experience, however, suggests we can expect enough ingrowth on these sites that a light precommercial thinning will be necessary at about 30 years. The Prognosis Model does not yet account for such ingrowth, but precommercial thinning costs were included. A regeneration extension to the Model will soon be available from IFRES.

The stand is to be commercially thinned, favoring the white pine more strongly than Douglas-fir and ponderosa pine. As a consequence of this thinning and low mortality in white pine (Appendix 2), the proportion of white pine will be increased to 34 percent of the trees per acre at rotation. About 34 percent of the regeneration harvest volume will be in white pine.

The total volume harvested in the regeneration harvest will be 52,528 BF/A. An additional 6,611 BF/A will have been harvested in the commercial thinning, bringing the total volume to 59,139 (Table 3).

Discounted total revenues are \$399.17. Discounted total costs are \$100.75. The net present value is \$298.42, and the benefit/cost ratio is 3.96 (Table 3).

Alternative 2--plant Douglas-fir and ponderosa pine. In this alternative only Douglas-fir and ponderosa pine would have been planted, 361 trees per acre. Some natural white pine (10 percent resistant) and grand fir volunteers would have brought stocking to 510 trees per acre today, 59 percent Douglas-fir, 18 percent grand fir, 12 percent white pine and 12 percent ponderosa pine. Here, again, the stand would be precommercially thinned at age 34 years.

The mortality rate of white pine would be so high and initial stocking so low that the proportion of white pine would be only 3 percent of the trees per acre at rotation. About 3 percent of the regeneration harvest volume (47,277 BF/A) would be in white pine. The total volume harvested would be 52,788 BF/A (Table 3).

Discounted total revenues are \$278.23, and costs \$100.75. Net present value is \$177.48 and benefit/cost ratio is 2.76 (Table 4).

Alternative 3--plant susceptible white pine, Douglas-fir and ponderosa pine. Here the site would have been planted 364 trees per acre white pine (10 percent resistant), Douglas-fir and ponderosa pine. Volunteer grand fir would have brought the stocking to 480 trees per acre today, 44 percent of which would be Douglas-fir, 25 percent grand fir, 19 percent white pine and 13 percent ponderosa pine.

Despite high mortality in the white pine, the thinnings would be able to maintain white pine at about 13 percent of the trees per acre through to rotation. About 14 percent of the regeneration harvest volume (49,284 BF/A) would be in white pine. The total volume harvested would be 53,356 BF/A (Table 3).

Total revenues are \$313.82, total costs are \$100.75, and the net present value is \$213.07. The benefit/cost ratio is 3.11 (Table 1).

Comparisons. The most obvious contrast is in revenue received from final and intermediate harvests (Table 3). The higher the proportion of white pine, the larger the revenue. This difference results from the higher value of white pine stumpage and from the increased volumes associated with the faster growing, better formed white pine. Even trivial differences in yields, as between Alternatives 2 and 3, generate significant differences in revenues. Wherever differences in revenue are large, differences in benefit/cost ratios are large, because costs for the three alternatives are identical.

A contrast that is not apparent is the reliability of the growth and yield forecasts. Alternative 1 is far more likely to be achieved than either of the other two. Here's why:

TABLE 3

COMPARATIVE YIELDS AND ECONOMIC BENEFITS

ULM CREEK SITE

	Alternatives		
	1	2	3
Volume Harvested (BF/A)	59,139	52,788	53,356
Revenue (\$\$)	399.17	278.23	313.82
B/C Ratio	3.96	2.76	3.11

TABLE 4

COMPARATIVE YIELDS AND ECONOMIC BENEFITS

ASH CREEK SITE

	Alternatives		
	1	2	3
Volume Harvested (BF/A)	71,366	94,453	57,178
Revenue (\$\$)	497.81	1,106.23	265.86
B/C Ratio	4.94	10.98	2.64

In Alternative 1, about 91 trees/A are white pine trees. At least 55 of those will be able to survive blister rust, so only 36 trees (40 percent) are subject to the whims of blister rust disease development in the stand over the rotation. In Alternative 2, about 61 trees/A are white pine, and only 6 are sure to survive blister rust, leaving 55 subject to the whims of the disease. The picture is similar in Alternative 3. Clearly, overstocking or understocking is far more avoidable for the silviculturist uncertain about the natural fate of 36 of 91 trees than for the silviculturist uncertain about the fate of 55 of 61 trees.

Finally, an unexpected outcome of this analysis was the position of ponderosa pine in the picture. On these south-facing sites, ponderosa pine was just as desirable as white pine; it grows fast, is just as well formed, and it commands as much stumpage. Indeed, were ponderosa pine seed more abundant in the seed bank, this species would be more strongly featured on these sites.

The North-facing Site

This 30-acre site is in the Ash Creek Drainage on a 55 percent slope. The Habitat Type is hemlock/Pachistima, and the productivity is about 130 cu. ft/A/yr. The elevation is 3,200 feet, and the soil is similar to that of the Ulm Creek site.

The site was clearcut and regenerated in 1976. We compare the existing stand with two alternatives, using the same growth and yield and economic comparisons as for the Ulm Creek site. The assumptions common to the three alternatives were the same as those for the Ulm Creek analyses, except:

..... The stand is precommercially thinned to 350 trees per acre at age 27 years, and commercially thinned to 120 trees per acre at age 67 years.

Alternative 1--plant white pine 35 percent resistant. This alternative is the existing stand. About 300 white pine trees per acre were planted. Naturals have brought stocking up to 2,654 trees/A today, 49 percent white pine, 42 percent grand fir, 6 percent Douglas-fir and 3 percent western hemlock.

The thinnings and modest mortality (see Appendix 2) in the white pine permit a stand at rotation to consist of 41 percent white pine, 39 percent Douglas-fir, 10 percent western hemlock, and 10 percent grand fir (in trees per acre), yielding 68,077 BF/A, 56 percent of which will be in white pine. The total yield for the stand, including the commercial thinning, will be 71,366 BF/A (Table 4).

Discounted revenues are \$497.81, and costs are \$100.75. The net present value is \$397.06 and the benefit/cost ratio is 4.94 (Table 4).

Alternative 2--plant white pine 60 percent resistant. This alternative was not available to Wallace in 1976 because of the shortage of stock of this quality. Had it been available, the final proportion of white pine in the stand could have been increased to 68 percent of the trees per acre and the total yield to 94,453 BF/A, including the commercial thinning volume (Table 4).

Now, the revenue would have been \$1,106.23 the cost \$100.75 and the net present value \$1,005.48. The benefit/cost ratio would have been 10.98 (Table 4).

Alternative 3--plant Douglas-fir. Had this site been planted during the moratorium, only Douglas-fir might have been planted, at about 300 trees per acre. Naturals would have raised stocking to about 2,700 trees per acre today, 40 percent grand fir, 39 percent white pine, 17 percent Douglas-fir and 3 percent western hemlock. After high mortality in the white pine and two thinnings, the stand at rotation would consist of 83 trees per acre, only 10 of which would be white pine. The stand would yield 53,322 BF/A in the regeneration harvest, plus another 3,856 BF/A in the commercial thinning, for a total of 57,178 BF/A.

The discounted revenue would be \$265.86, the cost \$100.75, and the net present value \$165.11. The benefit/cost ratio would be 2.64.

Comparisons. Alternative 2 (60 percent resistant white pine) is spectacularly the most productive prescription (Table 4) because the proportion of white pine both at final harvest and commercial thinning is so much higher than in either of the other alternatives. In the regeneration harvest in Alternative 2, 68 percent of the trees per acre (i.e. the white pines) yielded 68 percent of the volume. In Alternative 1, 41 percent of the trees per acre were white pines and they yielded 56 percent of the volume. The advantage to increasing the white pine component is clear.

The results of Alternative 3 demonstrate that species other than white pine which are appropriate for these sites are slower growing and display lower form class than white pine, for they do not yield as well when managed similarly in mixed species stands depauperate in white pine. Moreover, none of the alternative species command the stumpage differences to generate startling revenue differences.

Again, a contrast not apparent in the analyses (because Prognosis does not very effectively project mortality due to blister rust) is the unreliability of the future stocking estimates for Alternative 3 (and, to a lesser extent for Alternative 1). To avoid overstocking, the silviculturist may count on blister rust killing a high proportion of the 1,053 white pine trees between now and age 27 years. If blister rust fails to kill those trees, the stand may be overstocked.

EXTRAPOLATING TO OTHER ACRES

If we regard these two sites on the Wallace District as representative of all other acres planted with white pine in the Northern Region, then we can apply the preceding yield gain calculations to estimate Region-wide added gains. First, what will be the gains for the acres already planted, then, what will be the gains for all acres ultimately to be planted with this material?

About 8,100 acres have already been planted with rust resistant white pine. The Ulm Creek site represents about 6 percent of those acres (≈ 486), and the Ash Creek site about 94 percent of those acres (≈ 7614). ^{1/} We apply the yield gains shown in Table 3 (Alt. 1 minus Alt. 2) and Table 4 (Alt. 1 minus Alt. 3) to acreages listed in the preceding sentence. We discover that the added yields to be harvested from the acres we have planted to date will be about 11.1 MM bd. ft. (Table 5a).

About 760 M acres will ultimately be planted with this material. Extending the rationale of the preceding paragraph to 760 M acres results in an estimate of 10425.5 MM bd. ft. (Table 5b), or about 115.8 MM bd. ft. of white pine in hand today it would have a value of about \$16,646,000.

These extrapolations are conservative because of the yield gain estimates applied from the Ash Creek site (Table 4 Alt. 1 minus Alt. 3). The existing stand consists of stock 35 percent resistant only because of a shortage (in the mid-70's) of 60 percent stock. As the supply of the latter has increased, the proportion of stands planted with the more resistant material has increased and will continue to increase. For 60 percent stands, yield gain estimates are 37275 bd. ft./A (94453-57178), rather than 14188 bd. ft./A.

CONCLUSIONS

For both north and south-facing white pine sites, increasing the proportion of the white pine component in the stand, without serious over- or understocking, increases revenues and benefit/cost ratios (Tables 3 and 4).^{*} These increases result from:

1. Increases in yields due to white pine's faster growth and better form, compared to other species, and
2. Stumpage value differences between white pine and other species.

Preventing over- or understocking, however, is more likely when highly resistant stock is planted.

The advantages of western white pine are greater on north-facing slopes than on south-facing slopes because:

1. Its form is better on north-facing than south-facing sites so its proportional yields and stumpage values are greater.
2. The "second best" species on north-facing sites (Douglas-fir) is relatively lower in yields and value than the "second best" on south-facing sites (ponderosa pine).
3. North-facing sites are more productive overall, so percentage yield increases due to white pine magnify absolute increases.

^{1/} From data submitted to TM by Forests in 1983 estimating planting program by Habitat Types.

* The exception to these results would be stands with a high ponderosa pine component on south-facing slopes; the species grows as well and is as valuable as white pine, but seed supply currently limits its use.

The costs of managing the alternative stands which are reasonable for north-facing sites are quite comparable, but revenues differ spectacularly. For alternatives on south-facing sites, management costs are similar among alternatives, and revenues differ, but not as much as on north-facing sites. South-facing sites are cheaper to manage than north-facing sites, primarily because of lower stocking levels and, therefore, thinning and final harvest costs. But revenues are substantially lower on south-facing slopes, as well, so the benefit/cost ratio is lower for the most productive alternative in Ulm Creek vs. the most productive in Ash Creek.

Extrapolating the two site-specific analyses to all acres to be planted with WP suggests an opportunity for immediately adjusting timber sell programs to reflect an allowable cut effect from planting resistant stock. Such adjustment, however, is as much policy as biology, and is not in the scope of the current analysis.

Tables 5a and b

Extrapolating Yield Gains:
to All Acres Planted to Date^{1/} (Table 5a)

<u>Representative Site</u>	<u>Acres Represented</u>	<u>Yield Gain (Bd Ft/A)</u>	<u>Total Yield (Gain (MM Bd Ft))</u>
Ulm Creek	486	6351 ^{2/}	3.1
Ash Creek	7614	14188 ^{3/}	108.0
GRAND TOTAL			111.1

to All Acres Ultimately to be Planted^{4/} (Table 5b)

Ulm Creek	45.6M	6351 ^{2/}	289.6
Ash Creek	714.4M	14188 ^{3/}	10135.9
GRAND TOTAL			10425.5

^{1/} $\approx$ 8100 acres

^{2/} 12.0% gain, Alternative 1 over Alternative 2

^{3/} 24.8% gain, Alternative 1 over Alternative 3

^{4/} $\approx$ 760,000 acres

Appendix 1

Description of CHEAPO

ECONOMIC ANALYSIS - CHEAPO

A computer program "Computerized Help for the Economic Analysis of Prognosis-Model Outputs" (CHEAPO), has been developed by the College of Forestry, Wildlife and Range Sciences, University of Idaho, to interface with Stage's Growth Prognosis Model. For the Ulm and Ash Creek stands, the CHEAPO economic model was used to undertake an investment analysis of the different alternative management regimes and their associated simulated growth and removal projections.

Discounted costs and revenues from the timber removals were determined and expressed in the output as both net present value (NPV) and a benefit-cost (B/C) ratio.

The CHEAPO model determined the economic feasibility and appeal of different management regimes by computing the harvest year when NPV and B/C ratio for the stand was greatest.

The major base case economic assumptions used in CHEAPO are displayed. They include:

1. Appreciation rate. This real value rate was set at 2.0 percent. This was the average annual rate of stumpage increase for Douglas-fir from 1910-1970.
2. Discount rate. A 4-percent real value rate is currently being used by the Government for public investments and was used in the CHEAPO analysis. A Government study recently found 4-percent to be the real rate of return of new capital investments by private corporations. It therefore represents the opportunity cost of capital from private investors by the tax system.
3. Specifications on three tree product categories. Large sawtimber, small sawtimber, and poles. By specifying a difference in size classes, value revenues could be determined for each species by tree size.
4. Minimum removal volume 2.5 mbf/acre to be considered a commercial operation.
5. Specified stumpage revenue values by tree product category and species. These stumpage values were obtained using the Idaho Panhandle National Forest's Stumpage Valuation Equation. This equation was developed by regression analysis using data from 65 major timber sales sold on the IPNF.

The Idaho National Forest's Stumpage Value Equation is shown on the following page. The simplified form of the equation, which incorporates a mean number of sale bidders was used. The Xy dependent variable, shows that stumpage value increases as tree dbh increases. For the X₁ dependent variable, a weighted average lumber price for all species was not used since the CHEAPO model can take individual species value inputs and will automatically determine total revenues by actual volume removed by species.

The stumpage values calculated by this equation, reflect end-product value after all logging and milling costs, plus a margin for profit and risk have been subtracted.

STUMPAGE VALUE EQUATION
IDAHO PANHANDLE NATIONAL FORESTS

Regression analysis of 65 sales sold from 12/74 thru 4/80 resulted in the following simplified equation:

$$Y_2 = -287.06 + 0.7743x_1 - 0.5153x_2 - 0.7873x_3 + 80.55x_4$$

where:

- Y_2 = high bid value per mbf (first quarter, 1980 \$)
- x_1 = species mix weighted average lumber price, L.T. (1st qtr., 1980 \$)
- x_2 = percent of sale volume jammer logged
- x_3 = percent of sale volume skyline logged
- x_4 = the summation of the natural logarithm of each dbh class times the proportion of the total net sale volume in each class (analogous to $\ln(\text{median dbh})$).

This is the equation we will use to calculate stumpage values for the Forest plan. A unique value will be determined for each mix of analysis area characteristics and prescription requirements. The equation is a reduced version of an equation which also includes the following significant variables: market condition, lumber price trend, contract length in months, SBA sales and the number of bidders.

The simplified equation is solved in the following example:

<u>AACharacteristics</u>	<u>Rx Requirements</u>	<u>Lumber Price, LT.</u>
median dbh = 20 inches	logging method = 80% tractor	DF = \$221.50/mbf
species mix = 70% DF	20% jammer	WWP = \$343.33/mbf
30% WWP		
slope = less than 40 %		

$$\begin{aligned}
 Y_2 &= -287.06 + .7743 [.70(221.50) + .30(343.33)] - .5153(20) + 80.55 [\ln(20)] \\
 &= -287.06 + 199.81 - 10.31 + 241.31 \\
 &= \$143.75/\text{mbf}
 \end{aligned}$$

If we used 100% tractor logging, the value would be \$154.06/mbf; 100% jammer would be \$102.53/mbf; 100% skyline would be \$75.33/mbf.

Appendix 2

Mortality Multiplier Conclusions

Mortality Multiplier Conclusions

Change of MORTMULT to .5 - Decreases mortality too significantly resulting in unreasonably high BF vol. (93,000 BF @ 90 years), PAI (451 ft.³/ac./yr.), BA/A.

Change of MORTMULT to 2 - Doubles mortality too significantly, only 2 percent of the WP make it through the 90 year projection. (25 WP out of 1300).

Baseline mortality rate of 1, represents well a stand of WP planted w/35 percent BRR stock.

321 WP planted → Expect 110 WP @ rot.

1300 WP total (includes 321 planted/ac.) → 169 WP @ rot.

Additional 59 due to 10 percent resistance of remaining 979 natural WP.

To simulate BR, mortality on 60 percent BRR stock of WP planted - change mortality rate, MORTMULT to .75.

Total of WP @ end of rot. will not = 60 percent of planted WP and 10 percent of natural WP due to other mortality factors such as suppression, max BA.

i.e. Begin 1300 WP - 321 60 percent BRR 979 natural.
End w/256 WP from 366 T/A @ rot.

With/321 planted → Expect $\approx$ 190 @ 60 percent resis.
979 naturals → Expect $\approx$ 100 @ 10 percent resis.

or

256 vs. 290

To simulate BR mortality on nursery-run (millrun) WP change MORTMULT Increase it to 1.60.

A change of 1.75 yields only 3 percent resistance, or 44 WP from 1300.

Appendix 3

Summaries of Prognosis Runs

Ulm Creek, Alt.#1 - 60% BRR WP,DF,PP - EXISTING STAND

Begin 480 T/A	44% DF	211 T/A
	25% GF	120 T/A
	19% WP	91 T/A
	13% PP	62 T/A

Col. MAI Precommercial thin not needed since only 333 T/A age 24
@ 100 yr. (2002).

projection
2082

Commercial thin to 100 T/A @ 2042 (age 44).

At Rot. 79 T/A	43% DF	34 T/A
	35% WP	27 T/A
	18% PP	14 T/A
	3% GF	2 T/A

Commercial thin vol. 6,611 BF	71% DF
	15% WP
	8% PP
	5% GF

Regen. harvest vol. 52,528 BF	43% DF	22,587
	34% WP	17,859
	21% PP	11,031
	2% GF	1,050

Total harvest vol. 59,139 BF

Median DBH = 23.4", Quad $\bar{x}$ DBH = 24.2"

ULM CREEK ALTERNATIVE #2 ONLY DF PLANTED w/WP,PP Nat.

Begin w/ <u>510</u>	T/A	59% DF	300 T/A
		18% GF	92 T/A
		12% WP	61 T/A
		12% PP	61 T/A

Cul. MAI.

@ 100 YR. No precommercial thin. only 335 T/A @ 2002 comm. thin to
project 100 T/A @ 2042 (age 64).
2082.

At rot.	76 T/A	73% DF	55 T/A
		23% PP	17 T/A
		3% WP	2 T/A
		1% GF	1 T/A

Comm. thin. vol. 5,511 BF	85% DF
	10% WP
	5% PP
	1% GF

Regeneration harvest vol. 47,277 BF	68% DF = 32,148
	28% PP = 13,237
	3% WP = 1,418

Total harvest vol. 52,788 BF

Median DBH = 23.2" Quad $\bar{x}$ DBH = 24.5"

ULM CREEK, ALTERNATIVE #3 - Nursery Run WP w/DF + PIPO

Begin 480 T/A	44% DF	211 T/A
	25% GF	120 T/A
	19% WP	91 T/A
	13% PP	62 T/A

Cul. MAI. Precomm. thin not done only 312 T/A @ 2002 (age 24)
@ 100 Yr.
projection Comm. thin to 100 T/ A @ 2042 (age 64)
2082

At rot. 75 T/A	65% DF	49 T/A
	18% PP	14 T/A
	13% WP	10 T/A
	4% GF	3 T/A

Comm. thin. vol. 4,072 BF	62% DF
	20% PP
	11% WP
	7% GF

Regen. Harvest vol. 49,284 BF	65% DF	=	32,034 BF
	18% PP	=	8,871 BF
	13% WP	=	6,407 BF
	4% GF	=	1,971 BF

Total Harvest vol. 53,356 BF

Median DBH = 22.8"

Quad. $\bar{x}$ DBH = 24.8"

ASH CREEK, ALTERNATIVE #1 (35% BRR WP) - EXISTING STAND

Begin 2654 T/A	49% WP	=	1300 T/A
	42% GF	=	1114 T/A
	6% DF	=	160 T/A
	3% H	=	80 T/A

Cul. MAI
@ 100 Yr.
projection

2082 Precomm. thin to 350 T/A @ 2002 (age 27)
 Comm. thin to 120 T/A @ 2042 (age 67)

<u>At rot.</u>	85 T/A	41% WP	35 WP
		39% DF	33 DF
		10% WH	8 H
		10% GF	9 GF

Comm. thin. vol. 3,289 BF	78% WP
	18% GF
	3% H
	1% DF

Regeneration Harvest vol. 68,077 BF	56% WP	=	38,123
	32% DF	=	21,784
	6% WH	=	4,085
	6% GF	=	4,085

Total harvest vol. 71,366 BF

Median DBH = 23.1", Quad. $\bar{x}$ DBH = 24.4"

ASH CREEK, ALTERNATIVE #2 (60% BRR.)

Begin 2654 T/A	49% WP	1300 T/A
	42% GF	1114 T/A
	6% DF	160 T/A
	3% H	80 T/A

Cul. MAI

100 Yr. Proj.

Year 2082 Precommercial thin to 350 T/A @ 2002 (age 27)
 Comm. thin to 120 T/A @ 2042 (age 67)

<u>At rot.</u>	93 T/A	68% WP	63 T/A
		32% DF	30 T/A

Comm. thin. vol.	16,641 BF	94% WP
		4% DF
		2% GF
		1% WH

Reg. cut volume	77,812 BF	68% WP =	52,912 BF
		32% DF =	24,900 BF

Total harvest volume = 94,453 BF

Median DBH = 23 inch Quad. $\bar{x}$ DBH = 24"

ASH CREEK ALTERNATIVE #3 (assume DF) - EXISTING STAND

Begin 2700 T/A	40% GF	1080 T/A	
	39% WP	1053 T/A	
	17% DF	459 T/A	
	3% H	81 T/A	
Cul. MAI			
@100 yr.	P.comm. thin. to 350 T/A @ 2002 (age 27)		
proj. 2082	comm. thin to 120 T/A @ 2042 (age 67)		
<u>At. rot.</u>	83 T/A	67% DF	56 T/A
		12% WP	10 T/A
		13% WH	11 T/A
		8% GF	7 T/A
Comm. thin volume = 3,856 BF		41% WP	
		37% DF	
		20% GF	
		2% WH	
Regen. cut volume 53,322 BF	67% DF	=	35,726
	12% WP	=	6,399
	13% WH	=	6,932
	8% GF	=	4,266
Total volume harvested = 57,178 BF/AC.			
Median DBH = 23" Quad. $\bar{x}$ DBH = 24"			

HOW SHOULD WE CONSIDER OTHER RESOURCES IN SILVICULTURAL PLANNING?

Jim McDivitt and Chris Hansen

Our initial reaction to the question of how to consider other resources in the silvicultural planning process is fairly simple: estimate the effects of the silvicultural practices on the other resources in the area (e.g., wildlife, soils, water, recreation) either quantitatively (volumes, costs, benefits) or qualitatively, and use that information in choosing the best combination of practices to achieve if possible the desired silvicultural objectives, while maintaining levels of other resource outputs that result in the greatest possible positive effects.

Our main thesis is that other resources must be considered along with the trees in silvicultural planning, in order to achieve the highest value possible for society. The approach we take in this presentation is to explain why other resource considerations are important, and to provide a framework within which you can organize your own thinking about these other resources. We will not be discussing details on a resource by resource basis of how to determine resource yields and associated costs and benefits. That would require more time than is available this morning, particularly with the tremendous variety of resource situations represented by your home Forests.

The approach to consideration of other resources we want to discuss this morning will be primarily in economic terms, but it is deeply rooted in ecological principles. From an economic standpoint, critical to the consideration of other resources in silvicultural planning are the concepts of joint production (you can't change output levels of one resource without changing output levels of another); opportunity costs (the true economic cost of producing something is the value of what you give up by not producing something else); and externalities (side effects of your actions on a third party). These economic concepts are based in the physical/biological reality of ecosystems, capsulized by the two ecological precepts which were made popular in the 1970's: "The web of life," or "everything is related to everything else," and "There ain't no such thing as a free lunch."

The concepts of joint production, opportunity costs, and externalities are closely related, but not necessarily coincidental. They make up the bulk of the framework we want to provide you as a way of structuring consideration of nontimber resources in silvicultural planning.

The overall purpose of Forest Service projects, whether designed for producing timber, providing wildlife habitat, or developing recreation opportunities, is to provide goods and services to society which: 1) are more valuable than the expenses incurred to provide them, and 2) provide the mix of goods and services that results in the highest value to society of all possible mixes. This can be done to a great extent through the use of the economic metric, but where that fails, we have to resort to more subjective judgements about the relative worth of things. At times this

may take the form of relatively arbitrary requirements or constraints that have to be met, such as no timber harvest within certain wildlife habitat areas, or no motorized travel on certain trails.

Silviculturists are generally (if I may use a double negative) not unaware of other resource considerations when planning silvicultural prescriptions and activities. If nothing else, current laws (T&E Species Act, NEPA, NFMA) and regulations require that awareness. It is difficult (though not impossible, as some have proved!) to write an Environmental Assessment without considering the environment, which does include things other than just trees!

Typically, activities planned or performed as silvicultural practices are designed to modify the natural succession of a forest or stand of timber. They are prescribed with a particular objective in mind, such as thinning a stand to a certain basal area and number of stems per acre, controlling or eliminating competing vegetation, or making a final harvest. However, the forest provides many products (or goods and services in economic jargon) other than just timber or wood fiber. Therefore, most silvicultural practices which modify the forest to achieve a timber objective will also have some influence on the level of one or more other forest goods and services, and may even affect other resources away from the immediate treatment area.

Joint Production

Silvicultural activities are part of a production process which is designed to convert physical and biological inputs (soil, moisture, light,

trees) into desired outputs (lumber, pulp, plywood) at a faster rate than would normally occur under unmanaged conditions by adding labor and capital. Joint production occurs when two or more outputs are produced by the same production process, and the level of one output cannot be changed through the production process without the level of the other(s) changing as well. Because of the interrelated nature of the forest ecosystem, silvicultural activities often result in joint products.

Joint products may be either complementary or competitive. In other words, making changes in the production process to increase levels of one output may result in increases (complementary) or decreases (competitive) in the levels of the associated joint products. The silviculturalist need not know or remember the economic nomenclature of joint production, but the concept is important. Its basis is in the ecological principles of resource interrelationships, with which silviculturalists are familiar.

An example of joint production could be the harvest of timber by clear cutting. This silvicultural practice will provide a quantity of timber for sale that (generally) has positive economic value. In addition, ungulate species which favor early successional vegetation stages will benefit from increased forage and browse for several years, and water runoff may increase, providing additional water to users lower in the watershed. These effects are joint products with the production of timber. Cutting timber to achieve any one of the three outputs in the example will also result in increasing levels of the other two.

On the other hand, in certain circumstances cutting existing old growth stands may eliminate habitat necessary for survival of some wildlife species in the area, and may eliminate the opportunity for recreation experiences of a primitive character in that watershed. Again, these effects are joint products, but the joint production process is competitive, or inversely related. An increase in one output is coincidental with a decrease in one or more other outputs, and vice versa.

Many policies exist which are designed to minimize the negative, or competitive, joint product effects on different resources. For instance, NFMA requires that viable populations of wildlife species be maintained in an area, even if it means reducing the amount or type of timber harvest done. These added policies usually increase the costs of, or lower the benefits from, producing target outputs by requiring more expensive management practices or foregoing some portion of the target output altogether.

Opportunity Costs

Opportunity costs are the value of products foregone because of a decision to produce one good rather than another when resources are limited (which they always are). The true economic cost of a production process, then, includes not just the direct production and management costs, but also the values foregone by not producing some other product.

Some silviculturalists have a view of the forest as a timber producing unit to be managed for maximization of biomass. The idea of harvest at the culmination of mean annual increment results in maximizing wood fiber

available. This philosophy of wood fiber production, regardless of cost, still holds sway in many places within the Forest Service. However, maximization of wood fiber from the forest may not be consistent with the demand for timber products in any given time period, nor with the fluctuations of timber prices in the market place.

From this viewpoint, any policy, such as spotted owl management, which requires an extension of rotation ages or other less intensive silvicultural practices, and a concomitant reduction in wood fiber production, is seen as a cost rather than as a means of increasing total benefits by managing for multiple resource outputs. Biomass maximization for the most part disregards economic and other resource considerations. Over-mature timber (that beyond the age of culmination of mean annual increment) is not a desirable objective. The silvicultural practices prescribed to achieve maximum wood fiber outputs may result in such effects as a decrease or elimination of old growth stands, a consequent decrease or elimination of wildlife species which depend on old growth for all or a portion of their necessary habitat, and elimination of undeveloped areas. Although these resources all have some value to society, biomass or wood fiber maximization goals tend to blind the silvicultural planner to the opportunity costs -- values foregone -- of the effects of harvest on these other resources.

Opportunity costs, then, whether as part of a joint production process or as values foregone by not pursuing other management options, should be considered in the planning of silvicultural objectives and corresponding activities. The loss in value because of declines in old growth dependent

wildlife species, or because of losses of certain types of recreation opportunities, should be a consideration in the silvicultural planning process.

What we are saying is that silvicultural activities should be planned with an economic (costs and benefits) criterion in mind, and not simply with a physical or biologic maximization criterion. It is certainly true that use of an economic criterion which includes opportunity costs will not necessarily result in old growth maintenance as an objective for forest management. In fact, old growth maintenance may not be justified on an economic basis at all in some areas, even including opportunity costs. The important point, though, is that silvicultural activities can cause losses, as well as gains, in value to some segments of society. Those individuals either lose the opportunity to "do their thing" altogether, or they have to incur greater costs to gain access to similar opportunities elsewhere. It is important to consider these value losses to society -- opportunity costs -- in the silvicultural planning process.

Externalities

An externality is an output or effect of a production process which does not enter into the producer's cost or benefit calculations, but which affects someone else outside the production process. Externalities can be either positive or negative. Negative externalities, such as air or water pollution, result in costs to some portion or portions of society, but not

to the producer. Therefore, the cost of the externality is not incorporated into the production process, and thus does not show up in the cost of the final good to the consumer. Rather the cost is borne by all or a portion of society at large. Not surprisingly, negative externalities are often known as "joint bads."

Silvicultural activities have the potential to generate a number of externalities because of the nature of the practices and the size of the areas treated which are often involved. Some of these externalities are the results of joint production. For instance, the timber producer does not take into account the additional values enjoyed by hunters and nonconsumptive wildlife recreationists that result from timber harvest activities leading to an increase in the number of deer in the area (a joint product, as we saw earlier). If the increased water runoff (also a joint product) from the timber harvest is so great that it results in downstream flooding, that cost is not borne by the producer, but by those who have been flooded. Neither does that same producer take into account the costs to commercial and sport anglers of decreases in anadromous fish populations caused by increases in stream sediment loading from harvest and road building activity associated with silvicultural practices.

Many laws and policies affecting forest management practices are designed specifically to force producers to account for the costs of negative externalities generated by timber production activities. Road construction standards are a good example. The standards are required in order to lessen the amount of sediment produced during road construction

and from the roadway, slopes and fills after construction. The costs to fishing enterprises from decreased fish populations because of increased sedimentation are shifted back to the timber producers in the form of increased costs for road construction. This process is known in economic jargon as "internalizing all the costs of production," or "internalizing externalities."

Hazards of Partial Analysis

Partial analyses are comparisons of costs and benefits of producing individual products when joint production actually exists. Historically, most analyses performed by federal agencies would be classified as partial. The National Forest Management Act and the land management planning which has followed have broadened the scope of analyses at the forest planning level in the Forest Service. The current struggle is to broaden analyses done at the project level to include joint production benefits and the costs of negative externalities.

Projects are normally proposed for a specific purpose and accomplished to satisfy a specific objective. Consequently, the tendency is to perform a partial analysis of only the target-specific benefits and costs considered relevant at the time. This analysis ignores the possibility of other benefits from joint production processes, as well as the costs of negative externalities.

A relatively small increase in costs for a project because of a design change may result in significant benefit increases in other products. For instance, higher road construction standards may decrease or eliminate the

possibility of a stream scouring and destruction of a fishery. The fisheries benefits saved may be worth far more over a period of years than the one-time increase in road construction costs. Economic analysis will help determine the appropriate action to take in this multiple resource consideration. These kinds of project modifications can improve both the output levels of the target product as well as the output levels of other joint products. Overall, the economic, as well as the physical and biological, desirability of the project may be improved when compared to other alternative actions proposed for the area.

Ignoring or failing to consider adequately the opportunity costs of losses by competing resource users represents an overstatement of benefits from the target product. This is misleading to decision-makers in terms of the economic value of the project. A statement of opportunity costs also alerts managers to the potential sources of objection to proposed project actions. A quantification of opportunity costs and an explanation of the cost determination provides a starting point for negotiations between conflicting users in the final decision-making process.

The calculation of opportunity costs is done by estimating the costs and benefits associated with the multiplicity of resource outputs and externalities involved in a proposed project and comparing those to cost and benefit streams of alternative resource actions. Depending on the proposed project, these alternatives might differ to a relatively minor degree, such as controlling competing vegetation with manual versus chemical means, or to fairly major degree, such as roading an area versus

leaving it unroaded and getting the harvest desired from another area. Opportunity costs should be specified for the project as a whole -- i.e., the total value given up if a project alternative is chosen that has a lower present net value than another alternative. Opportunity costs should also be specified to the extent possible for individual resources, so that it is clear to the decision-maker what are the major components of the overall opportunity costs.

Some Qualifiers

Now that I have so glibly told you what to do and why you should do it, let me add some caveats. Although the concepts of physical/biological inputs being converted to outputs through some production process is sound, the empirical methods for determining those production relationships leave much to be desired. As you are well aware, we have a difficult enough time estimating with any degree of consensus growth and yield tables for timber. Those production relationships for nontimber resources are even less clear. Some will argue that they cannot be specified at all.

We have found through the land management planning process that some estimates can be made, for instance, of sediment production from harvest activities, or of deer production from different types of habitat. Utilize the resource experts available to you, both within and outside of the Service. Utilize the work that has gone into Forest Plans and EIS's to the extent possible, modified as necessary for site specific conditions. At times, output quantification will not be possible. When

that happens, economic quantification will also not be possible. In those cases, put together the best qualitative description you can of the interrelationships and values involved. A qualitative assessment is better than just ignoring the other resource effects and values involved in the project.

Negative externalities, when ignored, result in a person or group who seemingly have no interest in your business suddenly acting like a partner. Since they are bearing some of the cost of producing your product, they want to transfer that cost back to you. This is often done by political pressure or legal action. To avoid considering the joint products, externalities, and opportunity costs of proposed projects is to assume a polyanna philosophy, which results in incomplete projects and ill feeling within the communities in which we live. We have had some good examples of this in the history of the Forest Service, particularly in the areas of visuals, herbicides, and primitive recreation. We are doing better, but we are not yet where we could be in carrying out complete project analysis.

Summary

The principal points in considering other resources during silvicultural planning can be restated as follows:

1. Remember the rules of ecology. It is possible everything is connected to everything else. If so, actions taken may produce more desirable products than only those targeted. Claim those benefits (but only those that would not be present without the project.)

2. Sometimes projects require that other products must be foregone. Consider these opportunities lost as costs or reductions in benefits.
3. Externalities (spillover effects) are costs or benefits to someone in society. While they do not change the costs of production for you, their results may be future legal actions which can result in rules that significantly increase your costs of doing business.
4. Inability to quantify production process relationships or economic values does not justify ignoring other resources in the silvicultural planning process. Get the best information you can from specialists in the area, and then do the best you can to lay out the interrelationships and tradeoffs.

In the last twenty years, increasing numbers of laws and regulations have made it less possible for silviculturists not to consider other resources in planning silvicultural activities. Those laws and regulations came about because joint products, opportunity costs, and externalities were not recognized or were ignored. Adding these concepts to your project planning process should help to recognize and incorporate more readily consideration of other resources.

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Interrelationships Among the Biological, Financial
and Silvicultural Decisions in Forestry

by

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Interrelationships Among Biological, Financial, and Silvicultural Decisions in Forestry

by

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Abstract

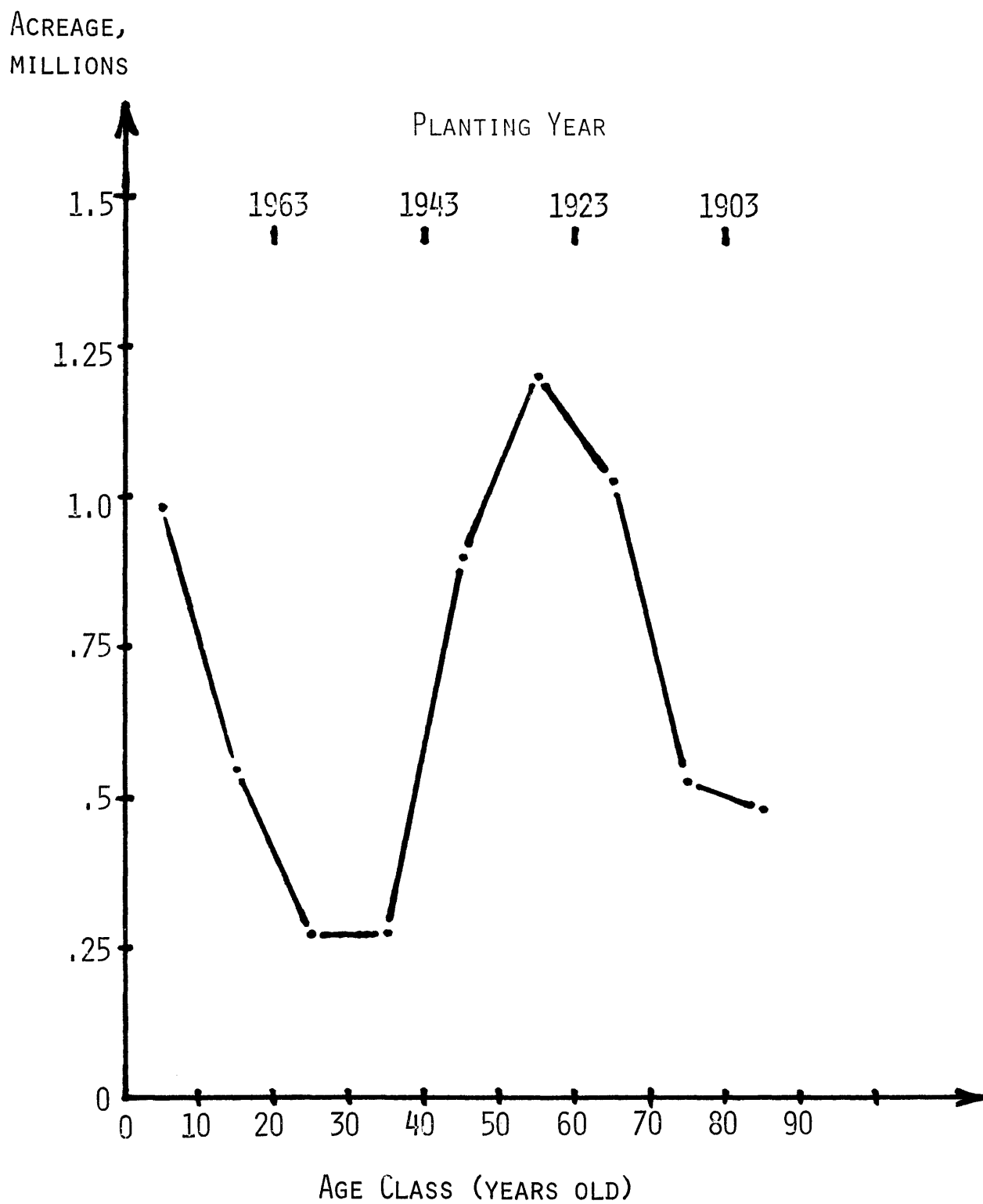
An important principle underlying the Forest Management and Planning Acts of 1974 and 1976 is that National Forests are ecosystems whose management requires consideration of the interrelationships among plants, animals, soil, water, air, and other factors. Such management is done in an administrative and financial environment that constrains and modifies actions to foster ecosystem balance. A system dynamics model of this complete forest management system for Region 8 has been developed to enable forest managers and planners to anticipate long run patterns of change in critical forest variables and to test the consequences of different decision policies relative to the biological, financial, and managerial aspects of the system in bringing about the desired ecosystem balance and benefits derived from the forest. Final model results are not yet available but examples of 200 year (1962-2162) simulated time histories of some critical forest variables are included to illustrate the way the model can be used.

Introduction

The Forest and Rangeland Renewable Resources Planning Act of 1974 (7) and the National Forest Management Act of 1976 (8) prescribe how land and resource management planning is to be conducted on National Forest System land. One of the guiding principles underlying these acts is the recognition that the National Forests are ecosystems whose management requires an awareness of the interrelationships among plants, animals, soil, water, air and other environmental factors within such ecosystems. Therefore, in the development and maintenance of land management plans, a systematic interdisciplinary approach is required to achieve integrated consideration of the physical, biological, economic, and other aspects of the National Forest System. Specifically, a team representing several disciplines is to be used at each level of planning to ensure coordinated planning which addresses outdoor recreation, range, timber, watershed, wildlife and fish, and wilderness opportunities.

The lack of information about the static relationships among these joint products of the forest makes the task of this team difficult. But the managerial job becomes much more difficult when one considers the dynamics of the situation facing the National Forest System in the South. Consider, for example, the acreage age class distribution in the Southern Region, Figure 1. For the next 30 years we see an increasing number of acres pushing into the older age classes followed by 30 years of a sharply declining number of acres. What kinds of problems will this distribution create for the timber sales and silviculturists of the Region? What will be the impact of these large acreage swings upon the joint products of the forest? In

FIGURE 1. REGION 8 SOFTWOOD ACREAGE BY 10 YEAR INTERVAL AGE CLASS.



light of the growing demand for all of these products, where and when is conflict likely to arise and what form is it likely to take? How do you manage the forest to reduce the potential for conflict among its various users? Are such timber harvest policies as regulation, even flow, 95 percent of CMAI, and average 18" DBH appropriate for both increasing and decreasing acreage flows or are more flexible policies required?

The answer to these questions cannot wait for the acreage swings to be upon us. Clearly, a model of the dynamic ecosystem coupled with the human intervention system is essential to meet the requirements of the above acts and to provide the analysis needed for formulating guidelines for the managerial decisions. The model described below is designed to demonstrate the utility of using a system dynamics approach to facilitate such an analysis.

Definition of System Dynamics

System Dynamics (SD) is a method of modeling the complex interactions that characterize our biological, engineering, managerial, organizational, and social systems. Its distinguishing feature is the application of feedback control principles to model problems. A feedback system exists whenever the environment leads to a decision that results in an action which affects the environment and thereby influences future decisions (2). Feedback control is fundamental to all life and human endeavor. For example, a thermostat receives temperature information and decides to start the furnace; this raises the temperature, and the furnace is shut off. A closing of the loop occurs, though a delay intervenes between the initial action and the feed back results. Closed loops and time delays are characteristic of all feedback processes.

The loops do not function separately, but rather are coupled together to form complex feedback systems that are whole interacting entities. Change in one system part eventually has an impact everywhere in the system. The continuing operation through time of these loops creates the performance time patterns of the system's variables. The study of feedback systems deals with the way information is used for the purpose of control. It helps us to understand how the amount of corrective action and the time delays in interconnected components can lead to system behavior. Thus system dynamics is based on the philosophy that the behavior of a system is principally caused by the system's structure. The structure includes not only the physical aspects of the system but, more importantly, the "policies" that dominate decision making within the system.

A second aspect of the SD philosophy is the concept that systems are viewed most effectively in terms of their underlying flows of people, money, materials, information, etc. A meaningful framework then results from tracing the cause-and-effect chains through the relevant flow paths of the system. A causal loop diagram is typically employed as the first step in modeling. These diagrams show the major cause-and-effect links between the system variables; indicating the direction of the linkage, and denoting the major feedback loops and their polarity. A positive feedback loop has very predictable behavior in response to a change induced in any of its variables. The loop can only act to reinforce or accelerate that initial change. A negative feedback loop on the other hand acts to counter the

direction of initial change in any of its variables. This frequently leads to oscillation.

From this perspective, all dynamic systems can be represented in terms of level and rate variables with auxiliary variables used to represent goals and other concepts that affect the rates. A level is an accumulation or an integration over time of flows or changes that come into and out of the level. For example, forest inventories grow or diminish over time depending upon the relative growth and harvest of the forest. A rate variable on the other hand is a flow or a decision that controls a flow into or from an accumulation. Forest system relationships can be translated into level, rate, and auxiliary equations that can be simulated by computer using a specially designed compiler program called DYNAMO (6).

Ecological Systems as Feedback Processes

Ecology is the study of organisms in relation to their environment (5). A community is an aggregation of living organisms having mutual relationships among themselves and their environment. Forest ecology, therefore, is concerned with the forest as a biological community with the interrelationships between the various trees and other organisms comprising the community and between these organisms and the physical environment in which they exist. The forest community and its habitat together comprise an ecological system, or ecosystem, in which the constituent organisms and their environments interact in a complex energy cycle.

This cycling of mineral nutrients from the soil to the vegetation and back again is basic to all life. Therefore, it provides a useful starting point for modeling the interrelationships that exist in a forest ecosystem. In such a system energy, primary production, biomass, dead organic matter, and inorganic nutrients are accumulated. These accumulations are determined by the material flows around the energy cycle and by the time delays that exist between these fundamental ecological variables. The coupling of positive and negative feedback loops in the forest ecosystem will produce a time history of forest biomass accumulation which we commonly refer to as a yield table.

In order to construct a testable model (3), this process must be articulated in terms of quantifiable interloop and intraloop relationships representing other variables of interest that exist within the forest ecosystem. The purpose here is merely to demonstrate that the balance of nature means that ecological systems are feedback processes. Hence, system dynamics is an appropriate tool for studying the complex interrelationships that exist among the trees and other variables.

Silvicultural Intervention in Forest Ecosystems

Silviculture is the theory and practice of controlling forest establishment, composition, and growth in order to make the forest permanently useful to mankind (4). Traditionally the activities of the silviculturist focused upon producing greater economic timber values. But it is now becoming increasingly clear that these same activities shape the composition of the

forest and hence the proportion and distribution of the land into different timber types and age classes from which all benefits of the forest are derived (1). For example, a stand of old-growth timber offers den trees for bear and mast for squirrels, but little browse for deer; undisturbed, the old growth stand minimizes sediment flow into streams but also minimizes the annual runoff of water. Large trees are aesthetically pleasing to recreationists and large logs, when harvested, provide premium quality solid wood products. A young forest, on the other hand, provides a different array of benefits.

The important point is that silvicultural intervention in the forest ecosystem has an impact upon the benefits received and, therefore, must be modeled to capture the reality within the forest ecosystem. There are several characteristics of this relationship that are important. First, a balance is required between forest development and use. Too much use destroys the forests' ability to reproduce itself. Too little use provides inadequate benefits to the users. "Appropriate" use simultaneously provides significant benefits while enhancing forest productivity and vigor.

The second consideration is the synergy or conflict among the users. Usually a utilization action such as cutting an area for timber has benefits and detriments relative to other uses. For example after cutting, an area frequently becomes available for grazing for a period of time after new trees are established and until they are large and dense enough to interfere with grazing. Temporary detriments arise as certain creatures' habitats are destroyed along with some of the scenic beauty of the area. These tradeoffs become important considerations in forest management decisions.

A third consideration is the response time horizon. An action may be beneficial in the short run for some purpose, but detrimental in the long run for that same purpose or others and vice versa. Mining an area may provide significant immediate revenues, but may contaminate the land in such a way that reforestation cannot take place for many years. Burning may destroy biomass in the short run, but increase plant productivity and habitats of desirable creatures in the long run.

The interventions by silviculturists usually require continuing actions, observation, and evaluation to ensure that the desired results occur and persist. This requires a continuing organization and management with authority and responsibility to determine and carry out the required tasks. The Forest Service is an obvious example of a continuing organization engaged in forest management necessitated by the need to continuously balance development and use, control coordination and tradeoffs between uses, and reasonably balance short and long range benefits and detriments.

Financial considerations and constraints arise as soon as a continuing management activity is supported. Furthermore, the balancing of forest development and use, the control of multiple uses, and the balance of short and long range considerations all contribute to the continuing need to provide costly intervention activities before benefits are realized. If money is required, a source must be found and control must be exercised over the utilization of funds. The consequence of this reality is that the forest biology, the decision structures of the associated human organizations, and the financial aspects of forest benefits, capital and operating costs of the

organizations all become interrelated in the short and long run to form a single entity--the forest management system. The biological, human, and financial aspects of this system are related through coupled feedback loops that operate continuously through time to create the patterns (growth and oscillation) of the system's variables.

These are the considerations which form the basic structure of the demonstration model described below. The key features of the model are the feedback processes, with multiple coupled loops and time delays, and the interdependence of the biological processes, managerial decision making, and financial considerations that constitute the forest management system.

System Dynamics Model of the Forest Management System of Region 8

The System Dynamics Model of the Region 8 Forest Management System (R8FMS) includes a set of equations which represents the causal relationships between the biological, managerial and financial activities that operate through time to create the system's historical patterns of performance. The current equations are the authors' best estimate of the policies and parameters of the system. However, extensive validation studies have not yet been done, so suggestions for improvement are welcome. The purpose of this paper is to illustrate how feedback principles apply to this system and to show how such a model, when properly validated, could be used to contribute to the planning, forecasting, and decision making activities at the congressional level and the national, regional, and individual forest levels in the Forest Service.

The R8FMS model is divided into seven sectors. These are timber, wildlife, recreation, budget, staff, forest products industry, and government and economy condition. Several important areas have been omitted for simplicity. These include range, soil, water and fish. Areas devoted to wilderness and mineral development are included in the timber sector. As the model is improved, existing sectors will be extended and refined and omitted areas will be added. The forest products industry and government/economy condition sectors represent exogenous influences from these areas in the form of projected time histories. These also need refinement.

The model is simulated over a 200 year period from 1962 to 2162. Each of the 182 dynamic variables is calculated annually. Time graphs of 46 of these variables are plotted. The first 20 years (1962-81) reconstruct actual history for which some data exist. Four variables' data are plotted--budgets for timber, wildlife and recreation and timber sales. 1962 was selected as the starting year because the data could not be found or estimated for some variables before that time. Long run Forest Service goals (1983-2029) are plotted for timber sales, wildlife improvement acres and recreation visitor days.

The important flows and feedback relationships included in the model are shown in Figures 2-8. The fundamental timberland loop is a positive one (Fig. 2) in which old stand timber "Acres Ready to Harvest" are perceived as a revenue opportunity that leads to "Land Clearing Harvest". That harvest reduces the "Acres Ready to Harvest" and increases the "Cleared Acres". After a short delay (2-3 years) the cleared acres are regenerated (trees are

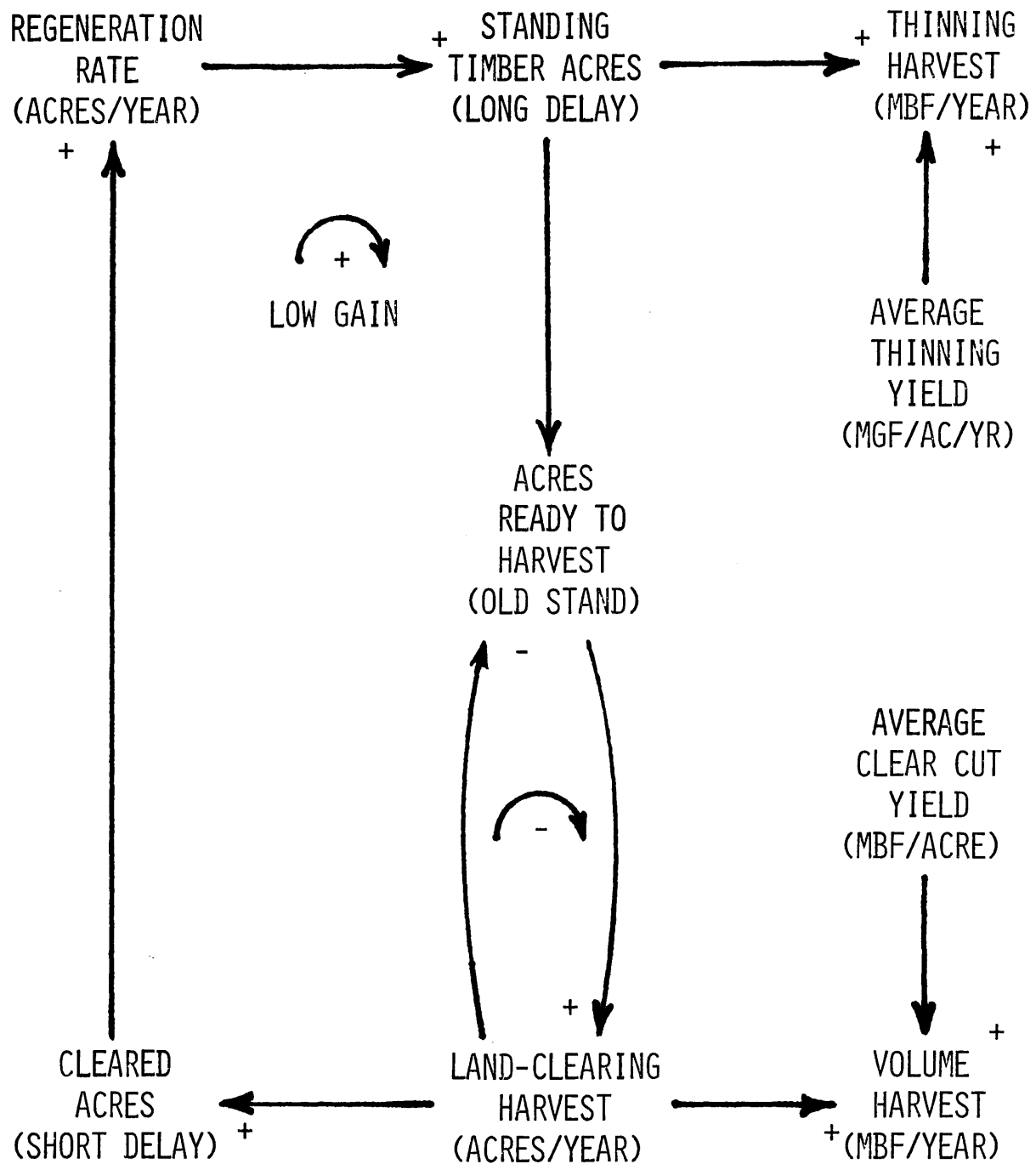


FIGURE 2. FUNDAMENTAL TIMBERLAND FEEDBACK LOOP WITH SAW TIMBER AND PULPWOOD HARVEST GOAL.

replanted) either through natural seeding or planting by the Forest Service (FS). After a long growing delay (60-150 years depending on the type of trees involved) the acres again become ready to harvest. This is a positive loop with low gain, so sustained growth in acres per year harvested is not possible unless new land is added. Timber harvest in thousand board feet (MBF) is determined from acres harvested and yield per acre for cleared land and from the volume of commercial thinning.

The arrow from "Acres Ready" to "L-C Harvest" in Fig. 2 represents the harvest decision. Many things influence that relationship. Figure 3 and Figure 4 are needed to show the factors included in the model. Pressures from recreation, wildlife and timber management considerations are shown in Fig. 3. Financial and staff pressures appear in Fig. 4.

Planning for the harvest is done about 5+ years before the actual harvest. There are 3 years before Congress acts on the plan and two to three more years after the sale of the timber before cutting is done. The plan includes "Acres Ready to Harvest" modified by "Wildlife Pressures" (do not cut too much old growth, so sufficient old stand habitats are retained; but cut enough to provide sufficient early growth habitats) and "Recreation Pressures" (do not cut so much old growth that visual beauty is destroyed, but cut enough so that early and middle growth hunting is assured and a fairly open, parklike vista is created). "Expected Forest Products Industry Demand" is also important. This is based on past demand. The "Planned Harvest" after a three year delay is considered by Congress in determining "Timber Budget". "Political Pressures" and other factors also influence "Timber Budget." The timber "Sales Goal" follows with some variability from the "Planned Harvest" and "Timber Budget". The "Sales Goal" becomes actual sales and, then two to three years later, "Land Clearing Harvest" unless "FP Industry Demand" is insufficient.

The varying recreation, wildlife and timber pressures to harvest do not in general lead to a constant year-to-year harvest in area or MBF. The model provides the option to select a harvest decision that maintains an area/rotation policy which will achieve a balanced distribution of acres in different age classes and attain the long-term sustained-yield capacity of the forest (i.e., a regulated forest).

There are also budget and staff influences on the harvest decision (Fig. 4). The harvest should be large enough to provide work for the existing permanent ranger staff, but not so large as to require hiring large numbers of new people. The existing staff is a reflection of past harvest volumes. The "Planned Budgets" must provide for the "Planned Harvest" without increasing substantially beyond the previous year's budget. The "Planned Budget" is then considered with "Planned Harvest" by Congress in setting "Timber Budget."

There are three places in the model where timber, wildlife and recreation considerations interact. The first is the harvest decision. Total harvest depends on all three pressures. The second is budget. If all of the individual budget requests cannot be met, the budget allocation to each area will be dependent on the area's own needs, the needs in the other areas and the priorities assigned to each.

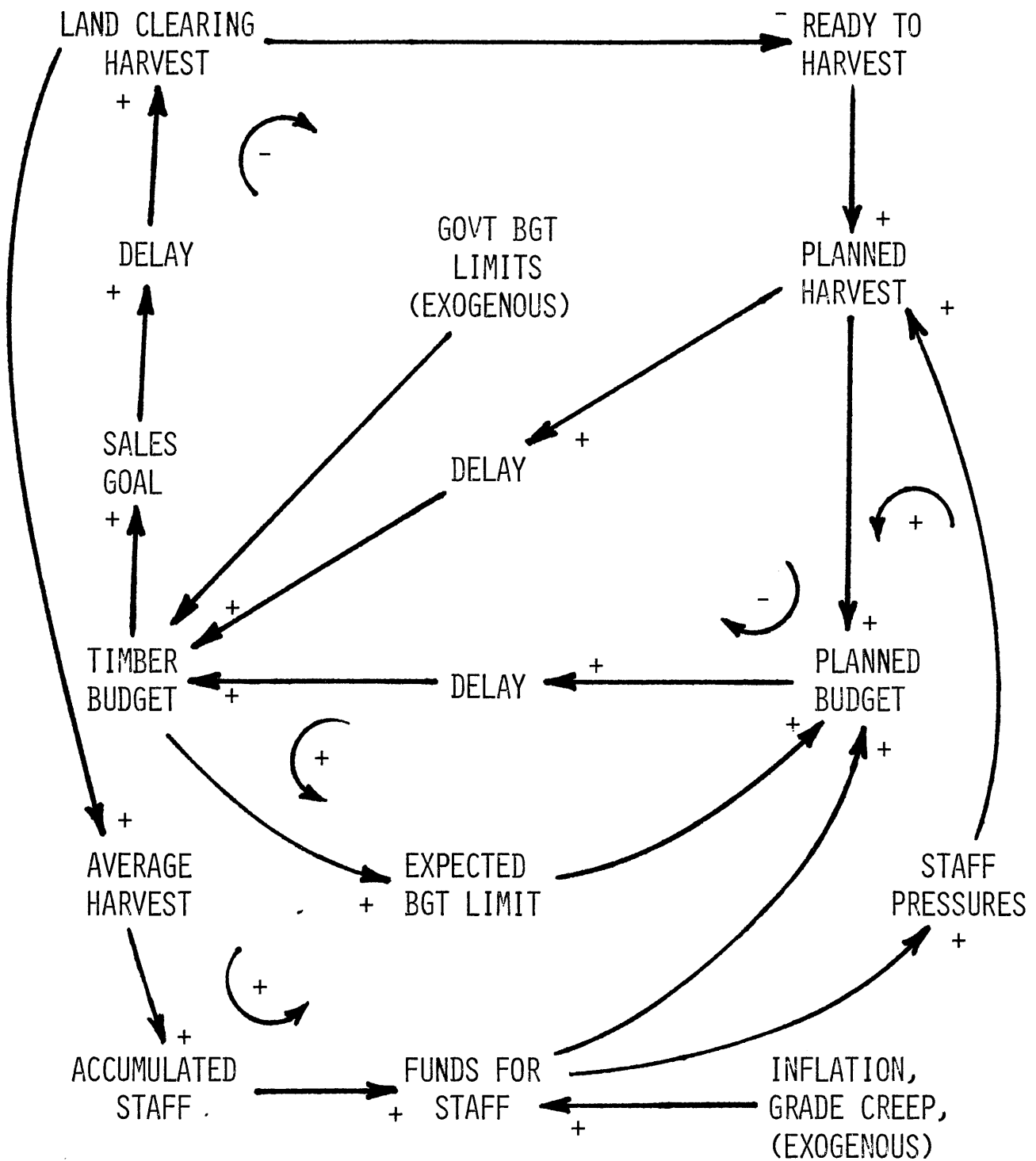


FIGURE 4. TIMBER HARVEST LOOPS FROM STAFF, FINANCIAL AND INFLATION PRESSURES.

The third interaction occurs in regeneration. Once the land is harvested it must be regenerated either naturally or artificially. The regeneration decision (Fig. 5) could be affected by considerations for timber, wildlife and recreation. In the model regeneration is further complicated by the three types of forest that are included. These are softwood natural stand, softwood plantation with improved trees and hardwood. Regeneration is based on acreage ready for regeneration and three primary proportions--the fraction of old softwood land to be regenerated as softwood plantation area; the fraction of old hardwood land to be regenerated as softwood plantation land; and the fraction of softwood land to be regenerated as hardwood land.

In recent years the trend has been toward softwood land because softwoods grow faster and there is greater demand for softwood timber. However, natural forest biology is biased toward hardwood forest, the successional climax condition. There is then a natural tendency for softwood land to become hardwood bearing, so it requires money and effort to keep the latter fraction small. The natural stand vs. plantation fraction balances long run greater plantation yield with short run greater plantation cost. The desired softwood vs hardwood proportion is dependent on expected timber demand for the two types, wildlife considerations (hardwoods are needed for most species for mast and dens) and recreation needs hardwoods are more attractive areas especially in the fall. Water, soil and range considerations are omitted for simplicity. The plantation vs. natural stand regeneration influences are shown in Figure 6.

The natural stand, plantation and hardwood stands are each divided into five age classes: seedling, sapling, pole, small saw timber and large saw timber areas (Fig. 7). Cleared land, wilderness area, and land devoted to mineral development are also included as shown by these flows and accumulations.

The generation of budgets and performance goals for timber, wildlife and recreation is shown in Figure 8. Planned performance leads to planned budget needed to carry out the performance with constraints imposed if total planned budget is greater than the government's budget limit. The final budget sets the performance goal which determines the actual performance. Past performance then influences planned future performance. When the total budget for timber, recreation and wildlife exceeds the maximum budget set by Congress, all three budgets must be reduced. The model reduces them proportionately, but priority weighting could be used.

Model Uses in Forest Management Planning and Decision Making

System Dynamics models are designed to serve the purposes for which they are constructed. The factors to be included, the level of aggregation, the types of evaluation variables, and the use of random variables (noise), exogenous variables, and data or analytic driving forces are all dictated by model purpose. There even may be several different models that are needed to answer different questions or generate different kinds of information. A model's validity can only be evaluated in the context of its purposes. Therefore, it is important to know the kinds of things SD models can do.

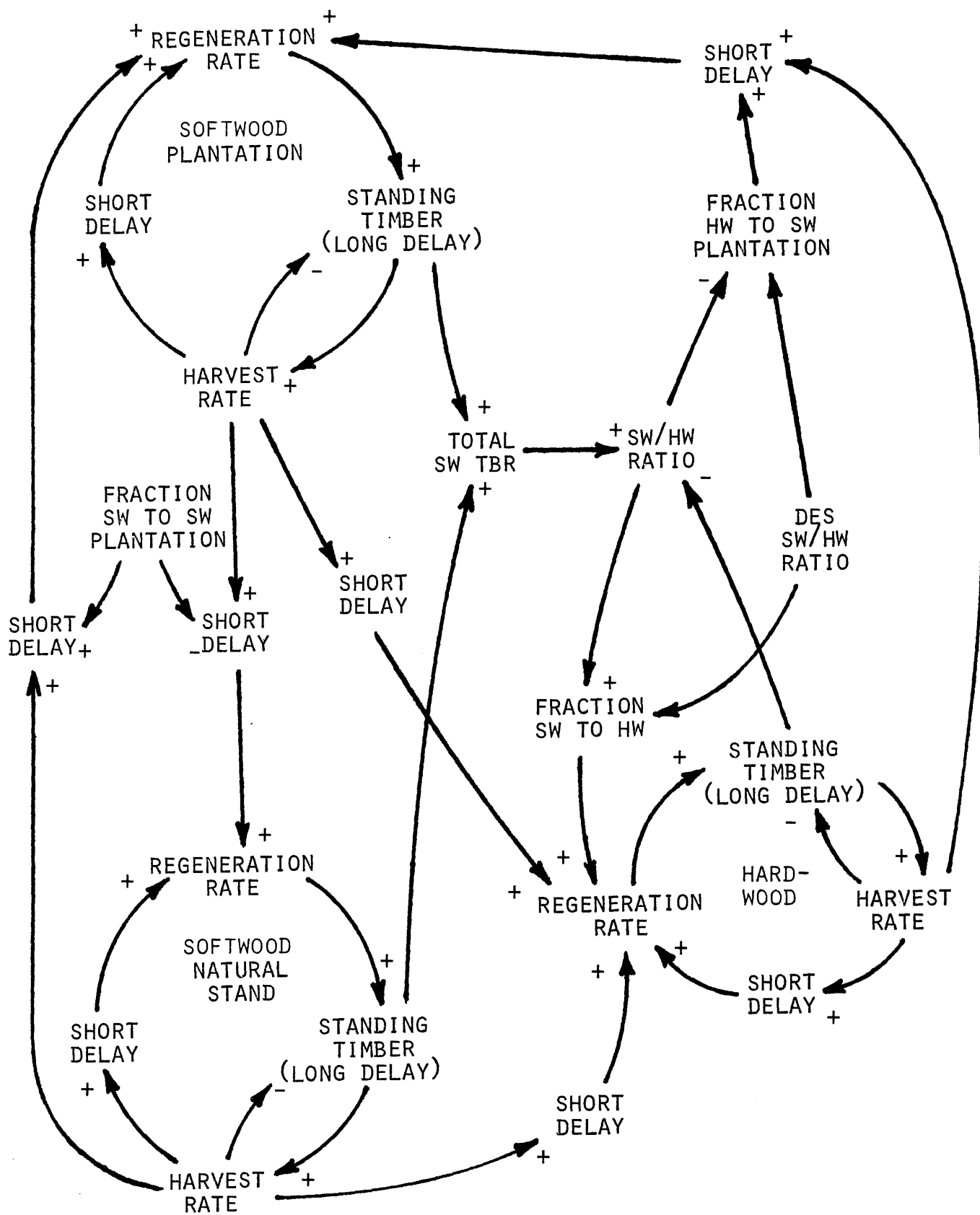


FIGURE 5. INTERACTIVE SUCCESSION CYCLE FOR HARDWOOD, SOFTWOOD PLANTATION AND NATURAL STAND FOREST TYPES.

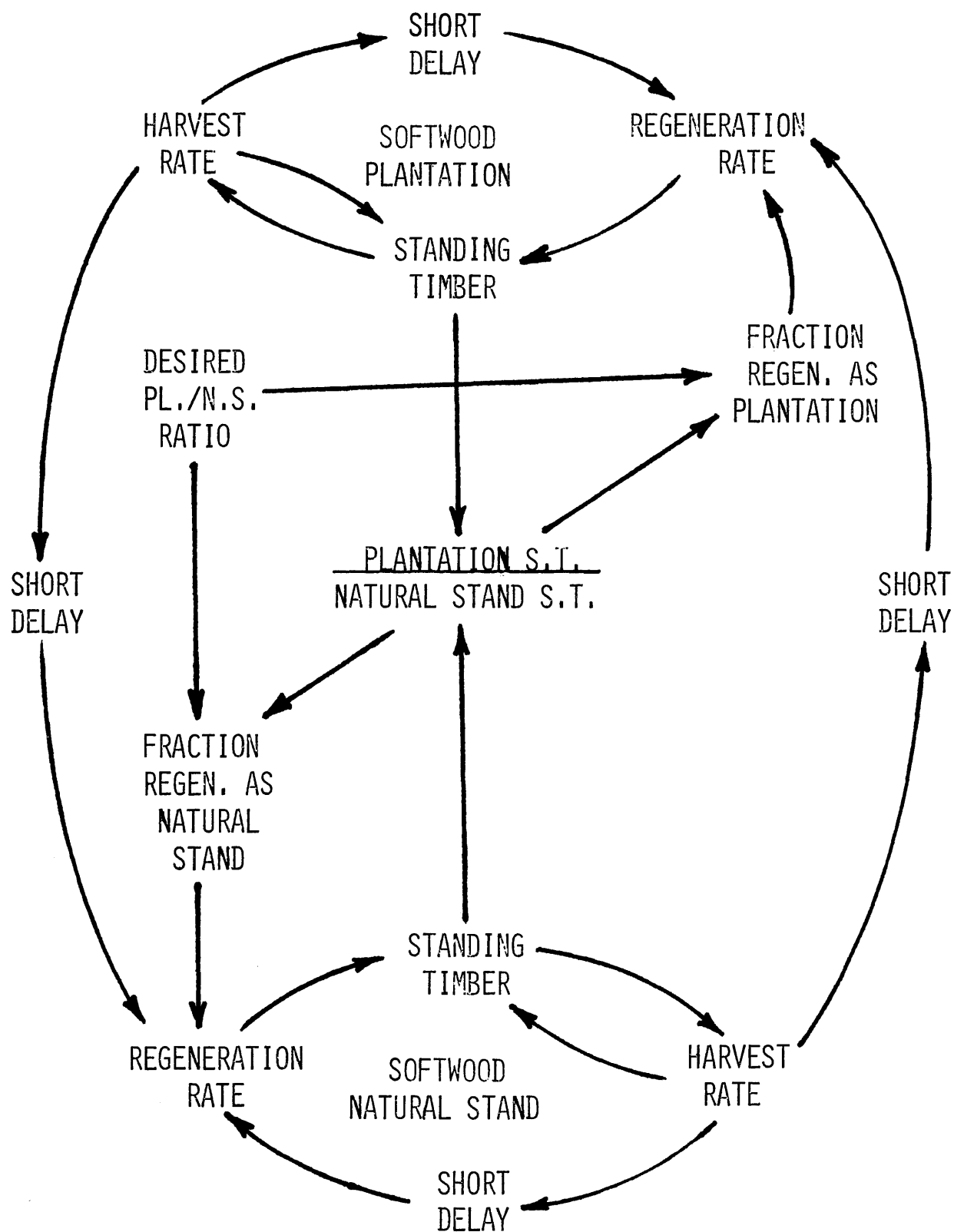


FIGURE 6. TRANSITION CONTROLS FOR A SOFTWOOD NATURAL STAND VS. PLANTATION BALANCE.

SOFTWOOD ACRES

HARDWOOD ACRES

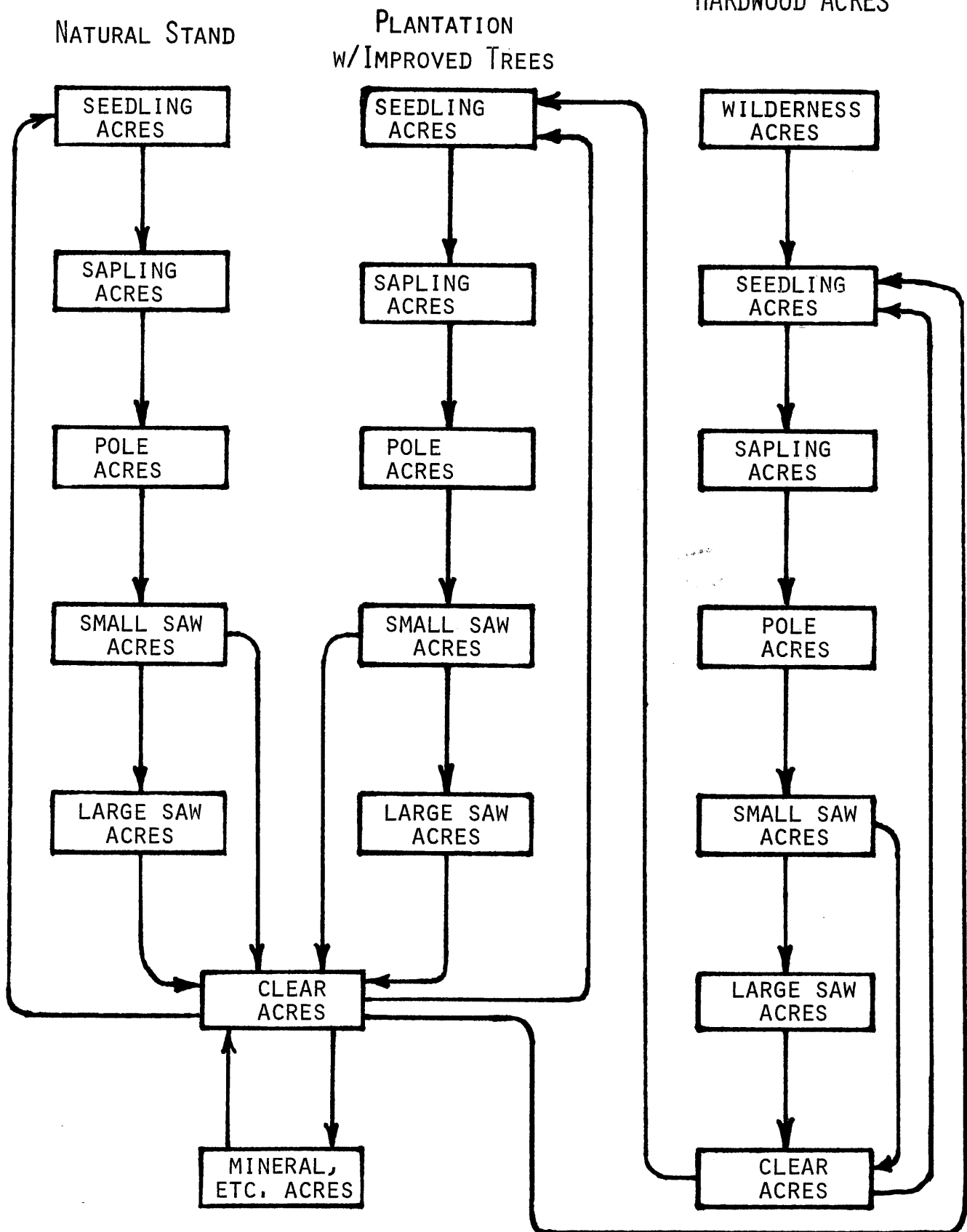


FIGURE 7. TIMBER LAND AGE CLASSES AND FLOWS FOR HARDWOOD, SOFTWOOD PLANTATION AND NATURAL STAND AREAS.

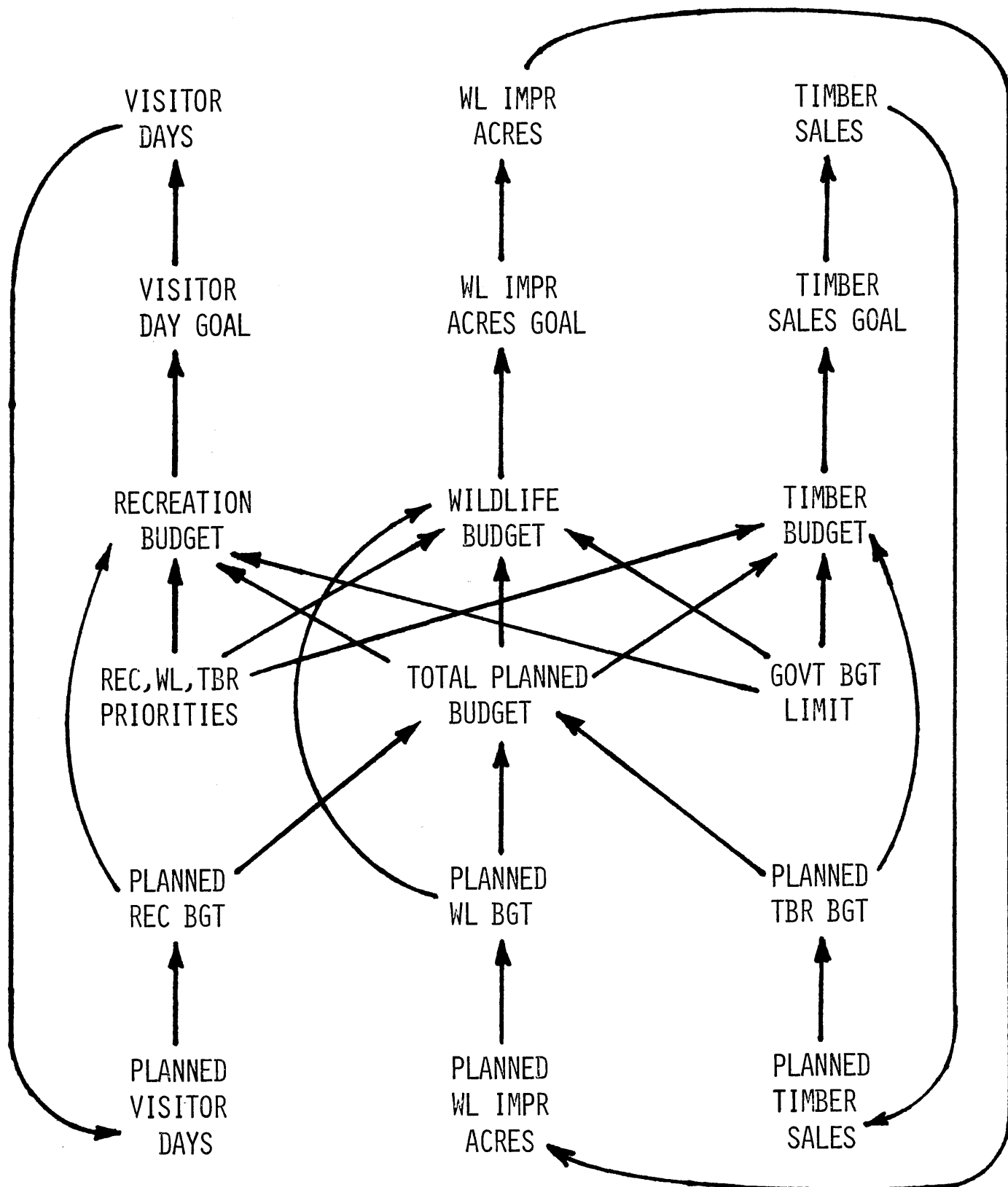


FIGURE 8. INTERACTIONS BETWEEN PLANS, GOALS AND OUTCOMES FOR BUDGETS AND ACTIVITIES IN RECREATION, WILDLIFE AND TIMBER MANAGEMENT

The timber sales decision with its supporting (or controlling) budget and demand constraint dominates the long run dynamic performance of the forest system. The regeneration decision which determines the proportions of the cleared land that are to be recycled with hardwood, natural softwood and improved softwood stands is an important secondary influence. Different policies for making these decisions can lead to very different patterns of availability of forest resources and of benefits realized.

The model is used to clarify the causes of the performance patterns, determine the importance of accurate data and test the dynamic consequences of different decision policies by calculating model performance annually over a long period of time. The model is still in development, so successful simulations are not yet available. However, an hypothetical model simulation is shown in Figure 9. Four variables (annual timber sales, wildlife improvement acres, recreation visitor days and total system budget) are included to illustrate the appearance of a simulated 200-year time plot. The patterns of the variables and the relationships between them for the decision policies used can be seen at a glance.

When the model is operating properly many simulations will be run each with one or more differences from all other runs in parameter values, exogenous variables' time histories or 1962 starting conditions. Differences in simulated performance patterns can then be attributed to the factor differences. Figure 10 shows an hypothetical plot of timber sales for three different decision policies--normal, regulated forest and severe budget constraint. A manager or planner could draw important conclusions about the desirability of following different policies by examining the results of a plot like the one in Figure 10. Several model uses are discussed in the following sections.

Loop Dominance Studies (Sensitivity)

SD models can be used to determine the relative contribution of different loops, policies, and/or parameters to the creation of important performance patterns. "Will Forest Service policies for permitted harvest volumes or budgets for forest maintenance and development have a greater influence on future standing timber and growth?" is a sensitivity question that a SD model could answer. The influence of estimated parameters, such as average stand maturation time and designated habitat area required per wild turkey, on costs and growth rates also can be determined.

Data Value Studies

Policy, loop, and parameter sensitivity studies relate directly to the importance of measuring various relationships accurately. If a $\pm 20\%$ change in a relationship has a small impact on model system performance, it is probably not necessary to spend a great deal to measure it to 5% accuracy. Most feedback systems are relatively insensitive even to fairly large changes (errors) in most parameters, but a few sensitive ones are usually present. It is extremely valuable to know which are critical and which are not, so data gathering resources can be concentrated on sensitive areas.

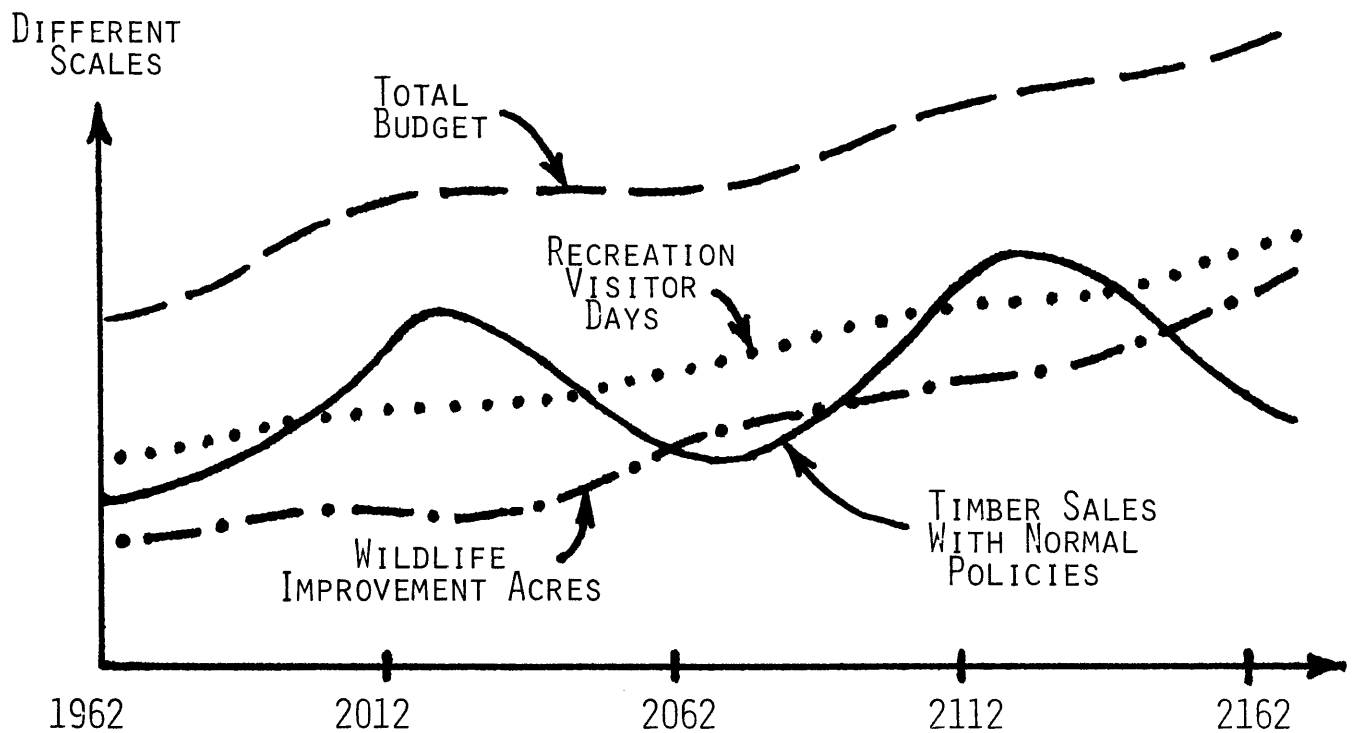


FIGURE 9. HYPOTHETICAL 200 YEAR MODEL SIMULATION SHOWING BUDGET, TIMBER SALES, WILDLIFE IMPR ACRES AND VISITOR DAYS.

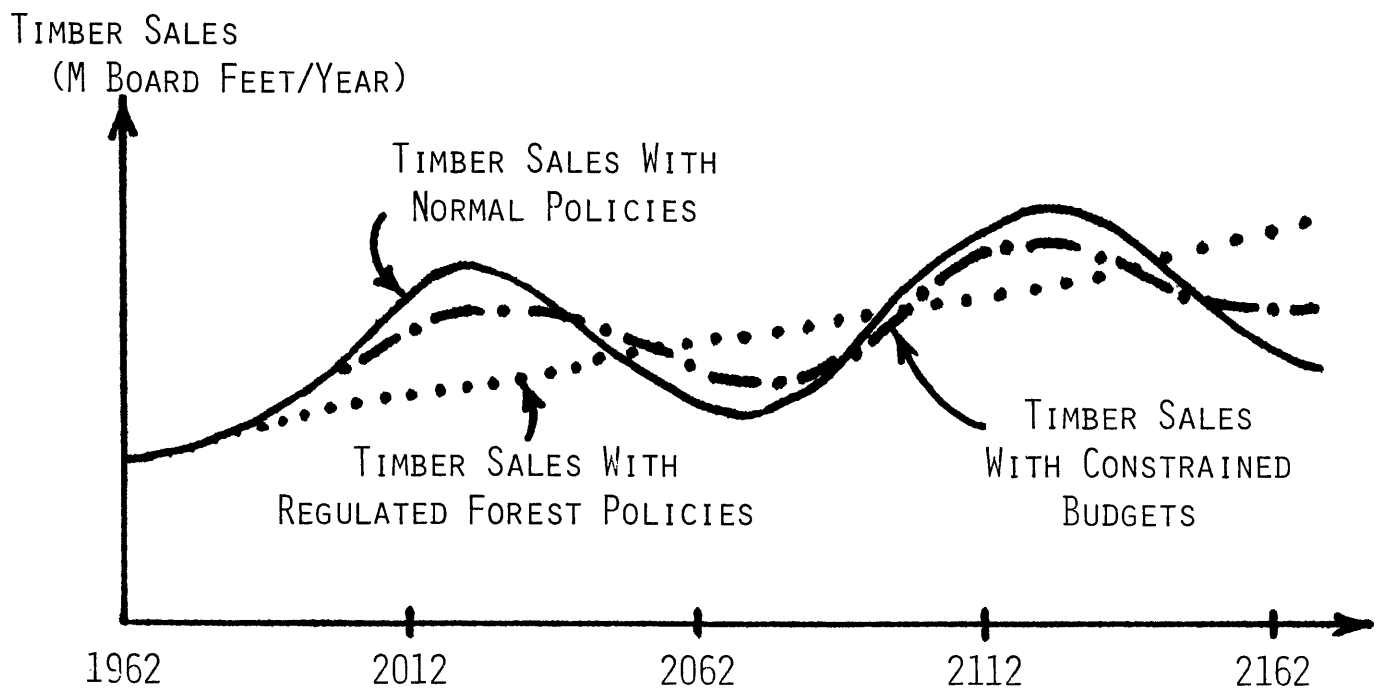


FIGURE 10. TIMBER SALES FROM THREE DIFFERENT HYPOTHETICAL SIMULATIONS SUPERIMPOSED FOR EASY COMPARISON.

Management Policy Laboratory

In most systems the management policies (the guidelines for how to make the required decisions) are not thoroughly understood. People have been using them for a while, perhaps many years, but they really do not understand their total impact on all aspects of system performance. The SD model can be used to test a policy's impact on any biological, organizational or financial variable in the model. The policy may be one currently in use, one proposed by the system managers or one arising from a creative synthesis by the SD analyst. Therefore, the model can be used as a management laboratory to answer "what would happen if ..." questions. This is an inexpensive way to identify ineffective or detrimental policies before they are tried in the real system where mistakes can be very expensive.

Forecasting of Future Performance Patterns

SD models can be used to forecast future time patterns. This is done in a simulation that starts the model accumulations at values corresponding to a real historical time, simulates the period of history up to the present and then continues the simulation into the (model) future. The patterns (trends and oscillations) created by the model are forecasts of the real system patterns. Future events usually can not be accurately forecast in this way. An event is the value of a variable at a point in time. Therefore, a SD model could predict a growth trend in standing timber or an oscillation in budget, but the specific amount of standing timber at a particular time could not be forecast as reliably as the pattern.

Budget Request Justification

In a system with long response delays, such as a forest, a current decision can influence performance for many years. A SD model that considers biological, organizational and financial variables in the long run can be used to demonstrate the total long run impact of policies, particularly in budget areas. This could be of significant value for private timber companies or government agencies such as the Forest Service when considering budget formulation and when submitting budget requests for approval by boards of directors or Congress.

Training

A SD model is a mathematical representation of a real system that has the same variables as the real system and operates the same way as does the real system. The model, unlike the real system, is accessible and manipulatable. Therefore, the model can be used to acquaint or train Forest Service staff, state forest managers, private forest owners, timber company managers, legislators, financial institution managers, environmentalists or the interested public. In particular, by changing model policies and parameters and observing the effects of these changes on behavior, people can be helped to better understand the dynamic forces at work in the real-world system. A SD model of a forest can be a useful tool in public involvement as required by the NFMA and in conflict resolution since the resulting simulation is one of the most effective means available for supplementing and correcting human intuition.

Planning

Frequently, the people in an organization who first develop and use SD models are planners. Anyone who must estimate the long and short run consequences of many interrelated decision alternatives in a complex, imperfectly understood response environment and then must apply multiple, time dependent, politically sensitive evaluation criteria to the estimates has a very difficult task. The realism of System Dynamics models and their easy use through the DYNAMO computer language can provide considerable help to forest system planners who face this type of situation daily.

Conclusion

Forest management systems including Region 8 are composed of many biological, human and financial accumulations and relationships that are organized into feedback loops that control the operation of the system parts and determine the performance patterns through time of the system variables. The system dynamics method has been developed to assist the understanding, modeling, planning, control, and improvement of systems of this kind. system dynamics focuses more than other analysis methods on the whole system, information feedback control process that creates in a realistic way the dynamic performance patterns far into the future. Therefore, it seems appropriate to suggest system dynamics' use as a tool to understand and improve forest management systems.

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SEARCHING THE RESPONSE SURFACE OF STAND SIMULATORS
UNDER DIFFERENT OBJECTIVES AND CONSTRAINTS.....
DFSIM AS A CASE STUDY

by

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ABSTRACT

Dynamic programming is discussed as a technique for efficiently searching the response surface of timber growth and yield simulators given an objective and constraints. An application to DFSIM, stand simulator for coastal Douglas fir, is presented under the objective of maximum volume and under the objective of maximum financial return.

Different combinations of thinnings and regeneration harvest form an important component in many of the prescriptions considered for national forest land in forest planning. Two timber management regimes of special interest are 1) the combination of thinnings and regeneration harvest that maximize stand growth, and 2) the combination of thinnings and regeneration harvest that maximize stand discounted value. Until recently, these regimes have been estimated by running stand simulators a number of times in hopes of locating the maximum. Now, however, a technique called "dynamic programming" has proven effective in searching over the response surface of stand simulators to find the maximum growth or maximum present net worth regime (Brodie and Kao, 1979, and Riitters, et al. 1982).

The intent of this paper is to acquaint the reader with dynamic programming, specifically as it is used in conjunction with the growth simulator DFSIM. Two examples, maximum volume and maximum financial return, will be presented using the dynamic programming - DFSIM (DP/DFSIM) model.

SYSTEMATICALLY SEARCHING STAND SIMULATORS

How Stand Simulators Function

Stand simulators generally grow the stand to a user-specified age or height, thin the stand back to the given specifications, grow the stand to the next user specified point, thin the stand again, and continue this process to the user specified rotation age. For example, if a stand has a beginning age of 20 years and is thinned at age 30, it will pass through nodes A, B, E, and F reaching node I at age 50 (Figure 1). A node represents the condition of the stand at a specific point in time. For this example, a node is defined in terms of residual volume in cu. ft. at a

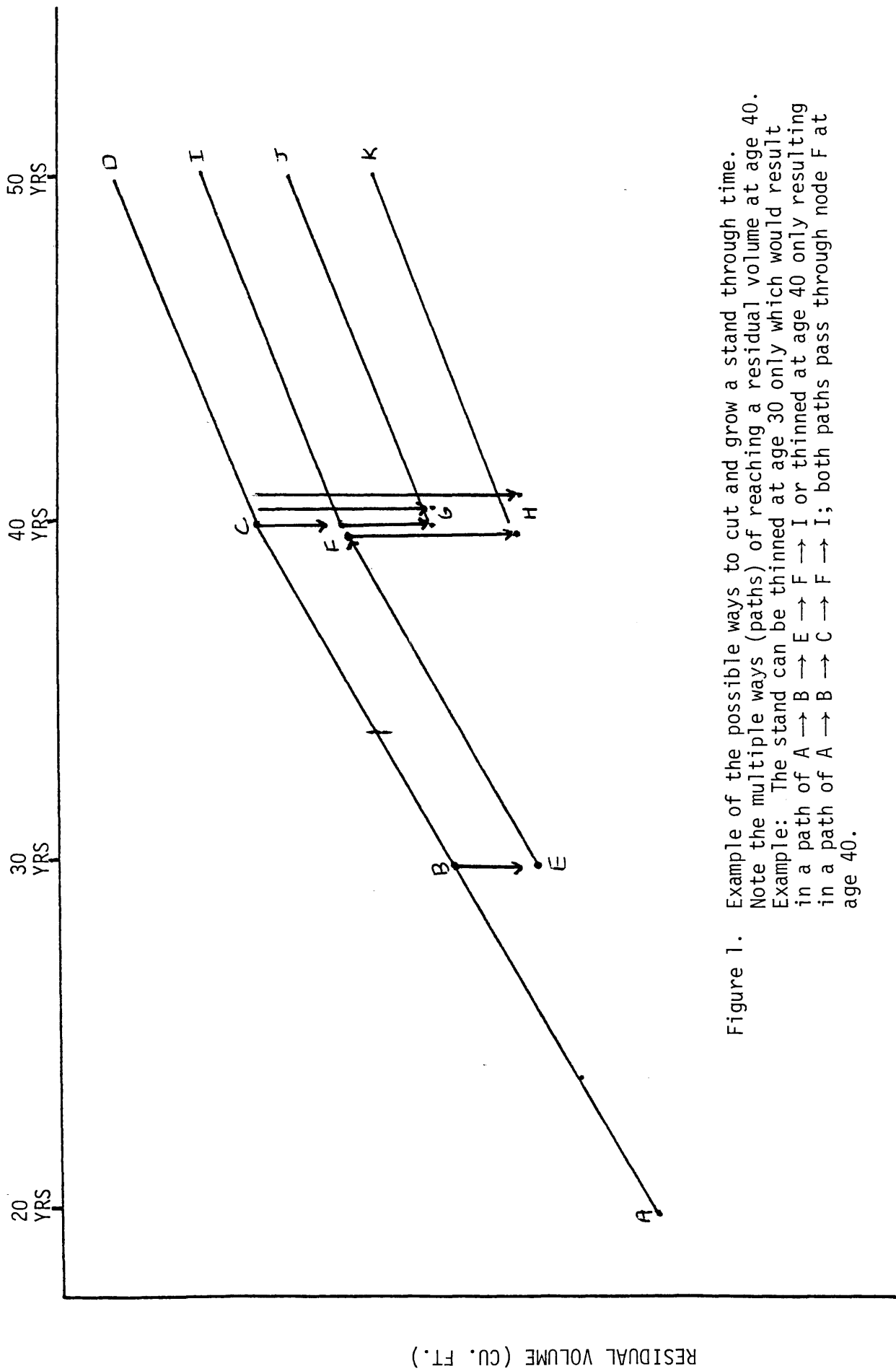


Figure 1. Example of the possible ways to cut and grow a stand through time. Note the multiple ways (paths) of reaching a residual volume at age 40. Example: The stand can be thinned at age 30 only which would result in a path of $A \rightarrow B \rightarrow E \rightarrow F \rightarrow I$ or thinned at age 40 only resulting in a path of $A \rightarrow B \rightarrow C \rightarrow F \rightarrow I$; both paths pass through node F at age 40.

specified age. A path consists of the collection of nodes a stand passes through, and the actions, such as intermediate harvests, taken to reach a node. Thus, nodes A, B, E, F, and I represent one path for the stand from age 20 to age 50. Another path for the same stand to take, if it is allowed to grow without any intermediate harvests, would be to pass through nodes A, B, and C reaching D at age 50.

There is, however, more than one way for the stand to be in node F at age 40. An intermediate harvest can be taken at age 40 instead of age 30, with the stand passing through nodes A, B, C, F, and I. Similarly, there is more than one path for the stand to take in reaching nodes G and H.

Stand growth and yield simulators track one path for a stand as it cuts and grows the stand over time to the final rotation age. Generally, these simulators are rerun for each alternative path of interest.

Examining Choices of a Simulator for Maximization

As discussed above, there are many possible paths that a stand can take between the beginning of a stand simulation and the final rotation age. The next example examines some of these paths, where the objective is to maximize volume produced over the rotation (Figure 2). The stand simulator is used to obtain the "rewards" shown in the figure for each action taken. A reward is the volume harvested at each age which ranges from 0 cu. ft. for a no-cut choice to 3604 cu. ft. for a final harvest.

When the stand is grown from age 30 to a final rotation age of 60 years without intermediate harvests, it reaches a volume of 3604 at age 60 (Figure 2a). The sum of the volume rewards will be 0 cu. ft. at age 40, 0 cu. ft. at age 50, 3604 cu. ft. at age 60 for a total of 3604 cu. ft. In one of the thinning options, the stand is also grown from node A to node B at age 40, but is cut back (thinned) to the residual growing stock level represented by node C (Figure 2b). The amount of volume removed in this thinning, i.e., the reward, is 871 cu. ft. Taking another intermediate harvest at age 50 with a final harvest at age 60, the sum of the rewards for the thinned path would be 871 cu. ft. at age 40, 559 cu. ft. at age 50, and 2667 cu. ft. at age 60 for a total of 4097 cu. ft.

Finally, all permitted paths through the network with the associated cu. ft. volume rewards can be identified (Figure 2c). These permitted paths are functions of the constraints placed on the search and the biological relationships in the growth and yield simulator. The path that will

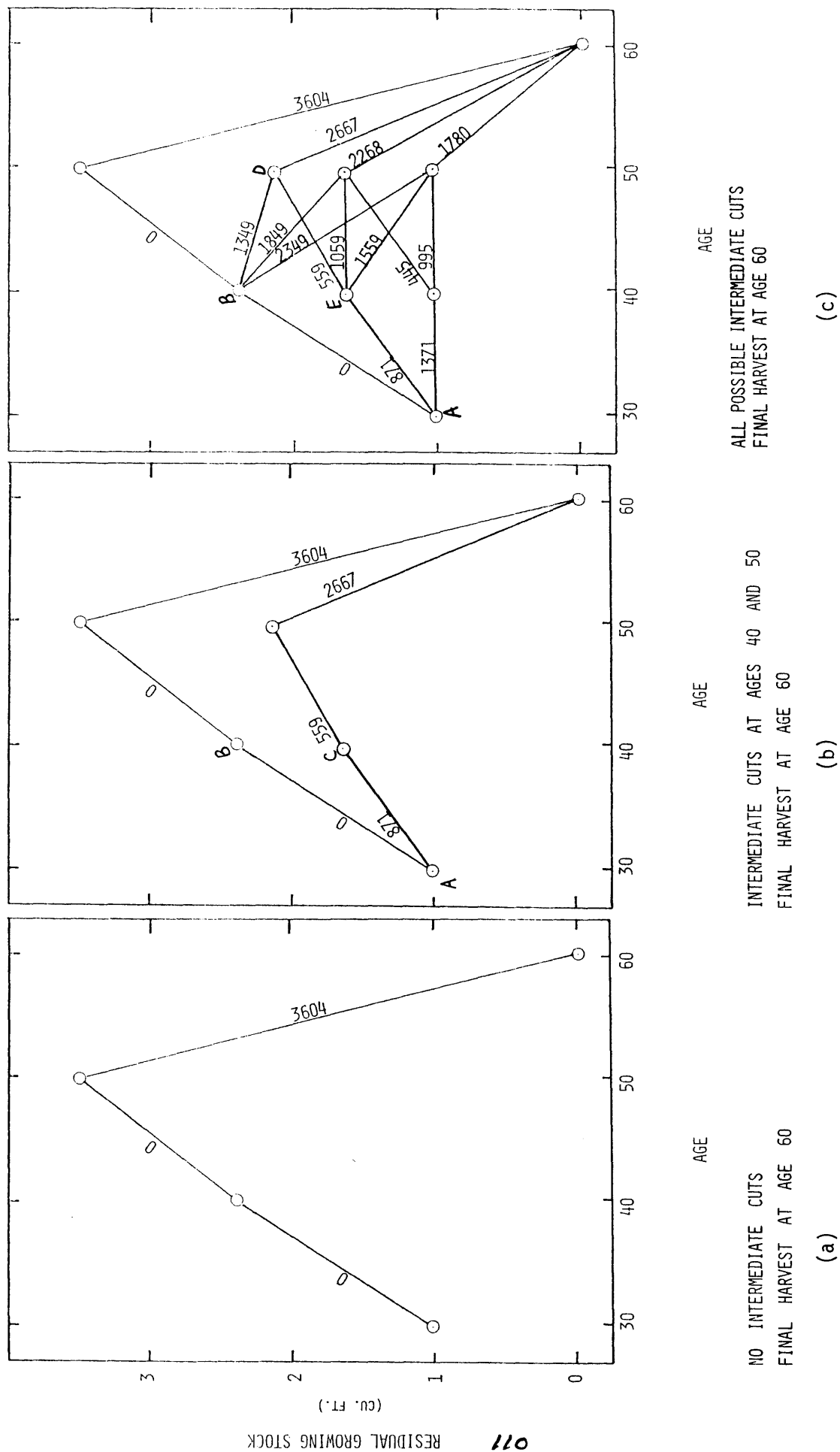


Figure 2. Intermediate harvest options ranging from a no-thin alternative (a), to intermediate cuts at ages 40 and 50 (b), to a wide variety of intermediate cuts (c). In (c) we assume that once the stand has been thinned it must continue to be thinned until the final harvest.

maximize the total volume reward in this example is 871 cu. ft. at age 40, 1059 cu. ft. at age 50, and 2268 cu. ft. at age 60, resulting in a total of 4198 cu. ft. This "best" path was found by looking over all the permitted paths to find the one that maximizes volume.

Using Dynamic Programming to Systematically Search the Response Surface

Dynamic programming is a technique for finding the best path without calculating the cumulative reward associated with each path. It will store the best path to any node, with "best" being defined as the path that results in the highest reward to that node.¹ For example, the best path to node D goes from A to E for a reward of 871 and from E to D for a reward of 559 giving a cumulative reward of 1430 cu. ft. from A to D (Figure 2c). The alternative path from A to D (A, B, D) gives a reward of 1349. Therefore, it is "best" to go through E to get to D. Node D may not be on the final "best" path for a rotation age of 60 years, but the best path to D and to all other nodes is stored. The path through the network for any rotation age that maximizes volume or value is not determined until the entire network is examined.

To correctly represent the stand at each node in the network, variables must be stored that describe stand conditions at that node such that growth and yield can be predicted. The values of these variables at each node in each 10 year time period must convey all information about the stand's previous behavior necessary for portraying the growth of the stand to the next time period and determining the reward.

In the previous two examples (Figures 1 and 2), the nodes and paths representing the possible cut and growth options were located on a network or grid dimensioned by stand age and residual growing stock levels. In theory, the grid should have a dimension of X^n , where n is the number of variables necessary to describe the stand. These variables should be able to portray stand growth and yield over time to estimate the reward associated with any action. The best path through the multidimensional grid that will maximize the desired reward can then be found.

Leaving one of these variables out of the grid may result in a sub-optimal solution. For example, if the d/D ratio is a variable, a d/D ratio greater than 1.0 may result in a higher amount of volume cut (reward)

¹Using forward recursive dynamic programming. See Schreuder (1971) for discussion of forward vs. backward dynamic programming. For a further discussion of forward dynamic programming, see Johnson (1981).

in the short-term than a d/D ratio of 1.0. Comparing two paths to an intermediate node, such as paths A to B to D and A to E to D, that have different d/D ratios may result in the one with the higher d/D ratio judged "best" and have its path stored as the way to get to the node. If stand top height is a function of the d/D ratio, a d/D ratio greater than 1.0 may reduce stand top height over the length of the rotation and lead to smaller rewards toward the end of the rotation. The net effect could be a suboptimal solution, since the long-term effect (on reward) of the d/D ratio is inversely correlated with the amount of short-term reward. If the d/D ratio is a variable, it should be specified as a dimension in the grid to ensure that harvests involving different d/D ratios do not compete for the "best" path to a node. By adding a dimension to the grid that represents different d/D ratios, the effect of choosing different d/D ratios can be traced and the path selected that gives the highest reward.

The difficulty in solving dynamic programs, however, goes up with the number of nodes that must be examined. Therefore, each proposed dimension to the network must be carefully justified. Compromises are often needed, in terms of recognizing the less important variables as network dimensions, to keep the problem computationally feasible.

APPLICATION TO DFSIM

The DFSIM Model

DFSIM (Douglas fir simulator) is a managed stand simulation program for coast Douglas fir (Pseudotsuga menziesii (mirb.) Franco var. menziesii). It was developed by Robert Curtis, Gary Clendenen, and Donald Demars (Curtis et al., 1981). As discussed in the user's guide:

It can produce yield tables for managed stands which include estimates of the effects of initial spacing, precommercial and commercial thinning, and nitrogen fertilizer. Given site index and a set of stand treatment specifications, DFSIM will generate yield tables depicting probable development of the stand over time. The procedure for projecting stand development operates in two stages: 1) juvenile stand (quadratic mean diameter less than 5.55 inches d.b.h.), and 2) main stand development (quadratic mean diameter greater than 5.55 inches d.b.h.). . . . DFSIM is a "stand average" model derived from small research plots. It represents the development of relatively homogeneous even-aged stands of one principal species. It is primarily a means of summarizing results of numerous small thinning and fertilization trials. It can, however, be used to estimate probable future development of existing stands, provided these are within the range of the data used and some judgment is used in application (Curtis et al., 1981).

Controlling Variables

In attaching the dynamic program to the DFSIM model, we first determined the variables needed to project the growth and yield of a stand through time for a given site (Figure 3). The growth of the stand from one time period to the next, volume cut, and residual volume are all functions of this set of variables.

The first four variables (breast height stand age, number of trees per acre, basal area per acre, and stand top height) describe current stand characteristics at any point in time. The next five variables (stand top height after most recent thinning, basal area per acre in the most recent thinning, basal area per acre before the most recent thinning, past quadratic mean diameter of mortality, and past basal area mortality) describe past stand characteristics. The final four variables (indicator switches for commercial thinning in dense stands, that at least one commercial thinning has been done, net basal area increment function and net cubic foot volume (total stem) increment function) accumulate present and past stand characteristics.

Defining the Dynamic Programming Grid for DFSIM

In our previous example (Figure 2), we examined growth and harvest as a function of residual cubic foot volume and age. In linking a dynamic program to DFSIM, we portray growth and harvest as a function of three variables in a manner similar to Brodie (1979): 1) age, 2) basal area, and 3) number of trees per acre. The other variables are carried along to describe the stand conditions, both past and present, at any node. In searching the possible combinations of basal area and number of trees at each age, the stand can be thinned by number-of-tree intervals, each resulting in a different basal area stocking. The resulting residual stand conditions define the nodes at each age and locate the paths through the network. Each node is then grown to the next age and thinned by the number of tree intervals, including a final harvest option. This is done for all nodes at a given age and the best path is stored for reaching each combination of basal area and number of trees along with the value of the other variables shown in Figure 3. These nodes are then grown to the next age and the process is repeated.

1. Breast height stand age
2. Number of trees per acre
3. Basal area per acre
4. Stand top height
5. Stand top height after most recent thinning
6. Basal area per acre cut in most recent thinning
7. Basal area per acre before most recent thinning
8. Past quadratic mean diameter of mortality
9. Past basal area mortality
10. Indicator switch for commercial thinning in dense stands
11. Indicator switch that at least one commercial thinning has been done
12. Indicator switch for net basal area increment function
13. Indicator switch for net cubic foot volume (total stem) increment function

Figure 3. Variables used in DP/DFSIM to project the growth of a stand through time for a given site, stand origin, d/D ratio, number of trees after precommercial thinning, and amount of fertilizer applied.

As discussed above, it may be possible that the objective function value could be increased by optimizing over the other variables mentioned in Figure 3 besides stand age, number of trees per acre, and basal area.

Stand top height and stand top height after the most recent thinning (variables 4 and 5, Figure 3) are both functions of stand age, site index, d/D ratio, and amount of fertilizer applied. Since their controlling variables are either fixed for each run or are currently a dimension to the grid, they need not be separately represented as dimensions to the grid.

Basal area per acre cut in the most recent thinning and basal area per acre before the most recent thinning (variables 6 and 7, Figure 3) are used as a ratio (BAC/BAB) to dampen the growth increase due to thinning when the thinning is less than 15 percent of the stand. Since the heavier the thinning, the lower the dampening effect will be and the greater the growth will be, short-term reward and long-term reward will be positively correlated if reward is a positive function of total volume.

Variables 10 through 13 (Figure 3) are four indication switches that are functions of 1) relative density and 2) the thinning/no thinning decision. Substituting relative density for basal area in the grid, to reduce the paths with different relative densities competing for "best" path to a node, and ensuring that thinning and no thinning paths exist to each age may be the best way to recognize the effects of these switches.

Variables 8 and 9 (Figure 3) are past basal area of mortality and past quadratic mean diameter of mortality. They set minimum future values for these variables. We do not know how including them as dimensions in the grid would affect the program solution.

In the discussion that follows, it should be remembered that the "best" path is being specified for a network defined by age, number of trees, and basal area. The other variables needed to describe the stand are being recorded at each node but they are not formally being searched over. We are currently investigating the usefulness of changing the network to represent more of these variables.

Constraining the Search

The search of the response surface of a stand simulator can be constrained to reflect biological and policy considerations. Constraints keep the search within the limits the stand simulator can validly predict and reflect policy considerations such as the maximum proportionate reduction in basal area at any thinning that meets visual quality standards.

The dynamic programming - DFSIM model (DP/DFSIM) allows the user to specify many types of constraints on the search for the regime that will maximize volume cut or financial return (Figure 4). These constraints include minimum basal area and diameter before the first thinning, thinning ages to consider, minimum volume to cut in any thinning, maximum proportionate reduction in basal area in any thinning, and minimum residual density for any thinning.

EXAMPLE OF DYNAMIC PROGRAMMING APPLIED TO DFSIM

Data and Constraints

We used the DP/DFSIM model to maximize both stand volume and stand soil expectation value in separate analyses. Starting with a stand planted to 300 trees per acre on a site index of 140 (50 years b.h.), we placed the same constraints on the search in both cases (Figure 5). These constraints included a minimum of 100 sq. ft. of basal area and 8 inches d.b.h. before the first thinning, a minimum of 500 cu. ft. removed in any thinning, a minimum residual density for any thinning, and a 40 percent maximum proportionate reduction in basal area for any thinning. Thinning ages considered were 35, 45, 65 and 85 years, and rotation ages considered ranged from 45 to 115 years by increments of 10 years.

The economic information used to calculate financial returns under both objectives (Figure 5) included a 5 percent interest rate, \$197 per acre for planting and site preparation, and \$35 per thousand cu. ft. of volume harvested for timber sale preparation. The stumpage price was indexed by six diameter classes and ranged from \$350 to \$800 per thousand cu. ft. harvested.

Results

Comparing the management regimes for rotation ages of 75 and 55 years under the maximum volume objective (Figure 6) reveals that both regimes take early light thinnings. The regime for rotation age 75 has two thinnings, a light one at age 35 and one at age 65. The regime for rotation age 55 has only one light thinning at age 35. Both regimes leave residual basal areas after each thinning above the 120 or 140 sq. ft. of basal area specified as the minimum residual density.

Minimum basal area before the first thinning
e.g., 100 sq. ft.

Minimum diameter before first thinning
e.g., 8 inches (DBH)

Thinning ages to consider
e.g., 35, 45, 65 and 85 years

Minimum volume to cut in any thinning
e.g., 500 cu. ft.

Maximum proportionate reduction in basal area at any thinning
e.g., 40%

Minimum residual density for any thinning
e.g., 120, 140, 140, 140 sq. ft. of basal area
or relative density ($ba/\sqrt{diam}$) of 30, 40, 40, 40

Minimum time between last thinning and final harvest
e.g., 10 years

Rotation ages to consider
e.g., 45, 55, 65 . . . 115

Figure 4. User constraints on the search for the optimal management regime for volume or financial return maximization. Includes examples for each constraint. These constraints are available in the DP/DFSIM model.

Site index 140 (50 years BH)
 Stand origin planted to 300 trees per acre
 Minimum basal area before first thinning 100 sq. ft.
 Minimum diameter before first thinning 8 inches (DBH)
 Thinning ages considered 35, 45, 65, 85 years
 Minimum volume to cut in any thinning 500 cu. ft.
 Maximum proportionate reduction in basal area in any thinning 40%
 Minimum residual density for any thinning
 120 - 140 - 140 - 140 sq. ft. of basal area
 Rotation ages to consider 45, 55, 65 . . . 115 years

Economic Information

Interest rate 5%
 Planting and site prep. \$197 per acre
 Timber sale prep. \$35 per thousand cu. ft. harvested

Stumpage Price by Diameter Class

<u>Diameter</u>	<u>\$/m cu. ft.</u>
4.5 - 9.0	350
9.0 - 12.0	420
12.0 - 14.0	540
14.0 - 16.0	660
16.0 - 18.0	730
18.0 - 40.0	800

Figure 5. Data and constraints for an example use of DP/DFSIM. This information was used in example analyses to maximize stand volume and to maximize stand present net worth.

MANAGEMENT REGIMES FOR DIFFERENT ROTATIONS AND OBJECTIVES

Maximize Volume

Rotation Age 75

Stand Age (Years)	Diameter (Inches)	Residual Merch. Trees	Residual Basal Area (sq. ft.)	Residual Volume (cu. ft.)	Volume Cut (cu. ft.)	Mean Annual Increment (cu. ft.)	Present Net Worth (\$/Acre)
35	11.3	223	156	5561	647	177	-152
45	13.8	202	211	9280	0	221	-152
55	15.8	184	251	12749	0	244	-152
65	17.7	151	258	14500	1312	253	-114
75	19.5	0	0	0	17418	258	229

Rotation Age 55

35	11.3	223	156	5561	647	177	-152
45	13.8	202	211	9280	0	221	-152
55	15.8	0	0	0	12749	244	392

Maximize Present Net Worth

Rotation Age 75

35	11.3	178	125	4423	1785	177	- 72
45	13.9	139	147	6414	1406	213	7
55	16.2	132	190	9606	0	233	7
65	18.2	78	141	7852	4637	241	155
75	20.5	0	0	0	10408	243	360

Rotation Age 55

35	11.3	208	146	5181	1027	177	-125
45	13.9	145	154	6726	2117	219	- 6
55	16.2	0	0	0	9973	238	467

Figure 6. A comparison of management regimes for different rotation lengths under the objectives of maximizing stand volume and stand present net worth.

Management regimes for rotation age 75 and 55 under the financial objective (Figure 6) suggest early heavy thinnings at stand ages of 35, 45, and 65 years. The residual basal areas after each thinning approach the limits of 120 and 140 sq. ft. specified as constraints. The financial solution may involve even heavier intermediate harvests early in the rotation if allowed.

Comparing the management regimes for a rotation age of 75 years under both objectives (Figure 6) shows that mean annual increment is 6 percent higher under the maximum volume objective and that stand present net worth, the discounted monetary return from one rotation, is 36 percent higher under the maximum PNW objectives. In all management regimes under the financial option, the residual basal area came as close as possible to the specified limits, suggesting heavier thinnings may have been chosen if allowed.

The final stand conditions for different rotations under each objective (Figure 7) contain stand information for each rotation age between age 45 and 115 at ten year increments, including the present net worth and soil expectation values. Soil expectation value (SE), the discounted monetary return from a series of rotations, is used to compare financial returns from different rotation lengths.²

Under the maximum volume objective, MAI reached a maximum of 258 cu. ft. at ages 75 and 85 and declines to 247 cu. ft. at 115 years. For the financial objective, MAI reaches a maximum of 244 cu. ft. at a rotation age of 85 years, declines to 238 cu. ft. at 115 years. MAI ranges from 1 percent to 6 percent lower under the financial objectives as compared to volume objective, with culmination of MAI being 6 percent lower. Final harvest volumes for the financial objective range from 5 percent to 40 percent lower than the volume objective due to heavier thinnings.

Soil expectation value (SEV) reaches a maximum at rotation age 55 under both objectives. With the maximum volume objective, SE is \$421 per acre at rotation age 55, and declines to \$22 per acre at rotation age 115.

²Present net worth was maximized for each rotation and soil expectation value was then computed to compare the financial returns from different rotation lengths. The SE values were computed directly from the PNW values by the following formula: $SE = PNW * (1 + R)^T / (1 + R)^T - 1$ where R is the interest rate, T is the rotation length. SE was computed directly from PNW so that only one reward (PNW) had to be calculated at each node.

FINAL STAND CONDITIONS FOR DIFFERENT ROTATIONS

Rotation Age	Maximize Present Net Worth					Soil Expectation Value (\$/Acre)
	Final Harvest Volume (cu.ft.)	Diameter (Inches)	Harvest Basal Area (sq.ft.)	Mean Annual Increment (cu.ft.)	Present Net Worth (\$/Acre)	
45	8843	13.9	201	219	372	418
55	9973	16.2	197	238	467	501
65	12244	18.3	219	242	413	431
75	10408	20.5	174	243	360	370
85	12879	22.4	204	244	311	316
95	12614	24.5	192	243	281	284
105	14854	26.5	220	241	255	256
115	16954	28.3	246	238	235	235
	Maximize Volume					
	Final Harvest Volume (cu.ft.)	Diameter (Inches)	Harvest Basal Area (sq.ft.)	Mean Annual Increment (cu.ft.)	Present Net Worth (\$/Acre)	
45	9280	13.8	211	221	370	416
55	12749	15.8	251	244	392	421
65	15183	17.7	270	254	330	345
75	17418	19.5	287	258	229	235
85	19982	21.1	311	258	128	130
95	18492	22.9	277	256	96	97
105	20642	24.5	300	252	52	53
115	22609	26.0	320	247	22	22

Figure 7. Comparison of final stand conditions for different rotations under the objectives of maximizing stand volume and stand present net worth.

For the financial objective, SE is \$501 per acre at rotation age 55 and declines to \$235 at rotation age 115. SEV ranges from 1 percent to 91 percent higher under the financial objective as compared to the volume objective, with the larger differences occurring on the longer rotations.

CONCLUSION

Procedures such as dynamic programming can be used to systematically search the response surface of a stand simulator given an objective and set of constraints. The resultant management regimes will be much used in the future because they will save the user considerable time in searching for a regime tailored to his or her specifications. The requirement that the user provide the objective and constraint set that will govern the regimes will necessitate a more explicit statement of what kind of regimes the user seeks.

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APPENDIX A

Network and Paths for Maximum Volume Example

The network and nodes for the volume maximization example are contained in a set of two-dimensional charts (Figure 1A and 2A). The nodes are located on the graphs at intervals of 20 sq. ft. of basal area and 15 tree intervals for each age and represent residual stand conditions. This format was developed by Brodie (1979). Each node is represented by a set of seven stand characteristics including diameter, volume cut, residual volume, basal area, number of trees, stand value, and the node the stand came from in the previous age.

Each residual stand at each age is associated with a node that covers 20 square feet of basal area and 15 trees. As an example, a stand that has a residual basal area of 156.37 sq. ft. and 222.64 trees per acre in our example will be associated with the node located at 160 sq. ft. of basal area and 225 trees. This node covers the "neighborhood" of 150-170 sq. ft. of basal area and of 217.5-232 trees. All possible residual stands that fall within this neighborhood are compared in terms of cumulative reward to that age. The exact basal area and number of trees are stored for the residual stand with the highest cumulative reward. This approach of a neighborhood storage location combined with retention of the actual values for the "best" residual stand reduces the number of nodes while avoiding the rounding errors that can occur when discrete state descriptors are used with continuous growth simulators. See Brodie (1979) for more discussion.

The network for stand age 35 (Figure 1A) contains six possible states of the stand after all thinnings have been tried. These six states range from a clear-cut to a no-cut option. There is a large gap in the network between the node representing a clear-cut (node A) and the next node (node B). Any intermediate harvests that could have produced nodes in this area would violate the specified minimum of 120 sq. ft. of residual basal area. Also, a gap exists between the no-cut option (node D, Figure 1A) and the next thinning option (node C, Figure 1A). A lighter thinning would have violated the constraint specifying a minimum of 500 cu. ft. of volume removed.

The stand on the path to maximize volume for rotation age 55 at age 35 (node C, Figure 1A) removes 647 cu. ft. of volume. The residual basal area and number of trees are 156 sq. ft. and 222 trees, and the stand is located in the neighborhood of 160 sq. ft. of basal area and 225 trees per acre.

The network for stand age 45 (Figure 2A) contains ten possible states of the stand after all thinnings have been tried. These states or nodes range from a clear-cut to a no-cut option. The minimum residual basal area constraint of 140 sq. ft. and the minimum harvest volume of 500 cu. ft. limit the possible number of residual stands. The stand on the optimal path to maximize volume for rotation age 55 at age 45 (node A, Figure 2A) does not have an intermediate harvest. The residual basal area and number of trees are 211 sq. ft. and 202 trees per acre, and the stand is located in the neighborhood of 220 sq. ft. of basal area and 210 trees per acre. This stand came from the neighborhood of 160 sq. ft. of basal area and 225 trees per acre at age 35 (node C).

Only one stand is represented for a stand age and rotation age of 55 years (Figure 2A). This node is the clear-cut option where 12749 cu. ft. of volume are harvested and is located in the neighborhood of 0 residual basal area and trees per acre.

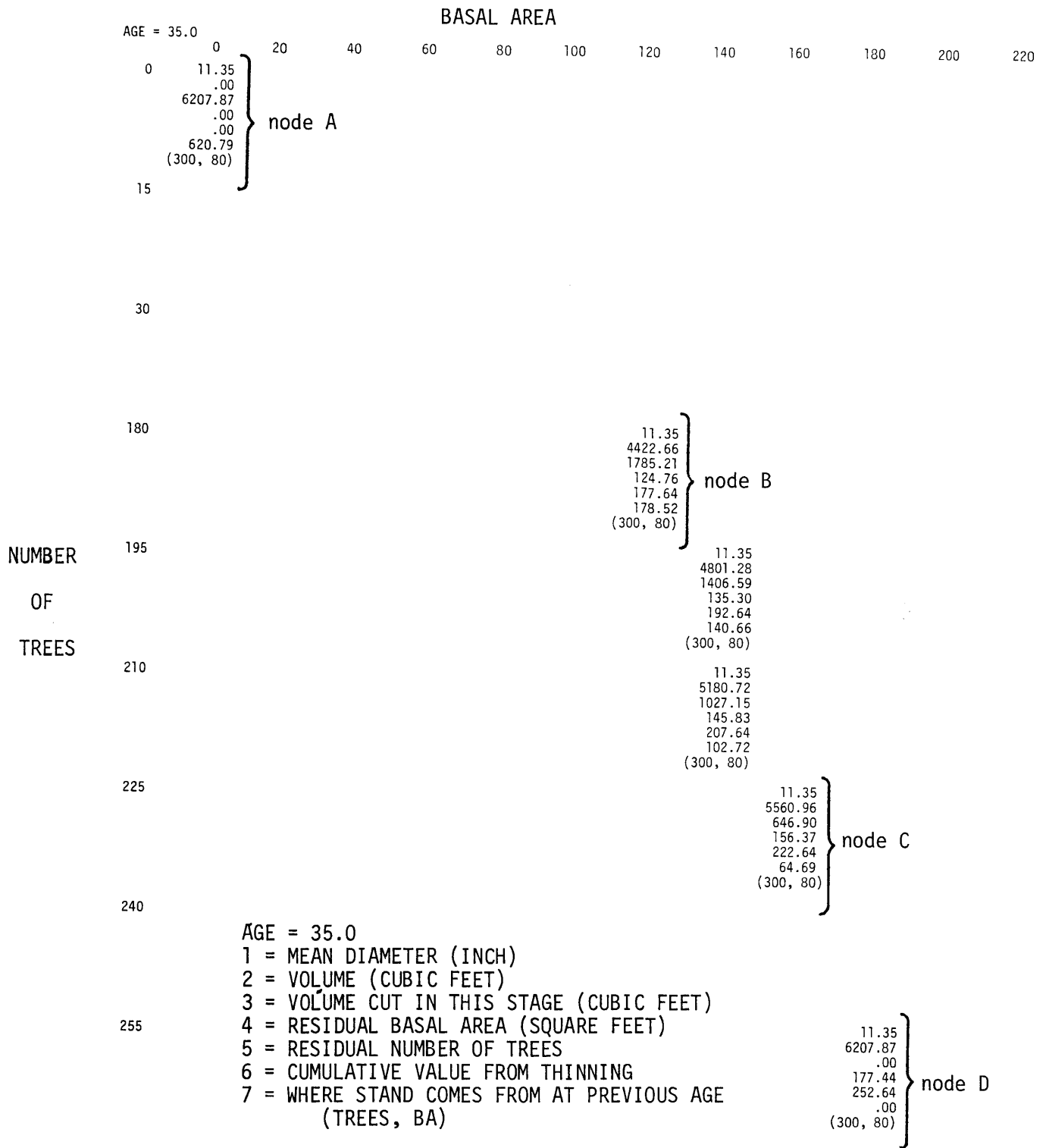
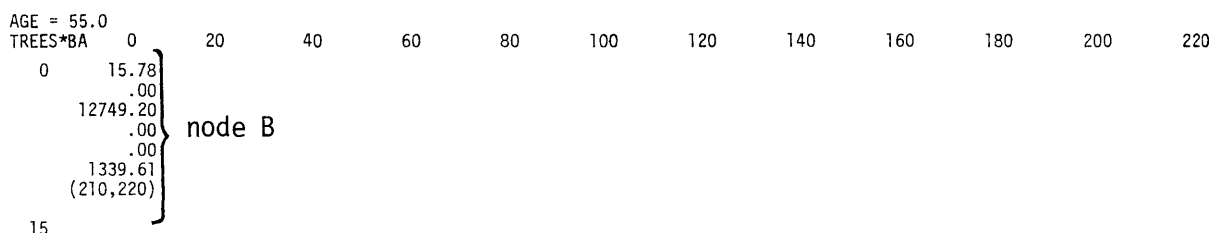


Figure 1A. Network for maximum volume example, age 35. Each set of seven numbers represents a node, or a possible state for the stand at age 35. Node C is the best state for the stand at age 35 if the rotation age is 55 years. The cumulative value from harvest is the harvest volume multiplied by 0.1.



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WHAT GOOD ARE EFFICIENT TIMBER PRESCRIPTIONS?

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WHAT GOOD ARE EFFICIENT TIMBER PRESCRIPTIONS?

An efficient timber prescription is one that maximizes the value of the land for timber production. This maximum value is commonly referred to by economists as the soil expectation value or land expectation value. If a dynamic program such as the one described earlier by Kathy Sleavin is used and only the timber costs and revenues are included, the "optimal" regime is the one that produces the maximum soil expectation value. Are such prescriptions likely to be widely used in forest plans? I don't think so. The National Forests are managed for multiple objectives, so there are usually other management objectives beyond efficient timber production, even on those acres where timber production is one of the major objectives. Often it will be necessary to do thoughtful tinkering with efficient timber prescriptions to accommodate other management objectives.

If it is necessary to tinker with efficient timber prescriptions to develop prescriptions for the forest plan, why bother at all? Why not just use the growth and yield simulator to develop the desired regimes? There are several reasons why it is advantageous to use efficient timber prescriptions as a starting point in the development of prescriptions for forest plans. While maximum financial return is not the sole objective of public forest management, efficient timber production is certainly one objective. Developing efficient timber prescriptions at the beginning of the process helps build awareness of the maximum timber values and the kinds of silvicultural regimes that will achieve them. Furthermore, the soil expectation value from the efficient timber prescription is the proper basis from which to measure the value that is forgone to achieve other management objectives. The soil expectation value of the efficient prescription, therefore, becomes the basis for tradeoff analysis. This awareness should enable the silviculturist to suggest ways to meet other management objectives with minimal

loss of timber value. Another advantage of using dynamic programming is that it would substantially reduce the number of simulations needed to develop the prescriptions. When prescriptions are developed using a simulator, the user can never be sure that reasonably efficient regimes have been found. There is a temptation to keep making one more simulation to see if a better regime can be found.

Using dynamic programming as part of the process of developing prescriptions is likely to result in prescriptions that are more defensible in several ways. One reason is that management objectives are treated more explicitly than is possible using only a simulator: A financial objective is optimized and then changes are made to the resulting regimes to meet other explicit objectives. This process makes it feasible to develop prescriptions that better fit the landscape where they are to be applied: They will better fit the management objectives for specific areas, and they will better fit the physical, biological, and economic differences between areas. Finally, Clark Row suggested earlier that a greater degree of site specificity than is now common in prescriptions may be required to meet legal requirements.

The remainder of the paper will deal with the question of how one can take advantage of capabilities that dynamic programming brings to the problem of developing prescriptions for forest plans. First I will discuss what data are needed to use this model in a reasonable way. I will discuss in more detail some of the reasons to tinker with the regimes that are developed using a dynamic program. I will then suggest ways to do that tinkering. I will show how to use the results to measure the cost of meeting non-timber objectives. Finally I will discuss the implications of using this approach for the various analysts involved in the planning process.

DATA NEEDS

In the discussion of data needs, I will assume that we start with an underlying growth and yield simulator, such as DFSIM (Curtis 1981), that has been joined with a dynamic program such as Kathy Sleavin discussed earlier. When developing efficient timber prescriptions, the effect of management decisions on costs and revenues must be treated in a reasonable way. One obvious way costs are affected is by decisions to apply silvicultural treatments such as reforestation and precommercial thinning. The cost data for silvicultural treatments are generally the easiest of the necessary data to acquire. Current experience from ongoing timber management programs can be used to estimate these costs. Because they occur early in the life of the stand, the problem of adjusting them for differences in the general price level is less than it is for revenues, which occur much later.

After the precommercial treatments, the primary concern is the net revenue from harvesting timber. Equation (1) shows the elements that need to be recognized when calculating net revenue from timber harvesting:

$$\begin{aligned} \text{Net revenue} &= \text{Gross product value} \\ &\quad - \text{manufacturing cost} \\ &\quad - \text{harvesting and hauling cost.} \end{aligned} \quad (1)$$

Because the net revenue data relates to a time period 20 and more years in the future, sensitivity analyses using different relationships for product prices, manufacturing costs, and harvesting costs will be useful.

Next, look at the individual components of the net revenue equation. Size of trees and volume per acre removed at an entry are two factors that are affected significantly by decisions about silvicultural prescriptions. These variables also have important effects on net revenues. The gross product value relationship is normally an increasing function of size of trees as shown in figure 1. This occurs because a higher proportion of the cubic volume of wood goes into primary products and the grade of products tends to increase. Because of efficiencies in handling and processing, the manufacturing cost relationship is expected to be a decreasing function of size of trees as shown in figure 2. The declining cost with increasing size reinforces the increasing value with increasing size, so the net revenue from manufacturing is even more strongly related to size. Logging costs are normally a decreasing function of size, once again reinforcing the relationship of net revenue with size. Logging costs are also a generally decreasing function with volume per acre removed. It is therefore important that logging costs deal with both size and volume per acre harvested. Yarding distance, type of yarding equipment, and perhaps some measure of residual stand are also important.

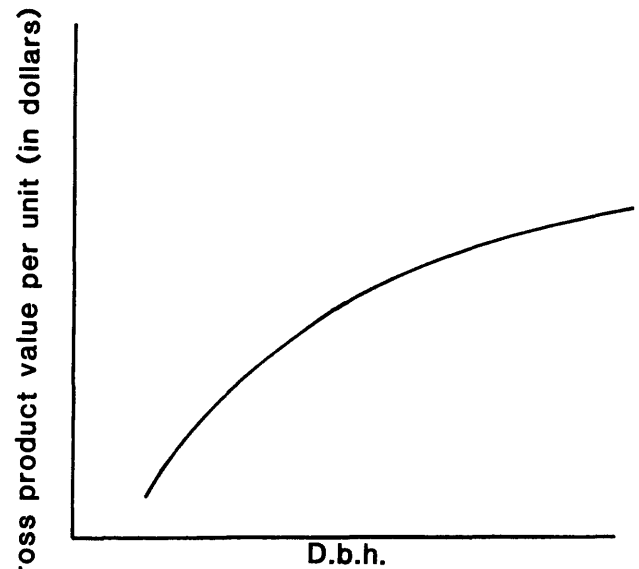


Figure 1.--Relationship of gross product value per unit to tree size.

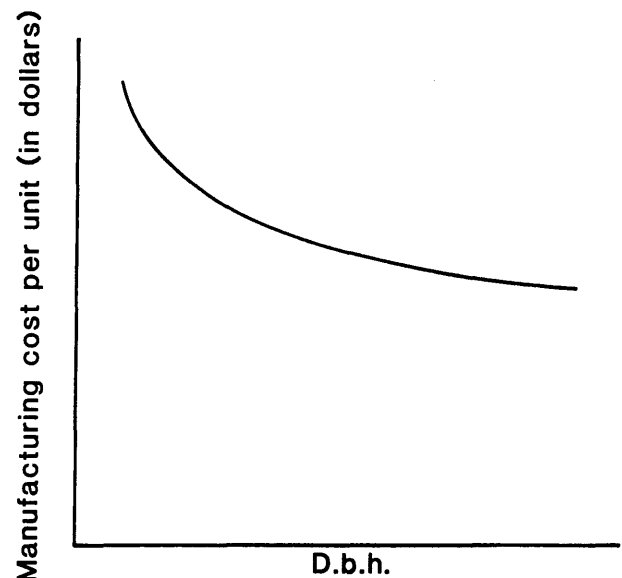


Figure 2.--Relationship of manufacturing cost per unit to tree size.

The way these relationships are brought together to develop the data needed by a dynamic program is shown in figure 3. For any given logging system and site condition, a logging cost simulator can be used to develop costs for relevant combinations of tree size and volume per acre removed. This information (as tables of values or equations imbedded in the dynamic program) provides the necessary data for the dynamic program to consider the effect of alternative regimes on logging costs and ultimately net revenue. On the product value side the net revenue from different sized trees is determined.

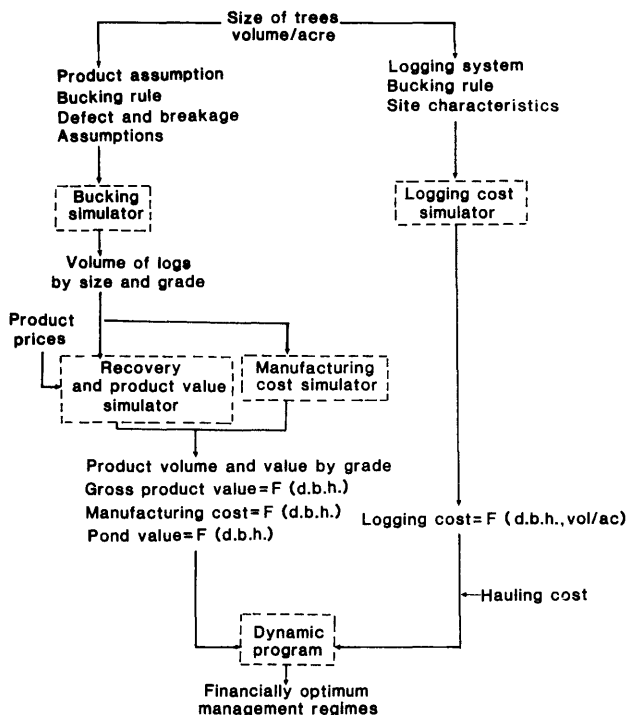


Figure 3.--Flow chart showing development of data needed to make reasonable use of dynamic programming.

To do this, bucking of the trees to logs is simulated. This step uses data from research on timber quality that relates log volume and grade to product recovery and value. Manufacturing costs must be simulated in order to determine the net revenue from manufacturing, which is referred to as the pond value (the value to the mill of logs delivered to the mill pond). Although much data exists that can be used to develop the necessary relationships, such data are not available in a form that is readily usable. I am currently undertaking a study to develop each of those pieces of needed data for Douglas-fir stands in the Douglas-fir region. That research should provide an indication of the problems in developing similar data for other regions and forest types.

Many people involved in National Forest planning may be accustomed to thinking of prices as a step function as shown in figure 4. The FORPLAN model that is widely used in forest planning requires that the price data be entered as a series of prices that apply over a size range. Furthermore, logs are commonly priced and purchased with prices that are a step function of diameter. I have no criticism of that in the context of using FORPLAN for developing a model of the forest. And certainly, using market-based pricing is the proper basis for developing appraisals for current sales. It is probably not a good approach to use in the development of efficient timber prescriptions, however. Because the dynamic program evaluates a very large number of combinations, it has substantial opportunity to increase the net revenue by putting off harvests until immediately after the

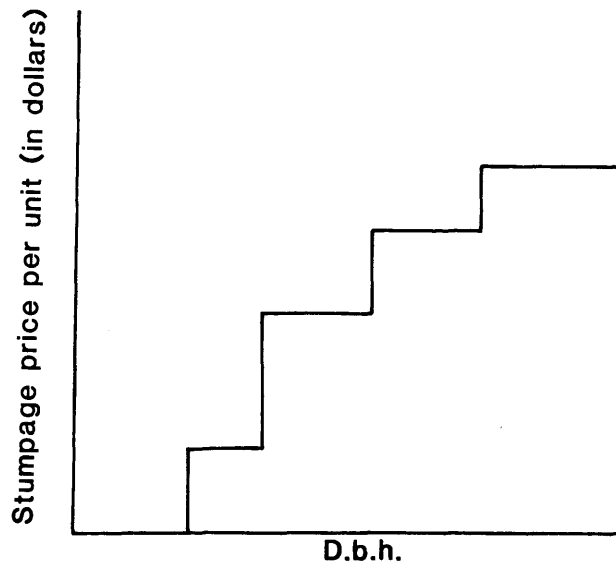


Figure 4.--Relationship of price per unit to size of trees.

point where the price jumps. It will also tend to delay harvests until just after the point where logging costs drop. I am unable to develop a good case for believing that such discontinuous jumps in costs and prices are likely to persist 20 and more years into the future even if they appear real today. It, therefore, seems preferable to use a smoothed curve for prices to reflect the net return from processing material over the relevant size range. It also seems preferable to use a smoothed curve for logging costs to even out discontinuous jumps that result from shifting from one piece of logging equipment to another. This approach will avoid distortions in the management regimes that are more an artifact of current institutions and assumptions rather than an inevitable response to underlying cost and value relationships.

REASONS TO TINKER

The principal reason to tinker with efficient timber prescriptions is that there are other objectives besides efficient timber production. Some of those other objectives may relate to the production of outputs to which prices may reasonably be attached. If the other output can be modeled as a function of some variable that the silvicultural simulation model can provide, and if prices can be attached, then the most direct way to deal with that case is to include the value of that output in the program along with the value of timber. The result is a regime that is efficient for the joint production of timber and other priced outputs. Regimes that meet non-financial objectives for the production of benefits to which prices may not be reasonably attached can only be developed by subjective modifications of the regimes.

Unpriced benefits may be of several types: those that are produced on individual acres, those that are produced on larger areas such as watersheds, and those that are produced from the forest as a whole unit. Forage for wildlife is one example of an output that is produced on individual acres. Modifying the prescription to increase wildlife forage is relatively straightforward. When the unpriced output is produced on a watershed level, as may be the case with sediment production, it is less clear that modification of prescriptions to better meet that objective is appropriate. If the level of sediment is a problem in some time periods and not others, the cost of using modified regimes in the time periods when the level of sediment is within acceptable bounds would be unnecessary. Providing alternative prescriptions to the forest scheduling model may be the more reasonable approach in that case. Other concerns, such as harvest flow constraints or budget constraints, may apply only to the forest as a whole. Efficient timber prescriptions may be inconsistent with these forest-wide objectives. For example, in some forests the non-declining flow level of harvest tends to be constrained by the lack of harvestable stands in decades four through seven of the plan: Most existing mature stands have been harvested, and young stands are not yet available in sufficient quantity to maintain the long-term sustained yield level of harvest. The overall plan objective may be better attained by allowing heavier thinnings from young stands during those time periods. The benefit of doing that is in reducing the cost of the non-declining flow constraint. For similar reasons overall plan objectives may be better met in some cases by increasing the volume produced from a prescription at the cost of some reduction in value on a stand basis.

TWO APPROACHES TO TINKERING

One approach to modifying efficient timber prescriptions is to go back into a simulation mode and use the growth and yield simulation model with a regime that the user specifies. That works, but the user must still figure out when enough simulations have been done to be confident that the prescription achieves the non-financial objectives at a reasonable cost in timber values.

Another approach is to continue to use a dynamic program to find efficient timber regimes, but to constrain the program to evaluate only regimes that include restrictions for the achievement of other management objectives. Earlier in the workshop we heard silviculturist Carl Puuri state his preference that other disciplines indicate what stand conditions are consistent with their objectives rather than what prescriptions are required. This approach would be particularly appropriate when dynamic programming is used. With this approach there is a high probability that prescriptions can be found to meet the required stand conditions with less loss in timber value than if a prescription is preselected.

MEASURING THE COSTS OF MEETING NON-FINANCIAL OBJECTIVES

Efficient prescriptions are the proper base from which to measure the costs of meeting other management objectives in a stand level analysis. What is given up in financial value to achieve a non-financial objective is called the opportunity cost of meeting the non-financial objective. Determining this value is sometimes called a tradeoff analysis and is very straightforward in this situation. The soil expectation value of the modified regime is subtracted from the soil expectation value of the efficient regime. This reduction in soil expectation value is a present value measure of the cost of meeting the non-financial objective.

The cost of meeting non-financial objectives can be expressed in several equivalent ways. The one or ones most easily understood by the user in the particular context should be used. If, for example, the reduction in soil expectation value is \$100 per acre when an efficient prescription is modified to increase forage for wildlife, one can say that the cost of increasing forage for wildlife is \$100 per acre. It might be more meaningful to express that as an equivalent annual cost. Reductions in soil expectation values can be converted to an annual equivalent by multiplying them by the interest rate. Using the 4% rate that is applied in National Forest planning, the equivalent annual cost of the \$100 per acre is \$4. Thus one can alternatively say that the cost of increasing forage for wildlife is \$4 per acre per year. Because the forage tends to be produced annually even if not in equal annual quantities, it may be more meaningful to express the cost as an equivalent annual cost. For outputs like forage for wildlife that can be quantified in units such as animal-unit-months one can go a step further and convert the cost to a cost per unit of output. If the modified prescription in the example produces two additional animal-unit-months of wildlife forage per acre per year, the cost of \$4 per acre per year can be divided by two for a cost of \$2 per animal-unit-month. Because this is much like the price for timber, forage for domestic livestock, and other marketed outputs, this cost per unit is likely to be most meaningful to planners and managers. If the outputs are not produced in equal annual quantities, the cost can still be converted to a cost per unit using standard discounting formulas (Ficht and Randall 1980).

IMPLICATIONS

Using dynamic programming in the development of silvicultural prescriptions enables the silviculturist to consider a broader range of issues, for example: (1) the effect of size premiums and cost relationships on the efficiency of timber production, (2) other outputs for which prices can be obtained, and (3) a way to measure the tradeoff between timber value and other objectives achieved by modifying the silvicultural prescriptions. Silviculturists will likely find that in some instances other objectives can be attained in alternative ways and that some alternatives involve substantially lower opportunity costs.

Prescriptions that are developed using dynamic programming are likely to be more defensible for several reasons. One is that using dynamic programming allows a more explicit recognition of objectives. The process begins with a financial optimization that is modified as needed to meet other specific objectives. This capability will make it possible to better fit the prescriptions to the landscape by considering the cost relationships and management objectives that apply to various areas of the forest. Tom Ortman said earlier that because of size-of-problem considerations, the number of prescriptions typically allowed per analysis area is four or five, sometimes only one or two. More prescriptions per analysis area may be feasible, but it may not be practical to develop a large number of prescriptions and let FORPLAN match the prescriptions to analysis areas. The prescriptions must be pre-screened, instead, so those few that are included in the forest plan are the ones that will best meet the objectives of the plan. Finally, prescriptions developed with the aid of a dynamic program are likely to be more cost efficient in meeting objectives for unpriced outputs.

Using a dynamic program to develop prescriptions also carries some obligations. The economic data that are used must anticipate price trends 20 years or more in the future. They must be free of aberrations that would cause the optimization program to "play games" with the regimes while attempting to produce the maximum financial value. A similar obligation is placed on the simulation modelers who are developing silvicultural simulation models. Just as the dynamic program will seek out aberrations in the economic data, so it will also seek out aberrations in the underlying silvicultural relationships. The silviculturist using the dynamic program inherits the obligation to understand the limitations of the growth and yield simulation model being used. In Jack Usher's immortal words, "computers are big, fast, and stupid." Unless the user understands the limits within which the results can be trusted and restricts the dynamic program to considering possibilities within those limits, prescriptions are likely to be developed that are not biologically defensible.

This application of dynamic programming is really nothing more than a tool that looks at a large number of possible regimes within specified limits, and identifies the ones that best meet the specified objectives. In many programs such as FORPLAN there are so many interactions that it is often difficult for an experienced analyst to determine why the results turned out as they did and whether or not they are correct. Not so with dynamic programming. The economic calculations for a particular regime can be verified by hand, and the silvicultural results can be verified by using the growth and yield simulator independent of the dynamic program. Silviculturists, therefore, need not be intimidated by dynamic programming. My guess is that dynamic programming will quickly become a standard tool of analysis for developing silvicultural prescriptions.

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HANDHELD PROGRAMMABLE COMPUTERS

by

L.O. (Pete) Stanger, Silviculturist
R-6, S&PF, Cooperative Forestry

Introduction

Handheld Programmable Calculators have been available for approximately 10 years. They have progressed from only numeric programming to both Alpha/numeric programming capability. Hewlett-Packard produced the HP-41C in 1979 with a built-in capacity of 63 registers and the option to add additional memory modules (64 registers each) to a total capacity of 319 registers (2,233 bits). In 1981, Hewlett-Packard introduced the HP-41CV which has 2,233 bits (2.2K) built-in and may be expanded to 6,454 bits with memory modules. Both computers use RPN language.

The number of handheld computers is increasing rapidly. In October, 1982, I examined the market and found six models available. In the February/March 1983 issue of Portable Computer magazine, eleven are listed as currently available. The majority of the newer models use BASIC language and contain from 1K to 48K RAM capacity.

Uses in State and Private Forestry

State and Private Forestry has attempted to encourage the use of handheld computers to assist State Service Foresters and Consulting Foresters in transferring technology of economic evaluation to the ground level when dealing with nonindustrial private landowners. Several programs for the HP-41 have been written for field sampling, statistical analysis and economic evaluation. A stand modeling program using Stand Density Index is also being reviewed at the present time.

Handheld computers will allow on-the-ground evaluation with the landowner. Different alternatives can be tested as well as evaluating current management practices. The landowner can decide whether changing management practices will be beneficial or not. Many uncertainties may be resolved in the landowner's mind if he elects to convert croplands or marginal timber stands to commercial forests.

Current Economic Evaluation Programs for the HP-41

REGIME - A single rotation program to evaluate Stand Management Alternatives. Calculates Internal Rate of Return, Present Net Worth, Benefit/Cost ratio and Future Net Worth. Uses 4 sides on two cards and requires extended memory on C model. Program is "interactive" or "user friendly" and runs automatically after inputting data.

INVEST - A Single Rotation Program to evaluate Stand Management Alternatives. Allows a real rate of change of costs and/or benefits to allow for future adjustment different than inflation rate. Calculates Internal Rate of Return, Present Net Worth, Benefit/Cost Ratio and Future Net Worth. Uses 5 sides of 3 cards and requires extended memory on C Model. Program is "interactive" or "user friendly" and runs automatically after inputting data.

ECOVAL - A "user friendly" investment analysis program featuring much of the flexibility in data manipulation and storage found in larger computers. New data files corresponding to a case study can be stored on cards for subsequent analysis. For identification, labels can be attached to each case and all investment events. Provision is made for data listing and editing. All features are "key" selectable from the following menu provided upon execution of the program:

- FILE MENU -

NEW DTA A
OLD DTA B
EDIT DTA C
RECORD DTA D
LIST DTA E
ANALAYZE DTA F
TERMINATE G

Two investment efficiency criteria are computed: PRESENT NET VALUE and BENEFIT-COST RATIO. Internal Rate of Return can be found by changing discount rate until PNW reaches zero. ECOVAL is particularly suitable to forestry investment analysis. Each investment event can be entered as a perpetual flow. Provision is made for optionally applying annual benefit and cost appreciation rates to each event.

Program Description

Program Title ECOVAL

Name Marc Wiitala and L. O. (Pete) Stanger

Date 5/6/83

Address USFS R-6 S&PF Cooperative Forestry P.O. Box 3623

City Portland

State Oregon

Zip Code 97208

Program Description, Equations, Variables, etc. ECOVAL is a "user friendly" investment analysis program featuring much of the flexibility in data manipulation and storage found in larger computers. New data files corresponding to a case study can be stored on cards for subsequent analysis. For identification, labels can be attached to each case and all investment events. Provision is made for data listing and editing. All features are "key" selectable from the following menu provided upon execution of the program:

- FILE MENU -

NEW DTA A

OLD DTA B

EDIT DTA C

RECORD DTA D

LIST DTA E

ANALYZE DTA F

TERMINATE G

Two investment efficiency criteria are computed: PRESENT NET VALUE and BENEFIT-COST RATIO. ECOVAL is particularly suitable to forestry investment analysis. Each investment event can be entered as a perpetual flow. Provision is made for optionally applying annual benefit and cost appreciation rates to each event.

Operating Limits and Warnings ERROR 01 - annual benefit appreciation rate adjusted for cost appreciation cannot exceed the discount rate.

DATA REGISTER ALLOCATION: 20 + (EVENTS * 6) registers must be allocated to data storage using XEQ SIZE function

When printer is not turned on contents of FILE MENU can be displayed item by item using R/S function. ✓

136
DO NOT USE THIS SPACE

User Instructions

[illegible]

User Instructions

				SIZE:
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Menu Routine: NEW DTA	A	Keyboard Entry	
			.XEQ	
2	Enter: case ID label	label	R/S	CASE ID?
	(labels should not exceed 6 characters)			
3	Enter: Number of incestment events		R/S	No. of Events?
4	Enter: event label	label	R/S	Event ID?
5	Enter: annual value appreciation rate (%)	%	R/S	Annual % ?
	(show 2-1/2% as 2.5)			
6	Enter: year of event occurrence	year	R/S	Year?
	(do not adjust cost year!)			
7	Enter: period of recurrence	period	R/S	Recurtime?
	or 0 for single occurrence			
	(if annual cash flow, enter 1)			
8	Enter: a positive cash value	value	R/S	Value?
	for event?			
9	Enter: 0 for cost or 1 for benefit	value	R/S	CST/BFT? 0/1
10	Steps 3-9 will be repeated			
	for each event, after which			
	program will return to			
	-FILE MENU-			

User Instructions

				SIZE:
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Routine: OLD DTA	B	Keyboard	-File Menu-
2	Prompts for data cards recorded from previous case:	cards	card reader	DATA CARD
3	DISPLAYS Case ID and returns to FILE MENU			case ID = -File Menu-
1	Routine: EDIT DTA	C	Keyboard	-File Menu-
2	Prompts for adding or changing data			Add/Chg. A/C?
	Enter: a for add/c for change	a or c	R/S	Enter A or C
	subroutine: Add event			
A.1	Refer to steps 4 - 9 in NEW DTA routine for adding event (to delete an event Value element zero) Subroutine: Change data			
C.1	Enter: order number of event to be changed	order no.	R/S	Event No.?
C.2	Enter: order number of data element to be changed (1 to 6)	order no.	R/S	Element No.?

User Instructions

				SIZE:
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
	Old data is displayed			Old data is:
				"old data"
C-3	Enter: new data or R/S	new data	R/S	New data?
	if no change desired			
	program returns to FILE MENU			
	for further editing, press C	C	Keyboard	-FILE MENU-
	Routine: RECORD DATA	D	Keyboard	File Menu
	Case ID is displayed			ID =
1	Enter: N if no/Y if yes	n or y	R/S	Rename Case?
2	Enter: New case label	label	card writer	RDY 01 of #
	prompted in display			

User Instructions

[illegible]

Program Listings

" ECOVAL "

01+LBL "ECOVAL"	51 CF 12	101 "VALUE?"	151 +
02 ADV	52 FS? 55	102 PROMPT	152 1
03 SF 12	53 STOP	103 XEQ 11	153 -
04 "COST/BENEFIT"	54+LBL 00	104 "CST/BFT? 0/1"	154 STO 02
05 AVIEW	55 FC? 55	105 PROMPT	155 CLA
06 PSE	56 STOP	106 XEQ 11	156 "OLD DATA IS:"
07 " ANALYSIS"	57 RTN	107 RTN	157 AVIEW
08 AVIEW	58+LBL A	108+LBL 11	158 PSE
09 PSE	59 CF 27	109 STO IND 10	159 CLA
10 ADV	60 CLA	110 ISG 10	160 ARCL IND 02
11 " VERSION 2.3 "	61 "CASE ID?"	111 RTN	161 AVIEW
12 AVIEW	62 AON	112+LBL 13	162 PSE
13 SF 15	63 PROMPT	113 ASTO IND 10	163 "NEW DATA?"
14+LBL "AA"	64 AOFF	114 ISG 10	164 PROMPT
15 FIX 2	65 ASTO 19	115 RTN	165 STO IND 02
16 SF 27	66 "NO. OF EVENTS?"	116+LBL B	166 XEQ "AA"
17 "-FILE MENU-"	67 PROMPT	117 CF 27	167+LBL 21
18 AVIEW	68 .00001	118 10.202	168 1
19 FS? 15	69 +	119 "DATA CARD"	169 ST+ 17
20 XEQ 00	70 STO 17	120 AVIEW	170 RDN
21 FC? 15	71 STO 11	121 XEQ "RDTAX"	171 .006
22 STOP	72 6	122 CLA	172 ST+ 18
23 CF 15	73 *	123 "CASE ID="	173 ST+ 10
24 "-----"	74 1000	124 "I"	174 XEQ 14
25 AVIEW	75 /	125 ARCL 19	175 XEQ "AA"
26 "NEW DTA A"	76 20.02001	126 AVIEW	176+LBL D
27 AVIEW	77 +	127 PSE	177 CF 27
28 XEQ 00	78 STO 18	128 XEQ "AA"	178 CLA
29 "OLD DTA B"	79 STO 10	129+LBL C	179 "ID="
30 AVIEW	80+LBL 12	130 CF 27	180 ARCL 19
31 XEQ 00	81 XEQ 14	131 CLA	181 AVIEW
32 "EDIT DTA C"	82 DSE 11	132 "A"	182 PSE
33 AVIEW	83 GTO 12	133 ASTO Y	183 CLA
34 XEQ 00	84 XEQ "AA"	134 "ADD/CHG: A/C?"	184 "N"
35 "RECORD DTA D"	85+LBL 14	135 AON	185 ASTO Y
36 AVIEW	86 CLA	136 PROMPT	186 CLA
37 XEQ 00	87 "EVENT ID?"	137 AOFF	187 "RENAME CASE?"
38 "LIST DTA E"	88 AON	138 ASTO X	188 AON
39 AVIEW	89 PROMPT	139 X=Y?	189 PROMPT
40 XEQ 00	90 AOFF	140 GTO 21	190 AOFF
41 "ANALZE DTA F"	91 XEQ 13	141 "EVENT NO.?"	191 ASTO X
42 AVIEW	92 "ANNUAL % ↑ ?"	142 PROMPT	192 X=Y?
43 XEQ 00	93 PROMPT	143 1	193 GTO 31
44 "TERMINATE G"	94 XEQ 11	144 -	194 CLA
45 AVIEW	95 "YEAR?"	145 6	195 "NEW NAME?"
46 ADV	96 PROMPT	146 *	196 AON
47 ADV	97 XEQ 11	147 "ELEMENT NO.?"	197 PROMPT
48 ADV	98 "RECUR TIME?"	148 PROMPT	198 AOFF
49 ADV	99 PROMPT	149 +	199 ASTO 19
50 ADV	100 XEQ 11	150 20	

Program Listings

"ECOVAL" (Version 2.3)

200+LBL 31	250 X>Y?	300+LBL 40
201 RCL 18	251 XEQ 42	301 RDN
202 10	252 /	302 ST+ 06
203	253 STO 09	303 RTN
204 XEQ "WDTAX"	254 RCL 10	304+LBL 41
205 XEQ "AA"	255 3	305 RDN
206+LBL E	256 +	306 ST+ 05
207 CF 27	257 STO 16	307 ST- 06
208 CLA	258 RCL IND 16	308 RTN
209 "PRINTER ON?"	259 X<>Y	309+LBL 42
210 AON	260 RDN	310 "ERROR 01"
211 PROMPT	261 X=0?	311 AVIEW
212 AOFF	262 1	312 PSE
213 ASTO X	263 CHS	313 RTN
214 X=Y?	264 X=0?	314+LBL 49
215 RTN	265 1	315 RCL 06
216 CLA	266 +	316 RCL 05
217 ARCL 19	267 XEQ 45	317 +
218 PRA	268 X<>Y	318 STO 04
219 RCL 18	269 -	319 CLA
220 .001	270 CHS	320 "PNV="
221 -	271 Y+X	321 ARCL 06
222 PRREGX	272 XEQ 45	322 AVIEW
223 XEQ "AA"	273 X=0?	323 FC? 55
224+LBL F	274 GTO 48	324 STOP
225 CF 27	275 CHS	325 RCL 06
226 0	276 RCL 09	326 RCL 05
227 STO 04	277 X<>Y	327 +
228 STO 05	278 Y+X	328 LASTX
229 STO 06	279 CHS	329 /
230 "DISCT RATE?"	280 1	330 CLA
231 PROMPT	281 +	331 "B/C="
232 100	282 /	332 ARCL X
233 /	283+LBL 48	333 AVIEW
234 1	284 X=0?	334 FC? 55
235 +	285 RDN	335 STOP
236 STO 01	286 XEQ 45	336 ADV
237 RCL 17	287 *	337 ADV
238 STO 11	288 XEQ 45	338 ADV
239 RCL 18	289 X=0?	339 XEQ "AA"
240 STO 10	290 XEQ 40	340+LBL G
241+LBL 44	291 X=0?	341 SF 12
242 1	292 XEQ 41	342 CF 27
243 ST+ 10	293 DSE 11	343 "SESSION ENDS"
244 RCL 01	294 GTO 44	344 AVIEW
245 XEQ 45	295 GTO 49	345 CF 12
246 100	296+LBL 45	346 END
247 /	297 RCL IND 10	
248 1	298 ISG 10	
249 +	299 RTN	

Sample Listing

CASE 104

XEQ "ECOVAL"			
COST/BENEFIT ANALYSIS			
VERSION 2.3			
-FILE MENU-			
NEW DTA A OLD DTA B EDIT DTA C RECORD DTA D LIST DTA E ANALZE DTA F TERMINATE G			
	XEQ B		
DATA CARD CASE ID=CAS104 -FILE MENU-			
	XEQ E		
PRINTER ON? Y CAS104		RUN	
R20= "SP/PLT" R21= 2.70 R22= 1.00 R23= 50.00 R24= 163.50 R25= 0.00 R26= "PCT" R27= 2.70 R28= 15.00 R29= 50.00 R30= 90.00 R31= 0.00 R32= "CT30" R33= 2.50 R34= 30.00 R35= 50.00 R36= 194.71 R37= 1.00 R38= "CT35"			
			R39= 2.50 R40= 35.00 R41= 50.00 R42= 414.41 R43= 1.00 R44= "CT40" R45= 2.50 R46= 40.00 R47= 50.00 R48= 493.08 R49= 1.00 R50= "CT45" R51= 2.50 R52= 45.00 R53= 50.00 R54= 570.39 R55= 1.00 R56= "HFR50" R57= 2.50 R58= 50.00 R59= 50.00 R60= 8,557.98 R61= 1.00
			-FILE MENU-
			XEQ F
		DISCT RATE?	
		4.00	RUN
		PNV=9,339.06 B/C=19.24	
		-FILE MENU-	
			XEQ F
		DISCT RATE?	
		10.00	RUN
		PNV=168.40 B/C=1.82	
		-FILE MENU-	
			XEQ F
		DISCT RATE?	
		11.50	RUN
		PNV=2.38 B/C=1.01	
		-FILE MENU-	
			11.60
		DISCT RATE?	XEQ F
			11.60
		PNV=-5.13 B/C=0.97	RUN

CASE104

CASE NO. 3 OF THIS RUN

INPUT FOR REFORESTATION DOUGLAS-FIR SITE 165-225 CU.FT./ACRE/YEAR

INTENSIFIED MANAGEMENT

YEAR	HARVEST CODE	PRICE	GROUP CODE	GROUP	BENEFIT	COST	GROUP CODE	REPETITION	PERPETUITY	DESCRIPTION
0						163.50	1	0	0	50 SITE PREP. AND PLANT
14					90.00		3	0	0	50 PRECOMMERCIAL THIN
30	1.5000	4	125.81	6	194.71			0	0	50 COMMERCIAL THIN
35	2.6000	4	159.39	6	414.41			0	0	50 COMMERCIAL THIN
40	2.8000	4	176.10	6	493.08			0	0	50 COMMERCIAL THIN
45	3.0000	4	190.13	6	570.39			0	0	50 COMMERCIAL THIN
50	38.0000	5	225.21	6	8557.98			0	0	50 FINAL HARVEST

AREA FOR CASE104 IS .02 THOUSAND ACRES

RATE OF RETURN SEARCH FINISHED

AT 12.70% SUM OF DISCOUNTED BENEFITS 120.943 IS LESS THAN INITIAL COST 163.500

***** WARNING - MULTIPLE RATES OF RETURN *****

REFORESTATION DOUGLAS-FIR SITE 165-225 CU.FT./ACRE/YEAR

BASE DATA PROFIT LEVELS

INTERNAL RATE OF RETURN 2.7053 11.5312

SPECIFIED INTEREST RATE	PRESENT NET WORTH	BENEFIT COST RATIO	PRESENT NET WORTH PER \$ INITIAL COST
3.0000	35624.5101	20.3458	217.8869
4.0000	9339.0723	19.2446	57.1197
7.1250	1155.9716	5.7606	7.0702
10.0000	168.4028	1.6234	1.0300

National Silviculture Workshop
Eugene, Oregon, May 16-20, 1983

Economic Efficiency in the Forest Service Planning Process:
A Critique of the Definition of Economic Efficiency

Lee Medema*

My task today is to address the topic of economic efficiency in the U.S. Forest Service planning process. In approaching this task, I investigated the legislative mandate for undertaking economic efficiency analysis, the interpretations of the mandate, and the guidelines established by the Forest Service to undertake an economic efficiency analysis. The following is a brief summary of my observations.

The organization of this paper focuses on portions of the definition of economic efficiency given in the Forest Service Manual (FSM 1970.5).^{1/} Economic efficiency is defined as:

"The usefulness of inputs (costs) and outputs (benefits) and effects when all costs and benefits that can be identified and valued are included in the computations. Economic efficiency is usually measured using present net value, though use of benefit-cost ratios and rates-of-return may sometimes be appropriate."

First, I will discuss the scope of the required analysis. Second, I will discuss the implications of economic efficiency versus equity analyses. Third, I will discuss measures of economic efficiency.

^{1/}The definitions used appeared in the version of the FSM printed in the Federal Register, Vol. 47, No. 80, Monday, April 26, 1982.

*Associate Professor of Forest Economics
College of Forestry, Wildlife & Range Sciences
University of Idaho

Definitions of Efficiency - The Scope of Analysis

That portion of the definition of economic efficiency is given in the Forest Service Manual (FSM 1970.5) that relates to the scope of analysis is "The usefulness of inputs (costs) to produce outputs (benefits)....when all costs and benefits that can be identified and valued are included in the computations."

In technical economic jargon, economic efficiency is just one performance criteria (or means of judging an investment), and there is more than one type of economic efficiency. Economic efficiency is a concept with several supporting components (figure 1).

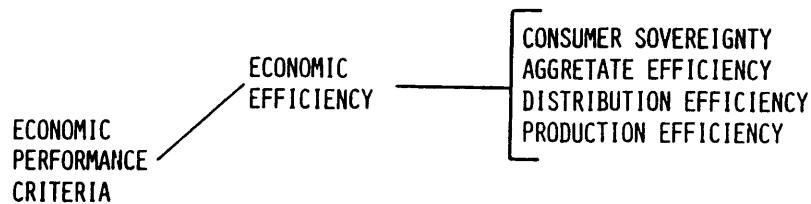


Figure 1. Economic Efficiency.

Among these components are a) consumer sovereignty which reflects the individual consumer's ability to obtain desired goods and services, b) aggregate efficiency which describes the productive employment of resources relative to full employment, c) distribution efficiency which deals with the notion that goods should be distributed to consumers who want them, and d) production efficiency which deals with the relationships between inputs (costs) and outputs (benefits) in a production process. Clearly this last component of economic efficiency (production efficiency), is most closely aligned with the definition of economic efficiency given in the Forest Service Manual.

In terms of inputs to a production process (or project), production efficiency is concerned with obtaining technically efficient (inferior processes are rejected) production processes that reflect the least cost combinations of inputs.

In terms of outputs of a production process, production efficiency is concerned with producing that combination of outputs that yields the largest net benefit.

In essence, production efficiency (or economic efficiency) is attempting to deal with minimizing unambiguous waste in a production process by avoiding a process which uses more of the same kinds of resources than an alternative process.

Recognizing the difficulty of undertaking an economic efficiency analysis in which all costs and all benefits that can be identified are included, must be considered (because of the difficulties in measuring externalities and valuing non-market goods), the FSM makes a distinction between economic efficiency and cost efficiency where cost efficiency is defined as "the usefulness of specified inputs (costs) to produce specified outputs." Hence, cost efficiency does not require that all costs and benefits be valued and included in the analysis.

This distinction is a moot point of some significance. Regulations published in the Federal Register (September 30, 1982) interprets the Forest and Rangeland Renewable Resources Planning Act (16 U.S.C. 1601-note) as amended by the National Forest Management Act (16 U.S.C. 1600-note) to require the Forest Service to develop a planning process in which, "The resulting plans shall provide for multiple use and sustained yield of goods and services from the National Forest System in a way that maximizes long term net public benefits in an environmentally sound manner" (36 CFR Part 219.1a).

Net public benefits are defined as "An expression used to signify the overall long-term value to the nation of all outputs and positive effects (benefits) less all associated inputs and negative effects (costs) whether they be quantitatively valued or not" (36 CFR 219.3). The implication here is that

the Forest Service must undertake an economic efficiency analysis considering all of the benefits and costs that can be identified and valued--not a cost efficiency analyses considering only specified benefits and costs.

However, Congress, in passing the National Forest Management Act, put specific constraints on the Forest Service planning procedures by establishing a series of "planning principles." One of these principles states "Management of National Forest System lands that is sensitive to economic efficiency...." (36 CFR 219.1). Sensitive to economic efficiency is interpreted to mean that each alternative considered "....shall represent to the extent practicable the most cost efficient combination of management prescriptions examined that can meet the objectives established in the alternative" (36 CFR 219.12). *Therefore the distinction between economic efficiency and cost efficiency and which type of anlysis should be undertaken is ambiguous.*

Definition of Economic Efficiency - Efficiency versus Equity

As stated above, economic efficiency deals with the relationship between inputs and outputs in a production process, and is not designed to assess the desirability of distributional considerations such as the distribution of income. For the distributional considerations of a production process (or project), a separate and distinct economic performance criteria is used--equity as measured through economic impact analysis procedures (figure 2).

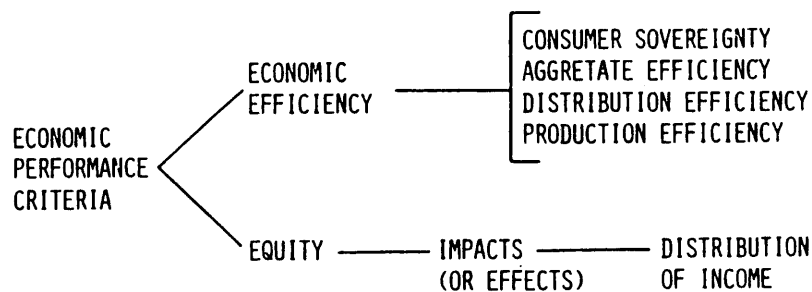


Figure 2. Economic Impacts (or Effects)

Economic impact analysis deals with the off-site impacts (or effects) on the general economy caused by a project--such as effects on employment and wages. It is designed, for the purpose of equity considerations, to determine who gains and who loses from a project. It is important to note the distinction. Economic impact analysis has nothing to do with production (or economic) efficiency. For example, an economically inefficient project may have desirable economic impacts or *vice versa*.

It is my contention that the Forest Service Manual fails to make the distinction between economic efficiency and economic impact analyses.

The Forest Service Manual defines economic efficiency as "the usefulness of inputs (costs) to produce outputs (benefits) and effects when costs and benefits that can be identified and valued are included in the computations." Effects is a term commonly utilized by the Forest Service in referring to the results of economic impact analyses. Additionally, the Manual further defines cost efficiency as "the usefulness of specified inputs (costs) to produce specified outputs (benefits). In measuring cost efficiency, some outputs (such as environmental, economic, or social impacts) are not assigned monetary values but are achieved at specific levels in the least cost manner."

Therefore, these definitions imply that economic (and social and environmental) impacts are to be included in determining a project's economic (or production) efficiency.

The last portion of the definitions of economic and cost efficiency confirm this implication as it states economic (or cost) efficiency "is usually measured using present net values, though use of benefit-cost ratios or rates of return may sometimes be appropriate."

This part of these definitions appears consistent with production efficiency until one examines the definition of present net value. The Forest Service Manual

defines present net value as "the difference between the discounted values (benefits) of all outputs to which monetary values or established market prices are assigned, and the total discounted costs of managing the planning area." It further makes a distinction between present net value and primary present net value by defining the latter as "the present value which includes only the benefits and costs of producing primary outputs, and excluding secondary benefits." Although primary outputs are not defined, the Manual defines a secondary benefit as "a benefit accruing to parties other than the resource owners, including effects on local, regional and national economies and on consumers of outputs." Consequently, present net values are to include effects from economic impact analysis and present net values are a measure for economic efficiency analysis. *This is a clear mixing of the two distinct economic performance criteria. It is therefore technically incorrect.*

The distributional aspects (or equity aspects) of land use decisions (or production decisions) must be distinguished from considerations of production efficiency. A failure to clearly make this distinction will undoubtedly lead to distorted measures of economic efficiency and potentially result in (1) production decisions based on pressures for shifts or redistributions in program costs or benefits rather than overall economic efficiency and/or, (2) the justification (or rationalization) of grossly inefficient projects on income redistributive grounds where this gross inefficiency is masked by combining the two types of analysis (economic efficiency and economic impact) into one.

I acknowledge that neither economic performance criteria alone (economic efficiency or economic impact analysis) is sufficient to justify a resource allocation decision. The trade-offs between economic efficiency and desired economic impacts has often times been an area of controversy. But, let's face the trade-offs head on rather than attempting to combine the two--where the tradeoffs become obscured.

Definition of Economic Efficiency - Measures of Economic Efficiency

It is my intention that the Forest Service Manual fails to make the correct distinctions between measures of economic efficiency.

The Forest Service Manual (Section 1971.3—Measures of Economic Efficiency) states:

"In general, present net values are more appropriate measures of economic efficiency than benefit cost ratios or rates-of-return^{2/} when comparing alternatives for managing the same resources in long-term analysis periods either without a budget constraint or with the same budget constraint. However, in allocation of limited budget funds in short-term analysis periods to implement long-term plans, present net values do not measure relative economic efficiency because programs or projects may differ greatly in scale. In such comparisons, benefit/cost ratios are more valid."

I have two comments on this statement. First, differences in project scale are hidden in benefit-cost ratio results as it is merely a ratio. Differences in project scale are also hidden in rate-of-return analysis results as it is merely a percent (since rate-of-return was not identified as the "more valid" measure of economic efficiency, it will not be discussed further). Present net value results explicitly reflect differences in scale. Consider the example given in Table 1.

TABLE 1. DISPLAYING PROJECT SCALE DIFFERENCES

	<u>PROJECT A</u>	<u>PROJECT B</u>
PRESENT VALUE OF BENEFITS	\$20	\$200
PRESENT VALUE OF COSTS	\$10	\$100
PRESENT NET VALUE	\$10	\$100
BENEFIT COST RATIO	2.00	2.00

^{2/}A benefit cost ratio is defined in the Manual as "a measure of economic efficiency, computed by dividing total discounted primary benefits by total discounted economic costs." Rate-of-return is defined as "the financial yield per unit cost, determined as the rate of interest at which total discounted benefits equal total discounted costs." The utilization of primary benefits in the benefit cost ratio is technically correct although inconsistent with the measure of benefits to be included in present net value and rate-of-return calculations.

Project B is ten times larger than Project A and this scale difference is reflected in the present net value results although both projects have the same benefit cost ratio.

The second point is that all measures of economic efficiency (present net values, benefit cost ratios, and rate-of-return) are "valid" depending on what opportunities one has for investing the scale differences (as well as opportunities for investing intermediate revenues generated by the project). Each performance makes different assumptions regarding these investment opportunities.

For example, consider the two alternatives depicted in Table 2.

TABLE 2. SELECTION OF PROJECTS WITH SCALE DIFFERENCES
(DISCOUNT RATE USED IS 10%)

<u>PERIOD</u>	<u>PROJECT A</u>	<u>PROJECT B</u>	
0	\$-10,000	\$-5,000	(INITIAL COST)
1	\$7,348	\$4,083	(REVENUE AFTER 1ST YEAR)
2	\$7,348	\$4,083	(REVENUE AFTER 2ND YEAR)
<u>CRITERIA</u>			
PRESENT NET VALUE	\$2,753*	\$2,086	
BENEFIT COST RATIO	1.28	1.42*	

The Forest Service Manual would have us believe that "in allocation of limited budget funds in short-term analysis periods to implement long-term plans" Project B should be selected because "benefit cost ratios are the more valid" measure of economic efficiency. In this example, the measures may vary (and are inconsistent in this example) on selecting the preferred alternative merely because of the different assumptions each measure makes regarding investment of scale differences. Present net value assumes that differences in scale are invested at the discount rate. Benefit cost ratio calculations assume that

scale differences are invested in another project having the same present value as the smaller project (e.g. instead of one Project A, you can have two Project B's).

If one recalculated the present net values and benefit cost ratios of one Project A compare to two Project B's, the results would no longer be inconsistent (Table 3).

TABLE 3. ADJUSTING FOR SCALE DIFFERENCES

<u>PERIOD</u>	<u>PROJECT A</u>	<u>TWO PROJECT B's</u>
0	-\$10,000	-\$10,000
1	\$7,348	\$8,166
2	\$7,348	\$8,166
NET PRESENT VALUE	\$2,753	\$4,068*
BENEFIT-COST RATIO	1.28	1.42

Although this is a highly technical point, it is crucial that one understand the meaning and results of the different assumptions each measure uses in determining which measure is valid. All of the measures are valid depending, as mentioned above, on the opportunities one has for investing scale differences and intermediate revenues generated.

Conclusion

In conclusion, I believe the Forest Service Manual is technically incorrect in its consideration of economic efficiency analyses in that (1) it fails to make the distinction between economic efficiency and economic impact analyses and (2) it fails to make the correct distinctions between measures of economic efficiency. Furthermore, the intended scope of required analyses in terms of benefits and costs to be included is ambiguous.

An Evaluation of Federal Silvicultural Investments
Made Through the 1979 Forestry Incentives Program

by

Christopher D. Risbrudt 1/

Abstract - An evaluation of federal silvicultural investments made through the Forestry Incentives Program in 1979 estimates they will yield a rate of return of over 8 percent above inflation. The investments increased the productivity of nonindustrial private forests by encouraging landowners to manage more intensively than they otherwise would. The increase in timber production will amount to almost 1.3 billion cubic feet over the first rotation. Federal taxes these owners will pay on their additional timber income have a present value of over \$2 for every dollar expended through this program.

Adequacy of future timber supplies has long been a concern of the federal government. Because nonindustrial private ownerships contain about 58 percent of the commercial forest in the United States, they must play an important role in satisfying the Nation's timber demands (USDA Forest Service 1981). Concerned over the low level of timber management investments made on these forest lands, and the resulting effect on the Nation's future timber supply, Congress in 1973 authorized the Forestry Incentives Program (FIP). Through this program, the federal government shares in the cost (up to 65 percent, depending on state guidelines) of forest operations such as site preparation, planting, cull tree removal, and precommercial thinning. By 1981, 1.2 million acres had been reforested and 1.0 million acres of forest stands had been improved through the FIP-related investments.

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To be eligible for cost-share assistance under the Forestry Incentives Program, a landowner must:

- ° Own no more than 1,000 acres of eligible forest land unless the Secretary of Agriculture determines it is in the public interest to grant an exception for a larger acreage not to exceed 5,000 acres. A ten acre minimum tract size became effective in 1977.
- ° Be a private forest landowner. Individuals, groups, associations, or corporations whose stocks are not publicly traded are eligible. They must not, however, be primarily engaged in the business of manufacturing forest products or providing public utility services of any type. *
- ° Have lands that can produce more than 50 cubic feet of commercial timber per acre per year.

The cost-effectiveness of FIP was first expressed in Congress during the drafting of the legislation, later in the Department of Agriculture when program guidelines were developed (Mills 1976), and also when the President signed the legislation. Although an analysis was made of the first year's accomplishments which showed an internal rate of return of over 10 percent for combined federal and private costs (Mills and Cain 1979), questions continue to be raised about its efficiency.

This article reports an evaluation of the cost effectiveness of the 1979 program. This year was selected because the program had been in existence for six years, and had settled into routine operation between the USDA Forest Service, USDA Agricultural Stabilization and Conservation Service and the State forestry agencies. The evaluation compares the probable timber yield and value increases with the costs of making the investment. A major assumption was that the land on which cost shares are expended would be, in most cases, forested naturally if the program did not exist. Through this assumption, the program was credited only with the difference in timber quantity and quality resulting from federal and concomitant private investment.

EVALUATION PROCEDURE

A stratified random sample of 676 cases was drawn from 8,622 qualifying program cases cost-shared in fiscal year 1979. Each sample case was inventoried in 1981 with on-the-ground measurements by specially trained professional foresters (Risbrudt and Ellefson 1983). The sampling took place in 1981 in order to allow two growing seasons to check for seedling survival. Fairly severe drought in 1979 and 1980 meant the reforestation cases would be evaluated after experiencing harsh conditions.

The Plains and Rocky Mountain regions were excluded from the evaluation because of their small program size (1.2 percent of program expenditures and 1.1 percent of total acres). Fencing, fire access roads, and special practices representing 0.5 percent of the total program expenditures were also excluded. The remaining 8,622 cases were stratified into 15 sampling strata based upon practices and forest type. In some instances the strata were further divided by state because of the strong influence state agencies have in the direction of the program, and there were a sufficient number of cases. Each sampling cell was subdivided into nine subcells, developed from three classes each of tract size and site productivity. Twenty cases were sampled from each cell, proportioned among the subcells according to the number of population cases in each. Sampling results were expanded to population estimates by using sampling intensities within the subcells as expansion weights.

The economic evaluation combined the physical measurements of each sampled case with projected harvest volumes, stumpage prices, and the cost of any silvicultural treatments necessary in the future. Costs of future treatments were assumed to be borne by the landowner. These costs (shown in Table 1)

were derived from several data sets, but were heavily weighted by actual FIP case treatment costs.

Table 1. 1979 FIP management regime practice costs per acre by region.

Practice	Species group	Region			
		South	Central	Northeast	Lake
		-----Dollars-----			
Site prep and plant	Southern pine	96	87	87	-
	Oak-pine	96	107	87	-
	Northern pine	112	117	97	79
	Other northern conifers	54	54	69	80
	Black walnut	91	119	42	74
Hardwood control	All groups	40	40	40	40
Prescribed burn	Southern pine	4	4	4	4
Precommercial thin	Southern pine	61	34	40	-
	Northern hardwoods	45	35	40	32
	Black walnut	22	22	22	22
Cull tree removal and understory release	Southern pine	33	28	-	-
	Other northern conifers	21	21	21	21
	Oak-hickory	31	30	33	26
	Cove hardwoods	31	39	34	27
	Northern hardwoods	-	39	34	27
	Black walnut ¹	32	32	32	32
	Black walnut ²	44	36	62	73
Pruning	Northern pine	43	75	29	34
	Black walnut ¹	15	15	15	15
	Black walnut ²	19	19	19	22

¹Natural stands.

²Plantations.

Note: Figures are for the total cost per acre.

Two levels of management were compared in each case: (a) a reasonably intensive level, which it was assumed that the owners would follow because they had made an investment, and (b) a level considered typical of current nonindustrial management as judged by regional silvicultural experts. Harvest volumes differed between management levels, the reasonably intensive level being higher because of more commercial thinnings, more basal area crop trees, and sometimes shorter rotations. Each regime was carried through a sawtimber rotation and then followed by an infinite number of rotations of standard conditions and length in order to eliminate time bias between cases with differing rotation lengths. The 180 regimes used are contained in Wingerd (1982).

Prices for up to 67 individual timber species were weighted together for each case, the weights being the post-treatment basal area of the crop species. As a result, the species composition of the tract, and the effect of the practice upon species composition, were reflected in the average stumpage price for each case. This adjustment was particularly important for hardwood cases. The annual increase in the real stumpage price (i.e., excluding inflation) was assumed to average two percent for softwoods and one-half percent for hardwoods, although the rates varied by region.

Each case, however, had to pass a set of minimum silvicultural standards before net benefits were assigned. These standards required, for example, the existence of 200 surviving crop tree seedlings per acre for regeneration cases, or removal of 10 percent of the stand basal area as cull (Table 2). If the case did not exceed these minimums, it was considered a failure and returns to the program were set to zero. All cases, including those which did not meet the standards, were included in the evaluation results.

Table 2. 1979 FIP stand and silvicultural practice standards by species group.

Species	Timber stand improvement		
	Practice ¹	Maximum age (yrs)	Minimum basal area reduction ²
Loblolly, shortleaf pine	Intermediate	40	10 sq.ft.
Slash pine	Intermediate	40	10 sq.ft.
Virginia pine	Intermediate	10	10 sq.ft.
Oak-pine	Intermediate	45	15 percent
Oak-hickory	Intermediate	45	15 percent
Cove hardwoods	Intermediate	50	15 percent
Black walnut	Intermediate	60	-
Black walnut	Prune	60	-
Northern hardwood (Northeast)	Intermediate	60	10 sq.ft.
White birch	Intermediate	45	10 sq.ft.
Northern pine	Intermediate	60	15 percent
White pine	Prune	60	-
Red pine	Prune	60	-
Spruce-fir	Intermediate	50	20 sq.ft.
Hemlock	Intermediate	60	15 percent
Planting and understory release			
Minimum surviving planted or established seedlings per acre			
Southern pine ³		200	
White pine		200	
Red pine		150	
Jack pine		200	
Spruce		200	
Black walnut		120	
Miscellaneous practice			
Oak-hickory and cove hardwoods	Removal of grapevines more than 7 years before final harvest		

¹Intermediate practices consist of cull tree removal, understory release, and precommercial thinning.

²A pretreatment B-level stocking was normally required.

³Except for virginia pine, which has a 250-tree standard.

COST-EFFECTIVENESS

In 1979, \$14.5 million in federal cost-shares were expended through the Forestry Incentives Program affecting treatment on nearly 330,000 acres (Table 3). Tree planting was accomplished on 211,997 acres with Federal reforestation costs per acre averaging about \$50 in the East and about \$95 in the West (Table 4). In 1979, almost half the pine seedlings planted on nonindustrial lands were funded through the program (Williston 1980). Timber stand improvement, which included precommercial thinning, understory release, cull tree removal, and pruning, was done on 117,623 acres with an average federal cost share of \$27 per acre.

Table 3. Accomplishments of the 1979 Forestry Incentives Program.

Region	Federal spending	Reforestation	Timber stand improvement	Total
	<u>Thousand dollars</u>		<u>Acres</u>	
South	10,948	192,353	35,557	227,910
North	2,396	11,890	74,188	86,078
Plains and Rocky Mountains	171	58	3,379	3,437
Pacific Coast	<u>944</u>	<u>7,686</u>	<u>4,461</u>	<u>12,147</u>
Total	14,458	211,987	117,585	329,572

Further breakdowns of the federal cost per acre in the 1979 FIP are also shown in Table 4. Nationally, most acres were treated for \$21-50 in federal expenditures. Less than 9 percent of the acres treated cost more than \$80, while nearly a fifth cost \$20 or less per acre. The largest single category in the program, in both acres treated and total cost, was site preparation and planting in the South. Only 10 percent of the acres treated in this category cost more than \$80 in federal funds.

Because of its large portion of relatively inexpensive TSI, the North had the lowest overall average cost per acre. Yet even in the high-cost region of the Pacific Coast, the average cost per acre for all treatments was less than \$75.

Among treatments, site preparation and planting had the highest per-acre cost, of \$51. The lowest was the combination category of cull tree removal and pruning (combined in the evaluation, but not in actual practice in the field), which averaged \$23 per acre. Overall, the average federal cost of a FIP treatment was \$45 per acre.

The productivity of the acres selected for treatment through the 1979 program was fairly high, with 70 percent in the medium-high class (86-120 cubic feet of merchantable timber per acre per year) as shown in Table 5. Nearly 20 percent of the acres will produce more than 120 cubic feet per year. Land not capable of producing at least 50 cubic feet per year is ineligible for the program.

About three quarters of the acres treated on the Pacific Coast were in the highest productivity class. In the other regions, the majority of the acres were in the medium-high class.

Table 4. Percent of acres treated by 1979 FIP, by federal cost per acre class, treatment, average federal cost per acre, and region.

Region and practice	Percent of acres, by cost per acre class				Average cost per acre
	\$1-20	\$21-50	\$51-80	\$81+	
----- South -----					
Site prep and plant ¹	12.1	37.8	40.6	9.5	49.6
Precommercial thin and release	28.1	70.0	1.2	0.7	25.1
Cull tree removal and pruning	24.0	74.6	1.4	-	25.6
Total	13.9	41.8	35.9	8.4	46.7
----- North -----					
Site prep and plant ¹	12.7	46.5	30.1	10.6	49.9
Precommercial thin and release	28.6	69.1	2.0	0.3	28.1
Cull tree removal and pruning	59.7	37.9	1.7	0.7	21.5
Total	33.7	56.9	7.1	2.3	30.4
----- Plains/Rockies -----					
Site prep and plant ¹	-	37.1	37.1	25.7	94.7
Precommercial thin and release	0.3	33.9	43.9	21.9	59.8
Cull tree removal and pruning	-	100.0	-	-	36.9
Total	0.3	38.8	40.5	20.5	59.6
----- Pacific Coast -----					
Site prep and plant ¹	4.1	9.1	17.9	68.9	94.9
Precommercial thin and release	52.3	13.6	13.3	20.8	41.8
Cull tree removal and pruning	-	-	-	-	-
Total	23.9	10.9	16.0	49.1	73.1
----- U.S. -----					
Site prep and plant ¹	11.9	37.4	39.4	11.4	51.0
Precommercial thin and release	29.6	64.1	3.8	2.6	29.1
Cull tree removal and pruning	46.5	51.5	1.6	0.4	23.1
Total	18.1	43.7	29.4	8.8	44.5

¹Site preparation for natural regeneration included in this practice.

Note: Due to rounding, figures may not add to 100 percent. See Risbrudt and Ellefson 1983 for the states included in each region.

Table 5. Percent of acres treated by 1979 FIP, by site productivity class, region, and practice.

Region and practice	Productivity class in cubic feet		
	50-85	86-120	121+
	----- percent -----		
----- South -----			
Site prep and plant ¹	7.3	74.2	18.5
Precommercial thin and release	10.3	82.2	7.4
Cull tree removal and pruning	9.5	78.3	12.2
Total	7.6	75.0	17.4
----- North -----			
Site prep and plant ¹	16.5	60.2	23.3
Precommercial thin and release	21.9	64.9	13.2
Cull tree removal and pruning	34.0	57.7	8.4
Total	24.0	62.2	13.8
----- Plains/Rockies -----			
Site prep and plant ¹	2.9	71.4	25.7
Precommercial thin and release	38.3	56.2	5.5
Cull tree removal and pruning	6.0	81.9	12.1
Total	34.5	58.7	6.8
----- Pacific Coast -----			
Site prep and plant ¹	12.6	13.5	73.9
Precommercial thin and release	8.0	16.6	75.4
Cull tree removal and pruning	-	-	-
Total	10.7	14.8	74.5
----- U.S. -----			
Site prep and plant ¹	7.9	71.7	20.4
Precommercial thin and release	17.7	66.2	16.1
Cull tree removal and pruning	25.0	65.2	9.8
Total	11.2	70.1	18.7

¹Site prep for natural regeneration included in this practice.

Returns to the investments made through the program varied depending on which initial costs were included. Each yielded a different internal rate of return and present net value discounted at a 4 percent interest rate (advocated for analysis by the USDA Forest Service as the real rate of return before taxes on investment in the private sector (Row, et al 1981)) for the 1979 program. All produced acceptable returns to the investments, as shown in Table 6. Although all income accrues to the landowner when he harvests the additional timber, this same benefit stream was used to calculate the IRR and PNW for both cost options.

Table 6. 1979 FIP aggregate financial returns by cost option and discount rate.

Cost option, weighted IRR, discount rate	Total PNW (\$ millions)	Average PNW (\$/acre)	Total benefit cost ratio	Cases earning discount rate (percent)
Federal cost plus delivery cost				
IRR = 8.9				
10 percent	13.2	49	1.5	45.9
7.125	73.0	271	4.0	57.5
4	421.6	1,564	15.7	72.8
Federal, private, and delivery cost				
IRR = 8.3				
10 percent	8.3	31	1.2	41.1
7.125	68.0	252	3.3	55.9
4	416.7	1,546	13.1	71.9

Site preparation and planting of southern pine far exceeded all other strata in size, accounting for over 63 percent of the 1979 program expenditures. Of the 15 species and practice strata, four had an average internal rate of return of 9 percent or higher for the federal investments--two of the southern pines, northern pine and oak-pine, and Douglas-fir and ponderosa pine combined (Table 7). These four strata with the highest rate of return also accounted for over 80 percent of the federal funds expended, for 64 percent of the additional sawtimber produced, and for 90 percent of the pulpwood produced.

Most of the remaining species group-practice strata exhibited acceptable rates of return, with only three falling below 4 percent. The southern pine and oak-pine, and northern pine and spruce-fir strata generally will produce favorable returns to the investments made through the program. Regionally, the forest type and practice strata in the South averaged an 9.1 percent internal rate of return, with an increase in mean annual increment (over current management) of 98 cubic feet per acre. Strata in the North averaged the lowest internal rate of return, 3.7 percent, with an increase in mean annual increment of 25 cubic feet. The Pacific Coast Douglas-fir and ponderosa pine practices averaged 10.3 percent; the increase in mean annual increment over what might be expected to occur without incentives, is 104 cubic feet per acre.

Most of the increases in growth will result in sawtimber. Over the first rotation, the investments in the South will produce an additional sawtimber increase of about 650 million cubic feet, plus more than 340 million cubic feet of pulpwood (Table 8). In the North, the incremental sawtimber yield will total more than 200 million cubic feet and pulpwood will increase by 28

Table 7. Financial returns and timber yield increases by species group and practices, to Federal investments, including overhead.

Species group and practice	Share of 1979 federal funds	Total yield increase		Internal Rate of Return
	<u>Percent</u>	<u>Sawtimber</u> <u>Million cubic feet</u>	<u>Pulpwood</u> <u>Million cubic feet</u>	<u>Percent</u>
Southern pine				
Plant bare land	8.7	109.8	65.7	10.2
Prepare site & plant	63.1	387.9	256.1	10.5
Southern pine & oak-pine				
Precom. thin & release	3.1	31.2	5.0	7.3
Remove culls	1.1	5.3	-1.9	8.4
Southern pine & oak-pine				
Prepare site for natural regeneration	2.2	22.9	9.7	13.3
Northern pine & spruce-fir				
Plant bare land	2.2	53.0	8.6	6.1
Prepare site & plant	1.5	56.3	4.2	7.7
Precom. thin & release	.4	56.6	6.7	4.0
Prune	2.6	4.4	-1.9	7.5
Oak-hickory				
Precom. thin & release	1.8	4.2	1.2	.1
Remove culls	3.2	13.0	1.0	3.9
Maple-beech-birch				
Precom. thin & release	.5	20.7	6.9	3.5
Remove culls	1.1	5.6	-0.5	6.5
Douglas-fir & ponderosa pine				
All practices	6.5	79.9	-3.3	10.3
Miscellaneous				
All practices	<u>1.6</u>	<u>91.1</u>	<u>8.9</u>	<u>3.4</u>
Total	100.0	941.7	366.5	8.9

million over the first rotation. As for the West Coast, the additional investments will yield nearly 80 million cubic feet of sawtimber, although pulpwood yield will be reduced because of the conversion of red alder to Douglas-fir. Several other individual strata also had reduced pulpwood yields.

Table 8. 1979 FIP additional timber yield, by region.

Region	Average MAI increase (cu.ft./ac.)	Total yield increase	
		Sawtimber	Pulpwood
		(millions of cubic feet)	
South	97.5	647.6	341.4
North	25.4	214.3	28.4
Pacific Coast	104.0	79.9	-3.3

Several of the species group and practice strata--the oak-hickory and maple-beech-birch forest types in particular--had low internal rates of return, usually because the cases cost-shared failed to meet the silvicultural standards. This was not necessarily a reflection of the economic opportunities available in these types. For example, one case consisting of a cull tree removal in oak-hickory earned an internal rate of return of over 11 percent. Some studies have estimated returns to practices in this timber type to range up to nearly 9 percent (Webster and Meadows 1971). The returns estimated to accrue to these timber types were, however, a reflection of investments made under the 1979 program. As the practices were applied, and in the stands in which they were done, the investments made did not yield particularly high returns. In some instances, a disproportionately high percentage of the cases did not pass the minimum silvicultural standards applied against them in this analysis. Failures in hardwoods were generally the result of poor technical advice given to the landowners, or poor practice applications. These problems were also noted in the 1974 evaluation.

ADDITIONAL PROGRAM CONSIDERATIONS

Three major considerations regarding the program are whether the expenditure of federal tax revenues is cost-effective, their effect on the forestry service business, and how many treated remain in timber production through time.

A reasonable estimate of the average federal tax rate on timber income is about 10 percent (Fesco et al. 1982). Since the present net value of future harvests resulting from the forest practice investments was \$422 million at the 4 percent discount rate, under the above assumption the present value of future federal tax receipts is one-tenth of that value, or \$42 million. This is the present value of the tax receipts generated by the 1979 program year which will accrue to the Federal treasury. Therefore, the program will generate federal revenues about 2 1/2 times the annual federal investments. State returns would add even more.

Another consideration is the effect on forestry service business. A seldom considered facet of the program is the ability to maintain an infrastructure of businesses that can apply forestry practices during difficult economic times. Vendors employ the labor and equipment for site preparation and planting, and timber stand improvement for any forest owner who might need this service. In the 25 states with the largest programs, state forestry personnel estimated there are about 2,056 vendors, and about 52 percent of their business is program related. The state foresters estimated that, without the program, 44 percent of these small businesses would be forced out of operation under conditions such as prevailed in 1981.

Retention in forest of cost-shared acres was found so far not to be a major problem. Local Agricultural Stabilization and Conservation Service or state

forestry personnel were asked to determine the areas removed from timber production and the cause of removal for a sample of cases cost-shared in 1974. Their examination revealed that 94 percent of the acres cost shared in 1974 remained in timber as of 1981. The major causes of removal were fire and drought. Other causes noted included development, insects and disease, and flooding. Retention rates are similar to those experienced for pine plantations established in the 1960's under the Agriculture Conservation Program (Kurtz et al. 1980) and the Soil Bank Program (Alig et al. 1980). No allowances were made for these small losses in estimating the economic returns.

ADMINISTRATIVE OPPORTUNITIES

Our evaluation of the 1979 Forestry Incentives Program shows that investments are being directed to stands and sites that will generate an acceptable return. Nevertheless, a number of cases did not meet minimum silvicultural standards, particularly timber stand improvement in the oak-hickory and maple-beech-birch forest types. These failures were strictly under the control and management of the forester, and resulted from any of three major causes. First, timber stands were so old that they will not have time to respond before harvest. Second, insufficient basal area was removed. Third, only understory trees were removed, without releasing or affecting crop trees.

Considerable improvement has been made, however, based on first analysis of the program (Mills and Cain 1979). Since 1974, the average federal cost per acre has fallen in real dollars. The improvement has resulted from generally improving program administration, lowering of the cost-share percentage by the various states, and increasing average tract size so as to capture some economies of scale.

Over the 8 years the program has been in operation, average reforestation tract size has increased 156 percent (Table 9). One of the recommendations of the 1974 evaluation was that reforestation on tracts under 10 acres in size be excluded from cost-sharing since the tracts would likely be too small to support a future commercial harvest. Acting on this recommendation, and placing a high priority on tracts larger than 40 acres, significantly increased the average size of the reforested tracts. These tracts now average nearly 41 acres, up from the 1974 average of 19. Although timber stand improvement is allowed on tracts less than 10 acres (if the owner has this minimum under management), the 1981 average tract size for this treatment has increased by 40 percent over the 22-acre average in 1974.

But program management can still be improved. On the basis of the present analysis, efforts are underway to:

- ° upgrade the technical assistance in the application of silvicultural treatments, especially in hardwood stands;
- ° improve the state level supervision of practice installation;
- ° increase training for field foresters involved in the program; and
- ° critically determine practice eligibility and further define priorities, through economic evaluation.

Through these efforts, improvement in the quality of technical advice and selection of stands should further increase cost-effectiveness of both the financial returns and timber volumes produced under the Forestry Incentives Program.

Table 9. Average Federal cost and average tract size, by practice and year.

Program year	Average federal cost per acre				Average tract size	
	Reforestation		Timber stand improvement		Refores- tation	Timber stand improvement
	Current dollars	Constant	Current dollars	Constant		
		1979 <u>1/</u> dollars		1979 <u>1/</u> dollars		
					-----Acres-----	
1974	39	57	20	30	18.7	21.8
1975-1976 ^{2/}	48	62	18	23	18.6	32.7
1977	47	56	20	24	30.1	32.2
1978	51	57	22	24	33.4	32.6
1979	54	54	26	23	43.0	31.6
1980	61	54	26	23	43.0	31.6
1981	70	56	27	22	40.7	30.6

^{1/} Deflated by the producer price index.

^{2/} Includes the short 1975 year when funds were received late, the full FY 1976, and the transition quarter when the beginning of the FY was changed from July to October.

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ANALYZING BIDS FOR SILVICULTURAL CONTRACTS PROMOTES EFFICIENT ALLOCATION OF FUNDS

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Abstract

Two ratio statistics, G and M, drawn from examination of earlier contracts for silvicultural services, can aid in evaluation of low bids in new contracts. The method is illustrated by 42 contracts from the Kisatchie National Forest, Louisiana, and the National Forests in Mississippi. The G-statistic is the ratio of low bid to mean of all unsuccessful bids on a particular contract. The M-statistic, the ratio of the difference between the two lowest bids and the low bid, represents the profits foregone by the low bidder from underbidding his nearest competitor. Land managers can use the distributions of G- and M-statistics from a set of earlier contracts to evaluate whether a newly opened low bid is a bargain, to help establish the "reasonable cost" of a contract before opening bids, and to help project future budget requests. National forest managers can use G and M to monitor trends in silvicultural contract costs and to help allocate timber management funds more efficiently.

INTRODUCTION

Interest in competitive bidding in forestry has focused primarily on sealed and auction bidding for national forest stumpage. The contractor who bids highest above the appraised value is awarded the right to cut the timber. But another area of competitive bidding has received scant attention--bidding to perform silvicultural services. Services such as tree planting, mechanical site preparation and herbicide injection, are frequently performed by contractors.

Preparing timber sales and service contracts for bidding requires expenditure of budget funds. National forest managers have control over the amount spent on preparing contracts. But the level of payments made to the low bidder to perform silvicultural services is beyond the direct control of the land manager. Because land managers do not have total control over the amount spent for silvicultural services, uncertainty enters the managerial process. Will enough money be available to do all the regeneration and stocking control work needed, or will the bids be too high?

How can foresters judge whether a newly opened low bid is a bargain? Presently, they rely on experience, rules-of-thumb, and intuition for subjective answers. This paper presents simple statistical methods for analyzing bids received on previous contracts for comparison with newly opened low bids. The methods provide an objective evaluation and a basis for improving reasonable-cost estimates and budget projections.

BACKGROUND

National forest managers often advertise and award a dozen or more contracts for silvicultural treatments annually. But the variety of treatments means that only two or three contracts may be awarded each year by a national forest for an activity. Because it is difficult to summarize costs annually by type of treatment, managers have tried to summarize over several years. For example, the low bids of all the shearing contracts over the past decade might be used to estimate average current shearing cost. But the rapid inflation of the late 1970s complicates the analysis of a time series of bids. The Kisatchie National Forest has tried this method with unsatisfactory results.

Similar problems exist in the construction industry, where award of contracts to the low bidder is the rule. Civil engineering contract services are similar to those in silviculture. In fact, more than one third of the successful low bidders for site preparation contracts on national forests in Louisiana and Mississippi in 1980 and 1981 had the word "construction" in their name. Many of the machines used in road and bridge work are also used in mechanical site preparation. Construction projects can also be as labor intensive as planting and herbicide injection.

Research into bidding for civil engineering contracts over the past 25 years has focused on determining the relative value of bids and bidding strategies. The major finding is that cost ratios and their distribution can be used to analyze bidding behavior. As reported here, this method has been modified to analyze bids received on silvicultural service contracts. The theory will be presented in detail in a separate paper.

APPROACH

The same method of analysis will be used for each of two ratio statistics, G and M, to be identified. First, the value of the ratio statistic will be calculated for each of a series of contracts already awarded. Second, because the value of the ratio statistic varies from contract to contract, the statistics will be sorted into a string from smallest to largest. The string of values will be graphed to create a "cumulative distribution function" (cdf) of all the values. This cdf will be called the "sample cdf" because it is based on the values actually observed. Various theoretical probability distributions, such as the normal or exponential distributions, have uniquely shaped cdfs. The third step in the analysis is to check, by means of a statistical test, whether the shape of the sample cdf matches the shape of the cdf from one of the theoretical statistical distributions. If the shapes coincide, the smooth cdf of the theoretical distribution can be used for analyzing future bids instead of the lumpy sample cdf.

The method of analysis is best illustrated by a case study. Contract files were reviewed for all the silvicultural service contracts awarded and successfully completed in FY 1980 and FY 1981 on the Kisatchie National Forest, Louisiana, and on the National Forests in Mississippi.

Two adjustments were made to the data. First, contracts having only one or two bids were not considered because the number of unsuccessful bids was either zero or one. Bidding competition on such contracts is minimal. There were 42 contracts having more than two bids (table 1). Second, all bids more than three times higher than the low bid were deleted from the analysis. Economic theory presumes that all bidders are well informed about the amount of labor and equipment needed to perform a specific job and the hourly costs of labor and equipment employed. But a bid 300 percent higher than low bid was judged to be an uninformed bid. One bid from each of four contracts was deleted for this reason. For analysis, three of the four contracts had 10 bids left; the fourth had 6 bids left. The mean number of bids per contract analyzed was 6.6.

G-Statistic

For each of the 42 contracts, the statistic G was calculated:

$$G_i = \frac{\text{Low bid on contract } i, \text{ in dollars}}{\text{Mean of all unsuccessful bids on contract } i, \text{ in dollars}}$$

The G-statistic measures the "goodness" of a low bid by relating it to the average of all the unsuccessful bids. Easy calculation is the foremost advantage of G. For example, suppose five bids on a handplanting contract were \$30, \$31, \$33, \$39, and \$41 per acre. The average of the unsuccessful bids is $(\{\$31 + \$33 + \$39 + \$41\}/4 =) \$36$. The value of G is $(\$30/\$36 =) 0.806$. Secondly, the ratio is dimensionless, not tied to the dollar value of the bid, and can be compared across contracts of different absolute cost and type of activity. Finally, G has a finite range between 0 and 1, making it easy to analyze statistically.

The analysis of G has three steps. First, the sample cdf was calculated. To do this, the G-statistics calculated for each of the 42 contracts were placed in order from smallest to largest. Because there are 42 contracts, each represents 2.4 percent of the whole set. The lowest G calculated was 0.452. Mathematically, the probability (Pr) that a G less than 0.452 will occur in the sample is 2.4 percent, or symbolically, $\text{Pr}(G < 0.452) = 0.024$. The first point in the cdf is therefore plotted at $(0.452, 0.024)$ (fig. 1). The rank order of the 42 G-statistics and their associated probabilities is listed in Table 2. The second lowest G in the sample was 0.456, so there is only a 4.8 percent $(2/42)$ chance that a G equal to or less than 0.456 will occur: $\text{Pr}(G < 0.456) = 0.048$. The second point in the cdf is plotted at $(0.456, 0.048)$ (fig. 1). This process continues up to the 42nd and last point plotted at $(0.946, 1.00)$. The plot forms an S-shaped curve called the sample cdf, $S(G)$ (fig 1).

Because small sample sizes cause problems in the following steps of the analysis, a minimum of 30 contracts should be included in the sample. To obtain this many for the case study, data from two adjacent national forests and two fiscal years were combined. The same contractor may hold more than one contract, either in the same year on both forests or in successive years

Table 1.--Summary of contract data

	Kisatchie National Forest	National Forests in Mississippi
Number of contracts	23	19
Types of treatments		
a. Planting	8	9
b. Mechanical site preparation	9	6
c. Herbicide injections	6	4
Mean number of bids	7.04	6.00

Table 2.--Rank order of G-statistics and $\Pr(G \leq G_i)$ for $i = 1, \dots, 42$ contracts

G	$\Pr(G \leq G_i)$	G	$\Pr(G \leq G_i)$	G	$\Pr(G \leq G_i)$
0.4527	0.024	0.6554	0.357	0.7289	0.690
0.4563	0.048	0.6563	0.381	0.7333	0.714
0.4639	0.071	0.6704	0.405	0.7445	0.738
0.5020	0.095	0.6767	0.429	0.7508	0.762
0.5507	0.119	0.6848	0.452	0.7622	0.786
0.5670	0.143	0.6955	0.476	0.7830	0.810
0.5700	0.167	0.6960	0.500	0.7853	0.833
0.5774	0.190	0.6975	0.524	0.8039	0.857
0.6062	0.214	0.6996	0.548	0.8149	0.881
0.6260	0.238	0.7003	0.571	0.8263	0.905
0.6389	0.262	0.7005	0.595	0.8309	0.929
0.6429	0.286	0.7039	0.619	0.8668	0.952
0.6443	0.310	0.7226	0.643	0.8686	0.976
0.6536	0.333	0.7242	0.667	0.9462	1.000

Figure 1.--Cumulative distribution function, $S(G)$, for the empirical set of G_i , $i = 1, 2, \dots, 42$

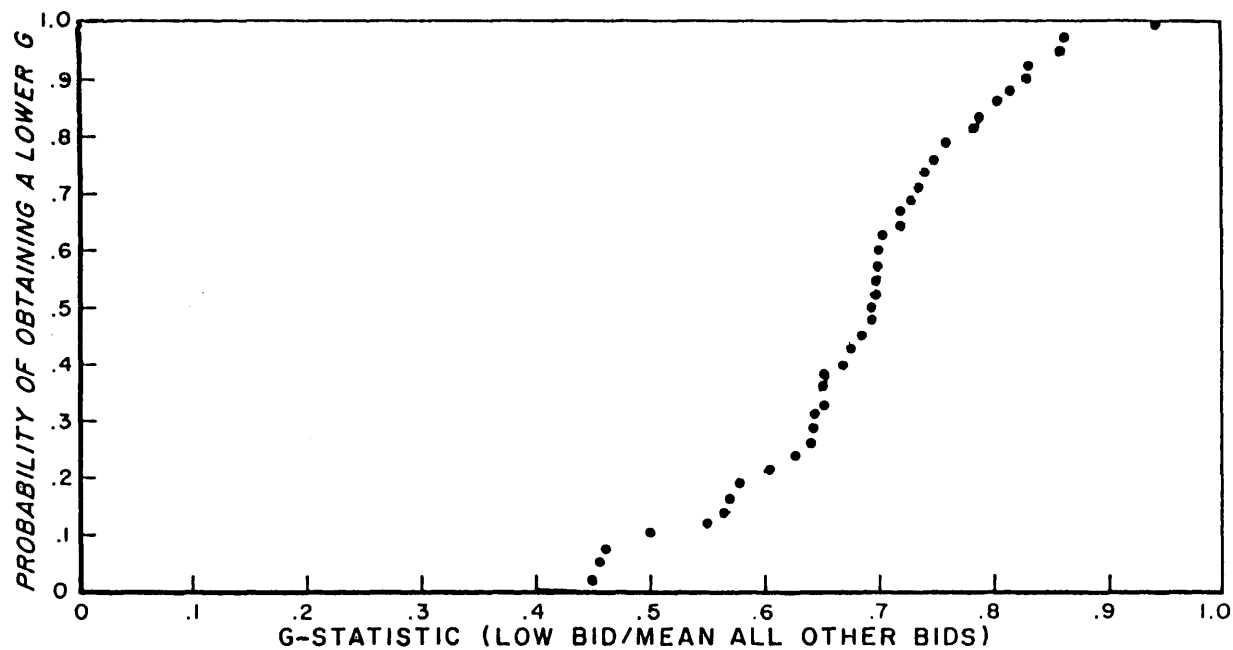
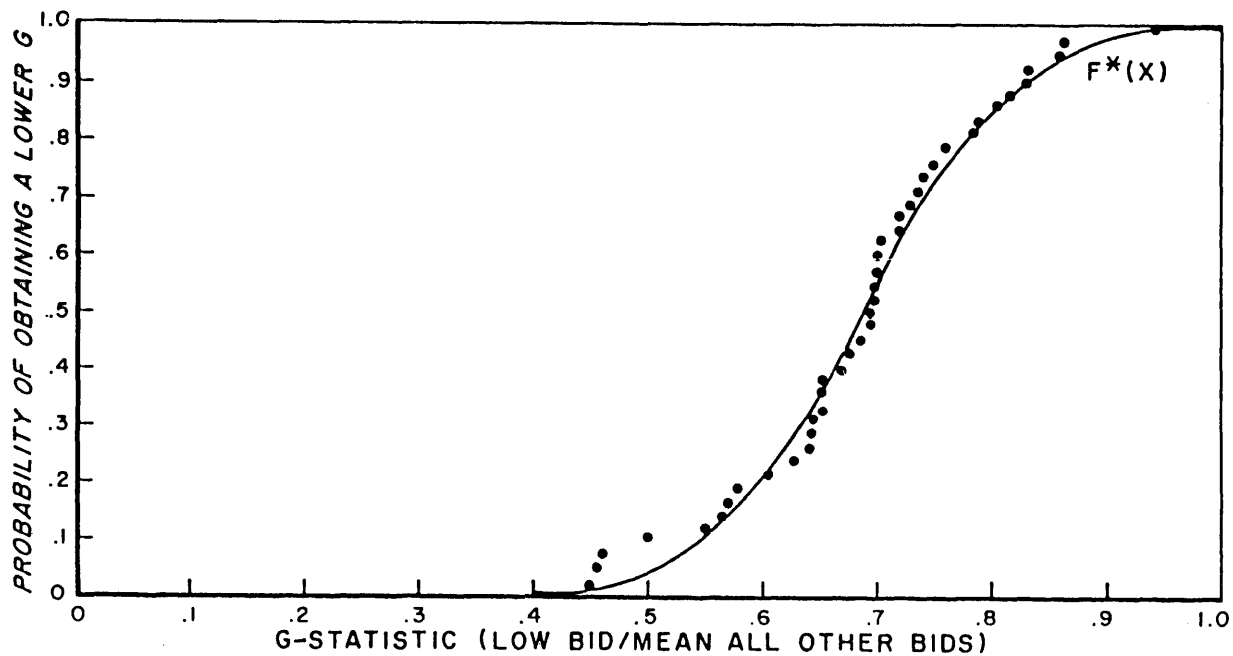


Figure 2.--Normalized cumulative distribution function $F^*(G)$ superimposed on the cumulative distribution function of the empirical set of points, $S(G)$.



on the same forest. This causes no problems. If data from several national forests are combined, a rule of thumb is to choose similar forests. For example, Texas national forest data could be easily combined with the 42 cases at hand because southern pine is the principal species and the geography is similar to that of central Louisiana and Mississippi. But data from the Daniel Boone National Forest in Kentucky, for example, should probably not be combined with data from Louisiana and Mississippi.

The S-shape of $S(G)$ is characteristic of the normal cumulative distribution. The second step in the analysis of G is to determine if the sample cdf reasonably approximates a normal cdf. We begin by calculating the mean ($\bar{G}$) of the 42 G -statistics and their standard deviation (s) about the mean, using the formula:

$$s = \frac{\left[\sum G^2 - \frac{(\sum G)^2}{N} \right]^{1/2}}{N-1}$$

The s for the case study data is 0.1118; $\bar{G}$ is 0.6876. These two values are used to transform the scale and location of the general normal cdf to that of the sample cdf, in order to calculate the normal probability of obtaining a G less than or equal to each G value. To do this, we calculate a new variable z_i , the standard normal variate, for each contract $i = 1, \dots, 42$.

$$z_i = \frac{G_i - \bar{G}}{s} = \frac{G_i - 0.6876}{0.1118}$$

The z_i will be negative for those G_i less than the mean. The probability of obtaining a z less than or equal to each z_i can now be looked up in a normal probability table (table 3). For example z_1 for $G_1 = 0.452$ is -2.11. Looking in Table 3, the probability of getting a z less than or equal to z_1 is 0.0174. Thus, the first point in the normal cdf, $F^*(G)$ in Figure 2, is (0.452, 0.0174). For $G_2 = 0.456$, $z_2 = -2.07$. The $\Pr(z \leq -2.07) = 0.0192$, therefore, the second point on the normal cdf is (0.456, 0.0192). The process of transforming each G_i into a standard normal variable z_i continues for all points. For the last G , $G_{42} = 0.9462$, $z_{42} = 2.31$, having a probability of 0.9896. The last point in the normal cdf becomes (0.946, 0.990).

The third step in the analysis of G is to compare the shapes of the sample and normal cdfs (fig. 2). The comparison is performed statistically by calculating the difference in probabilities between the sample cdf and the normal cdf for each G_i , in order to locate the maximum difference, D , between the probabilities of both cdf's. The assumption that the normal cdf is no different from the sample cdf can be accepted if the value of D is less than the value of D^* (N is the number of contracts):

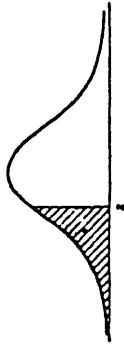
$$D^* = 0.886(N^{-1/2})$$

In the case study, $D^* = 0.1367^1$. Because the test shows no difference, the smooth normal curve $F^*(G)$ (fig. 2) can be used for further analyses instead of the original sample cdf.

¹ This procedure is a Kolmogorov-Smirnov test for goodness-of-fit at the 5 percent level, described by Lilliefors (1967).

Table 3.--Values for the standard normal distribution function

$$\Phi(z) = \int_{-\infty}^z \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{1}{2}u^2\right) du = P(Z \leq z)$$



z	0	1	2	3	4	5	6	7	8	9	z	0	1	2	3	4	5	6	7	8	9
-3.	.0013	.0010	.0007	.0005	.0003	.0002	.0002	.0001	.0001	.0000	.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
-2.9	.0019	.0018	.0017	.0017	.0016	.0016	.0015	.0015	.0014	.0014	.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
-2.8	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019	.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
-2.7	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026	.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
-2.6	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036	.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
-2.5	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048	.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
-2.4	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064	.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
-2.3	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084	.7	.7580	.7611	.7642	.7673	.7703	.7734	.7764	.7794	.7823	.7852
-2.2	.0139	.0136	.0132	.0129	.0126	.0122	.0119	.0116	.0113	.0110	.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
-2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143	.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
-2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183	1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
-1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0238	.0233	1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
-1.8	.0359	.0352	.0344	.0336	.0329	.0322	.0314	.0307	.0300	.0294	1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
-1.7	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367	1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
-1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455	1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9278	.9292	.9306	.9319
-1.5	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0570	.0559	1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9430	.9441
-1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0722	.0708	.0694	.0681	1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
-1.3	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823	1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
-1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985	1.8	.9641	.9648	.9656	.9664	.9671	.9678	.9686	.9693	.9700	.9706
-1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170	1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9762	.9767
-1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379	2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
-.9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611	2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
-.8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867	2.2	.9861	.9864	.9868	.9871	.9874	.9878	.9881	.9884	.9887	.9890
-.7	.2420	.2389	.2358	.2327	.2297	.2266	.2236	.2206	.2177	.2148	2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
-.6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451	2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
-.5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776	2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
-.4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121	2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
-.3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483	2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
-.2	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859	2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
-.1	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247	2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
0	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641	3.	.9987	.9990	.9993	.9995	.9997	.9998	.9998	.9999	.9999	1.0000

Note 2: For $z \geq 4$, $\Phi(z) = 1$ to four decimal places; for $z \leq -4$, $\Phi(z) = 0$ to four decimal places.

Note 3: Entries opposite 3 and -3 are for 3.0, 3.1, 3.2, etc., and -3.0, -3.1, etc., respectively.

Note 1: If a normal variable X is not "standard," its values must be "standardized":
 $Z = (X - \mu)/\sigma$, i.e., $P(X \leq x) = \Phi[(x - \mu)/\sigma]$.

M-Statistic

The second ratio analyzed was the M-statistic, the margin between the low bid and the second bid, expressed as a percentage of the low bid:

$$M = \frac{\text{Second low bid} - \text{low bid}}{\text{Low bid}} = \frac{\text{Second low bid}}{\text{Low bid}} - 1$$

For example, if the two lowest bids are \$40 and \$42, M is $(\{42 - \$40\}/\$40 =) 0.05$. The M-statistic is commonly used in construction bidding as a measure of the money foregone ("left on the table") by the low bidder. Ideally, the low bidder seeks to minimize the difference between his bid and the next higher bid.

The analysis of the M-statistics also proceeds in three steps. First, M-statistics for all 42 contracts were calculated, placed in rank order from smallest to largest, and a sample cdf, $S(M)$, plotted with the probability interval between points equal to $(1/42)$ 2.4 percent (table 4 and fig. 3). The shape of $S(M)$ is characteristic of the exponential probability distribution.

Plotting the exponential cdf, the second step in analyzing M, requires calculating mean M ($\bar{M}$), equal to 0.1890. Instead of having to look up probabilities in a table as in the analysis of G, we can calculate exponential probabilities directly from $Y(M_i)$:

$$Y(M_i) = 1 - e^{(-M_i/\bar{M})} = 1 - e^{-M_i/0.1890} = 1 - e^{-5.291M_i}$$

The answer for $Y(M_i)$ is the probability of obtaining an M less than or equal to M_i . Using $M_{21} = 0.1468$ as an example,

$$Y(M_{21}) = 1 - e^{-5.291(0.1468)} = 1 - e^{-0.777} = 1 - 0.460 = 0.540$$

Calculating and plotting for all 42 $Y(M_i)$ yields the exponential cdf, $Y^*(M)$ (fig. 4).

The third step in analyzing M is to compare the shapes of $S(M)$ and $Y^*(M)$. The differences in probabilities between $S(M)$ and $Y^*(M)$ for each M_i are calculated in order to locate the maximum difference, D, between the probability of the two cdf's. Here, D equals 0.066 at M_3 . The assumption that the exponential cdf is no different from the sample cdf can be accepted if the value of D is less than the value of D^* :

$$D^* = 1.06(n^{-1/2})$$

In the case study, $D^* = 0.164$.² Because the test shows no difference, the smooth exponential curve (fig. 4) can now be used for further analyses instead of the original sample cdf.

²This procedure is a Kolmogorov-Smirnov test for goodness-of-fit at the 5 percent level, described by Lilliefors (1969).

Table 4.--Rank order of M-statistics and $\Pr(M \leq M_i)$ for $i = 1, \dots, 42$ contracts

M	$\Pr(M \leq M_i)$	M	$\Pr(M \leq M_i)$	M	$\Pr(M \leq M_i)$
0.0001	0.024	0.0763	0.357	0.2250	0.690
0.0001	0.048	0.0800	0.381	0.2539	0.714
0.0010	0.071	0.0870	0.405	0.2558	0.738
0.0061	0.095	0.1025	0.429	0.2587	0.762
0.0149	0.119	0.1131	0.457	0.2626	0.786
0.0177	0.143	0.1171	0.476	0.2865	0.810
0.0256	0.167	0.1468	0.500	0.3266	0.833
0.0321	0.190	0.1593	0.524	0.3701	0.857
0.0325	0.214	0.1726	0.548	0.4461	0.881
0.0395	0.238	0.1743	0.571	0.4686	0.905
0.0453	0.262	0.1748	0.595	0.4751	0.929
0.0679	0.286	0.1850	0.619	0.5058	0.952
0.0696	0.310	0.1851	0.643	0.5399	0.976
0.0748	0.333	0.2089	0.667	0.8000	1.000

Table 5.--Student's t-statistic critical points for confidence intervals of 95 and 99 percent, by number of contracts in the sample

Number of contracts	t-statistic for 95%	t-statistic for 99%
10	2.262	3.250
15	2.145	2.977
20	2.903	2.861
25	2.064	2.797
30	2.045	2.756
35	2.034	2.732
40	2.023	2.709
50	2.013	2.684
60	2.001	2.662
90	1.990	2.640
120	1.983	2.618
∞	1.960	2.576

Figure 3.--Cumulative distribution function, $S(M)$, for the empirical set of M_i , $i = 1, 2, \dots, 42$

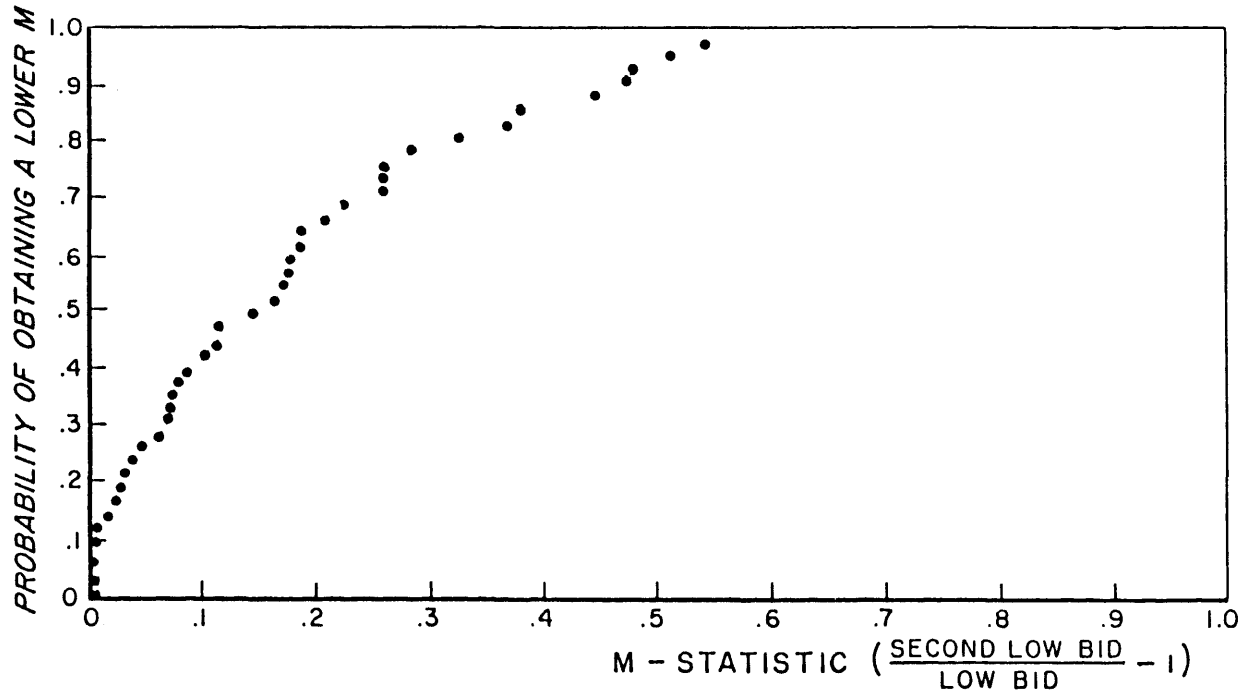
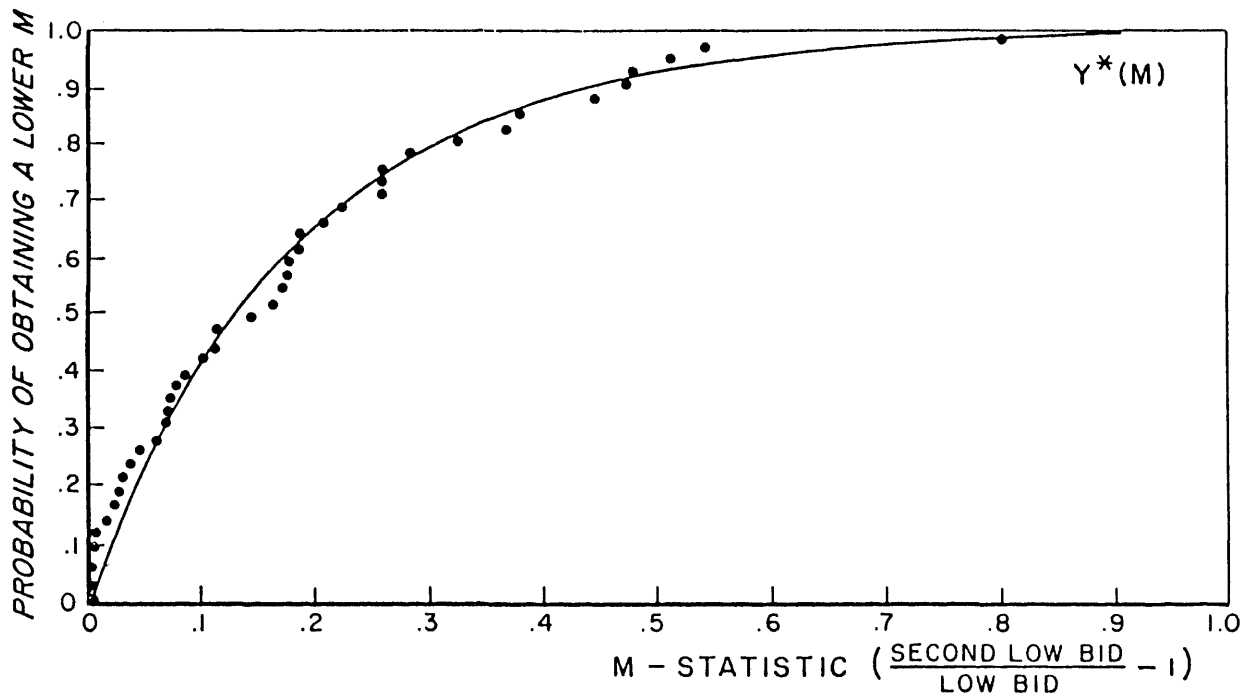


Figure 4.--Exponential cumulative distribution function $Y^*(M)$ superimposed on the cumulative distribution function of the empirical set of points, $S(M)$



DISCUSSION

Evaluating Bids

At present, land managers judge bid "fairness" or "competitiveness" by subjective methods, such as comparison with last year's low bid for the same task or comparing two current bids. But relying solely on memory, or just using past low bids for comparison, risks ignoring relevant information. For example, human memory tends to remember only the unusual events, those out of the ordinary. Similarly, using only current bids for evaluation ignores the question of whether the bids are relatively low or relatively high. Most subjective approaches lead to bias of one form or another. The G and M statistics provide a way to make bid evaluation more objective. They expand information use by incorporating all bids, (G), and the nearest competitor, (M).

To evaluate whether a newly opened low bid is a bargain compared to earlier contracts, calculate G and read the probability of obtaining a lower low bid from the y-axis of the normal cdf (fig. 2). For our study, the probability of receiving a bid with a lower G changes rapidly over a narrow range. For a newly opened set of bids with a G of 0.85, a lower low bid occurs 90 percent of the time. Such a bid is not much of a bargain. Conversely, a set of bids with a lower G than 0.60 occurs less than 20 percent of the time, quite a good bargain. Comparing G for a new contract to the distribution of G for past contracts measures the relative value of the new low bid.

It is often useful to categorize a bid on a new contract as a "bargain" or "not a bargain", compared to past contracts. How can the range of G be split into these two categories? Using $\bar{G}$ as the dividing line is one way of splitting the distribution. But as more contracts are added to the sample, $\bar{G}$ will change. If the G for new contracts added to the sample are distributed the same way as the first batch considered (in statistical terms, drawn from the same population as the first set of G), then $\bar{G}$ will vary as a function of the standard deviation (s) of the sampled G and the number of G-statistics in the sample. A "confidence interval" that will contain the actual mean G a certain percentage of the times $\bar{G}$ is estimated is calculated by the formula

$$X \text{ Percent Confidence Interval} = \bar{G} \pm t(s)(N^{-1/2})$$

where t is the Student's t-statistic selected for the desired probability level, usually either 95 or 99 percent (table 5). For the case study, therefore

$$\begin{aligned} 95 \text{ Percent Confidence Interval} &= 0.6876 \pm 2.019 (0.1118)(42^{-1/2}) \\ &= 0.6876 \pm 0.0348 \\ &= 0.6528 \text{ to } 0.7224 \end{aligned}$$

To be 99 percent certain of including the true mean in the interval, we would use the higher t value (table 5), which widens the interval to 0.6410 to 0.7342.

If G for a new contract falls below the lower interval boundary, managers can confidently assert that the low bid is a bargain compared to past

contracts. If G for a new contract is greater than the upper interval bound, the low bid is less of a bargain than expected. If G for a new contract falls inside the interval, it is not really different from $\bar{G}$, and hence cannot be labeled either as a bargain or not a bargain.

Naturally, managers are pleased to obtain low bids whose G falls into the bargain category. But a low G is also frequently associated with uninformed or erroneous bids. If a bidder unknowingly submits an unrealistically low bid, he may default part way through the job because he is failing to make a profit, or he may try to skimp on quality to hold down costs. Consequently, excessively low bids, while initially appearing to be a bargain, may turn out to be no bargain at all. Devoting special attention to suspect bidders may help prevent poor quality work, or identify probable defaults early enough that the contract can be rebid and the work accomplished the same season. This is especially important for planting contracts.

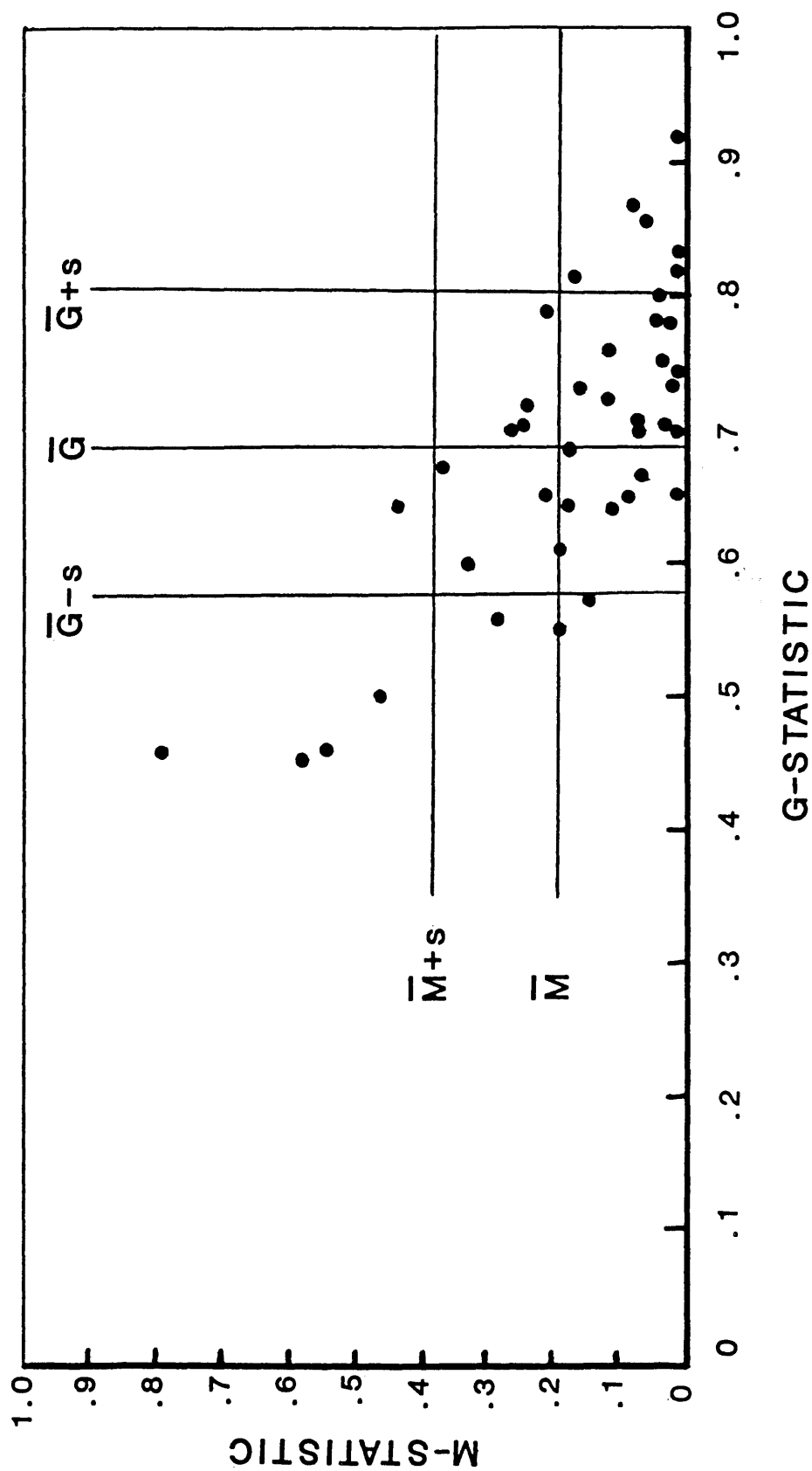
The M -statistic can help identify those contracts deserving special attention. Recall that M represents the margin between low and second low bids. The chance that two independent bidders will simultaneously make a mistake and hence bid abnormally low is less than that only one bidder will err. A low M means the two lowest bidders agree closely on their assessment of the cost of doing the job. A high M means the low bidder either has a distinct advantage over the second low bidder, perhaps due to lower cost structure, or has mistakenly evaluated job requirements. So in the event a new contract has a very low G and also a very high M , chances increase that the low bid is unrealistic. Contractors who combine low G , high M and good performance will usually be well-known, frequent bidders and bid winners. Contractors combining low G , high M and lacking experience in similar contracts will be infrequent or novice bidders. Special monitoring is indicated in such situations.

How low is "very low" G and how high is "very high" M ? The standard deviation measures the scatter of data points about the mean. Because our tests have shown that there is no significant difference between the sample and normal cdf, the probability of obtaining a G as low or lower than $\bar{G}$ minus s , ($0.6876 - 0.1119 = 0.5758$), is 15.9 percent--less than one chance in six. Similarly, assuming exponentiality (whereby s equals the mean), the probability of obtaining an M as high or higher than $\bar{M}$ plus s ($2 \times 0.1890 = 0.378$), is 13.5 percent--less than one chance in 7. Four of the 42 contracts fell into the suspicious field bordered by $(\bar{G}-s)$ and $(\bar{M}+s)$ (fig 5). Using these bounds appears a useful rule-of-thumb for flagging unusually low and isolated low bids.

Estimating Reasonable Costs

The G -statistics can help estimate reasonable costs. A land manager or contract officer, for example, may want to improve the reasonable-cost estimate for shearing and raking contracts. Considering the specific conditions and the cost of the extra work and time to justify awarding a bid when all bids exceed reasonable cost, he concludes that he can assume that at least one bid must be lower than the reasonable cost on 90 percent of the contracts advertised. From $F^*(G)$ (the normalized cdf), we find that the value of G having a probability less than 0.9 is 0.85 (fig. 2). Multiplying the 1980 average low bid for shearing and raking in the southern coastal plain,

Figure 5.--The joint distribution of the G and M statistics



\$95.52 per acre (Guldin 1983), by the quotient of desired G and mean G ($0.850/0.6876 = 1.23$) yields a 1980 reasonable cost estimate of \$117.66 per acre.

Because G is dimensionless, site variability and inflation do not complicate the process of summarizing information. Although dollar values of bids will be higher on more difficult sites, higher G's do not necessarily result. However, when G is used to estimate reasonable cost for a harsh site, the cost used as the multiplicand must be an average low bid from sites for similar difficulty. Although inflation raises both the low bid and the average of all remaining bids, the ratio of these two figures is virtually unaffected so long as inflation affects all contractors equally. Thus, ratios can be aggregated over a period of years without adjustments for inflation. However, adjustments are needed to project reasonable cost for future contracts. For example, inflation since 1980 and projected until July 1983 totals 21 percent (based on Bureau of Labor Statistics Producer Price Indices). Therefore, the 1980 estimate of \$117.66 per acre should be inflated by 21 percent to \$142.34 to estimate the reasonable cost of shearing and raking in 1983. Relegating inflation considerations to the final step in estimating reasonable costs greatly simplifies the analysis.

Estimating Budget Expenditures

The G-statistics provide additional information for helping project budget expenditures. Methods such as unweighted arithmetic averages of low bids, or averages weighted by contract acreage, fail to account for low bids that are unusually low or high, and therefore not likely to be repeated. Using the ratio of $\bar{G}$ to contract G to adjust unusual bid prices provides a firmer basis for projecting future costs.

To illustrate the problem, suppose a forester in the Kisatchie National Forest Supervisor's Office had to project FY 1982 herbicide injection expenditures based on the actual low bids from six contracts awarded in FY 1980 and FY 1981:

<u>Cost/Acre</u>	<u>Contract Acreage</u>	<u>G-Statistic</u>	<u>Probability of a Lower G</u>
\$42.00	305	0.6996	0.543
35.00	293	0.4639	0.023
24.85	541	0.6260	0.291
24.00	793	0.5507	0.110
23.40	458	0.8668	0.946
22.38	441	0.4527	0.018

Calculating the average cost weighted by the contract acreage yields an average cost per acre,

$$\frac{\sum[(\text{Cost/Acre}) \times (\text{Contract Acreage})]}{\sum \text{Acreage}} = \$26.89$$

On average, a G of 0.6876 is expected for each contract. Assuming that all the unsuccessful bidders bid approximately the same amount in FY 1982 (thereby keeping the mean of all unsuccessful bidders the same) and that the low bidder bids an average low bid instead of an exceptionally high or exceptionally low amount, we can find the projected per-acre contract cost. The computation must be adjusted by including the ratio of $\bar{G}$ to contract G:

$$\frac{\sum [(\text{Cost/Acre}) \times (\text{Contract Acreage}) \times (0.6876/\text{Contract G})]}{\sum (\text{Acreage})} = \$31.72$$

An extra \$4.83 per acre (18 percent more) is needed to compensate for the abnormally low Gs.³ The final steps are to increase the \$31.72 for an inflation percentage and multiply the result by projected acreage to be treated in FY 1982. If G for the set of low bids for a particular service has a normal distribution about mean G, there will be little difference in average per-acre costs with and without the G ratio adjustment. The adjustment serves to assure that national forests which obtain exceptional bargains in one or two years that have little chance of being repeated are not penalized in future years with lower budgets.

CONCLUSIONS

The G- and M-statistics are useful tools for foresters responsible for timber management and silvicultural service contract administration. They are easy to calculate, well-behaved statistically, and easy to interpret. The statistics provide information to help managers evaluate the relative value of low bids, estimate reasonable costs and project future management budgets. By using them to monitor trends in contract costs, managers have a more objective basis for allocating limited timber management funds.

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³ Interested readers can demonstrate that without weighting for contract acreage, average costs would rise from \$28.60 without the G ratio to \$33.83 per acre adjusted with the G ratio.

SOME ECONOMIC ASPECTS OF R8 PLANNING

Richard Greenhalgh
Regional Economist, R8

The NFMA regulations place a heavy emphasis on economic aspects of planning. We are directed to assess present and future demand, analyze a full range of supply capabilities with associated costs, develop alternatives reflecting an efficient combination of multiple use management prescriptions and determine a monetary expression of resource trade-offs and opportunity costs associated with achieving alternative resource objectives. Various versions of a linear programming model, referred to as FORPLAN, are being used as one of the main analysis tools to accomplish this task.

In this paper I have concentrated on the development of the silvicultural aspects of two basic data sets essential to this overall analysis framework. The two data sets are product demand and cost data.

Timber yields are another very important data set necessary for any economic analysis. Due to time, I will skip over the development of yields. I do think that R-8's effort in this regard, which involved coordination with TVA on a yield simulator, may have been a somewhat different approach and encourage anyone interested to pursue it with the Timber staff in R-8.

I will close with a discussion of some preliminary implications which have surfaced from our individual Forest analyses to date. The perfect plan is an ideal goal but reality suggests we should recognize our shortcomings and strive to improve upon them. It is in this context that I have approached the last section.

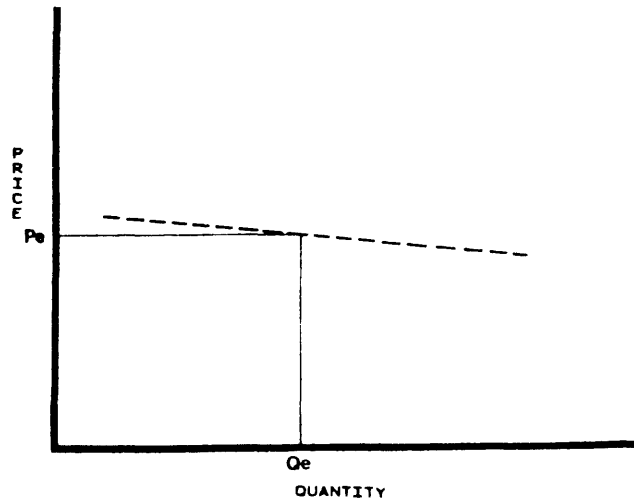
Demand Analysis

In the Southern Region, the National Forest system plays a very small role in the total supply of timber products and elasticity estimates by resource suggest a very flat demand curve. For these reasons, demand for timber was represented by a horizontal demand curve over a specified range in Forest Land Management Planning (FLMP). The current equilibrium price was determined from analysis of sales data and projected into the future based upon 1980 RPA value indexes. The Forests timber output targets in the Draft Regional Guide were generally used as point estimates of the equilibrium quantity for future periods.

Forests are estimating the equilibrium price (stumpage value) for several dominant timber types through an analysis of historical sales data. A trend value was established for the beginning of the planning period if a significant trend was established through regression analysis. If a significant trend was not found, a 5-year average was used. The equilibrium price estimated in this manner is further differentiated by product mix for each timber type.

Figure 1 graphically displays the theoretical model of demand we are attempting to reflect. The dashed line represents the downward sloping demand for timber on a specific Forest for a specific point in time. The equilibrium price (P_e) and equilibrium quantity (Q_e) represent the values that would result in a free market. It is at this level of output that producers in a market economy would be willing to supply the same quantity of timber as consumers demand at price P_e .

Figure 1



Competitive bidding prevails throughout the Region and these value estimates are considered to be very good representations of current equilibrium price in a free market. The future trends established for Region 8 in the 1980 RPA were assumed to be appropriate for all Forests in the Region. To do otherwise would have required some assumptions regarding geographic distribution of the development of new processing facilities and market expansions which are not easily predicted by forest market area. Some insight could be assembled regarding the first period, but beyond the first 10 years the data is not available at the individual Forest level.

Equilibrium quantities for future periods are assumed to be reflected by the Forest targets in the Draft Regional Guide. This assumption is based on the consistency between the trend in projected future demand for softwood and hardwood from all timber lands, public and private, in the South and the 1980 RPA timber output targets for R-8. The index of projected RPA targets for National Forests is somewhere between the indexes projected for softwood and hardwood at the aggregate level, Table 1.

Generally as supply expands, marginal and underutilized resources are brought into use. Many public lands are currently less accessible and harvested less intensively than private lands. As aggregate supply expands in the future, more intensive use of National Forest timber lands may be required. This type of trend is generally reflected in Table 1 with projected demand increasing by 239% over the next 50 years.

National Forest systems currently produce about 4% of the total supply of timber products in the South and the RPA targets reflect a general trend toward maintaining the current share of aggregate supply from public lands. It seems reasonable to accept the RPA timber targets as an estimate of the quantities demanded from R-8 in the future.

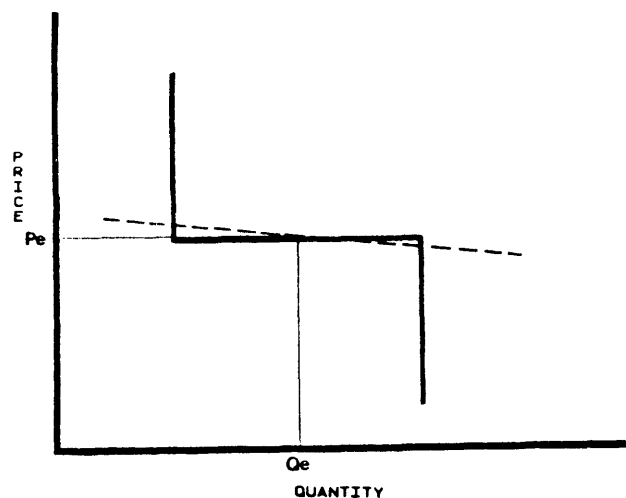
TABLE 1
INDEX OF PROJECTED CHANGE IN DEMAND AND RPA TARGETS
INDEX FOR 1976 = 100

<u>Period</u>	<u>Demand for South</u>		<u>R-8 RPA Targets</u>
	Softwood	Hardwood	
1990	140	189	143
2000	149	237	187
2010	166	285	245
2020	173	337	288
2030	181	367	339

The RPA targets for R-8 were assigned to individual Forests based upon several factors including knowledge of past production trends, current and future production capabilities, expected market conditions, and local concerns for timber production emphasis. Assuming that the 1980 R-8 RPA targets are good estimates of the quantities demanded at future times for the Region, then the timber target distribution in the Regional Guide are reasonable estimates of equilibrium quantities demanded for individual Forests.

The estimated equilibrium prices and quantities data are further expanded to reflect a horizontal demand over a specified range of $\pm 50\%$ for analysis purposes in FLMP. This approach is presented graphically in Figure 2.

FIGURE 2



The approach for timber in R-8 is supported by two related characteristics of demand: (1) Estimates of the elasticity of demand (slope of demand curve) for the South reflect a very elastic curve (very little slope) and (2) Supply from National Forest systems is a very small percentage of total from all lands. Elasticity estimates developed by research are generally less than .01 suggesting that a 50 percent change in quantity supplied would be expected to influence prices by less than .5 percent. Region 8 has one of the lowest elasticity estimates and a smaller market share than most Regions, thus the horizontal demand assumption is easier to justify.

The limited role National Forest systems play in the supply of aggregate demand is shown in Table 2. None of the Forests supplies more than 10 percent of the total supply of the respective states production. Market areas don't necessarily follow political boundaries but a similar situation would result from a more detailed analysis of National Forest supply as a percent of mill capacity in the market area of the individual Forests.

TABLE 2
TIMBER REMOVALS, RELATIONSHIP OF FORESTS TO STATES, 1976

<u>FOREST/STATE</u>	<u>STATE PRODUCTION</u> (MMCF)	<u>FOREST</u>	
		<u>Production^{1/}</u> (MMCF)	<u>% of State</u>
NFs in Alabama/Alabama	830.1	10.9	1.3
Ozark-St. Francis/Arkansas	601.2	6.6	1.1
Ouachita/Arkansas	601.2	32.7	5.4
Chattahoochee-Oconee/Georgia	1,041.1	11.4	1.1
NFs in Florida/Florida	326.1	11.3	3.5
Daniel Boone/Kentucky	142.5	3.5	2.4
Kisatchie/Louisiana	617.5	28.1	4.5
NFs in Mississippi/Mississippi	733.5	31.7	4.3
NFs in NC/North Carolina	666.0	1.3	.2
Francis Marion-Sumter/SC	502.2	1.8	.3
Cherokee/Tennessee	196.1	7.7	3.9
NFs in Texas/Texas	479.4	17.6	3.7
George Washington/Virginia	496.0	.5	.1
Jefferson/Virginia	496.0	.7	.1

Cost Data

Multiple use prescriptions for different levels of management intensity are developed for small areas on the Forest with similar physical characteristics. The cost of applying these prescriptions was developed by initially identifying the MIH code activities involved in each prescription. Average Forest-wide costs for these activities were adjusted through (1) professional appraisal of the appropriateness of existing accounting costs computed from annual budgets, and (2) identification of cost deviations from average conditions based upon physical and biological characteristics of the analysis areas.

^{1/}Volume reported sold in cut and sold report.

In the past, we have accomplished some unfunded or inadequately funded activities with whatever funds were available. Such an approach tends to bias any analysis of historical costs and hampers attempts to validate costs through comparative analysis with research information or similar Forest data. Recognition of past accounting procedures places a high importance to the first step. This emphasizes the need for professionals such as Silviculturists to work with Economists and others to validate the prescription costs.

The majority of the unexpected Forest analysis results which were traced to data errors in our Region have been related to inappropriate specification of cost data. One example relates to an evaluation by a Forest of the cost activities associated with single tree or group selection harvest. These costs were lower than the costs for activities involved in even-age harvest cutting methods. The Forest was finding considerable acreage being allocated to prescriptions with group selection based upon cost effectiveness. Further review of the cost data determined that some of the activity costs for selection harvest were underestimated.

There is a general inclination to resort to average costs when information on recognized differences is not readily available. The importance of reflecting significant cost differences between a specific activity in prescriptions for different areas of land and between different activities in prescriptions on the same tracts needs to be fully understood. For example, the site preparation costs of natural regeneration and stocking with superior trees can be quite different. Resource allocation should be influenced by a differentiation in these costs. Failure to estimate recognized difference leaves this aspect to random selection.

Just as it is important to differentiate between significant differences in activity costs, it is also important not to reflect differences when they do not exist. When the same costs are used, however it is important to check for random allocations. If clearcutting, seedtree and shelterwood harvesting methods are reflected in different prescriptions for the same area but no cost or yield differences are established, the selection between these prescriptions may be meaningless.

Road cost is another item which has substantial economic implications regarding resource allocation and the timing of silvicultural activities. From an economic perspective it is important that areas be differentiated with regard to access; and the costs of construction, reconstruction, preroading, etc. be properly identified. A simplistic approach toward Forest-wide average values for roads was initially contemplated by several Forests until they recognized the implications for their analysis. Such an approach would inappropriately fail to give economic preference to areas with some density of roads currently in place.

Consistency of approach is another critical consideration in developing cost data. For example, inclusion of O&M road costs for new roads as a variable cost in the prescriptions, and O&M costs for existing roads as a fixed lump sum Forest-wide cost separate from the prescriptions, gives undue economic preference to accessed areas.

I have provided several examples of how inappropriate cost data specification can impact FLMP. Minimizing these types of problems in FLMP requires a close working relationship between Economists and Silviculturists throughout the planning process. Encouragement and support of such a relationship by the Regional Office is also helpful.

Preliminary Economic Implications from FLMP

1. A wide difference exists between Forests in comparison of expected future demand and physical production capabilities in R-8.

(a) Generally, Coastal Plains Forests are finding projected demand to be approaching or exceeding resource capabilities.

(b) Mountain Forests, however, are identifying substantial production capability beyond expected demand.

2. Very limited cost data is available to reflect a range of activities for different silvicultural systems, harvest cutting methods, reforestation and TSI. Documentation by research or consensus by professionals is not always available.

3. Economic efficiency is generally accepted as dictating harvest prior to CMAI. When positive price trends and increasing value with larger diameters are considered this relationship tends to breakdown for at least some timber types.

A Practical Application of Economic Analysis
to Vegetation Management Treatments

Introduction

Region 5 is currently reviewing its policies and updating its Environmental Impact Statement (EIS) on vegetation management for reforestation. Economic analysis of the alternative Regional policies considered in the EIS is being given considerable emphasis both by the Region and the public through the NEPA process.

In his earlier presentation, John Fiske described how sites were stratified by productivity and treatment constraints as a part of the EIS analysis process. All of our economic analysis is based either directly or indirectly on the site productivity and treatment analysis John has described. The importance of closely coordinating the silvicultural and economic analysis work in a project like this cannot be overemphasized. As practicing foresters, most of you already have a good feel for what is cost effective in timber management and for how timber management affects employment opportunities and government receipts. All that an economist or an economic analysis can do is to refine and quantify what most of you already know. You should all keep this in mind as we see more economic terminology and make more use of some of the more sophisticated economic analysis tools in Forest Service decision-making.

To illustrate how economic analysis was applied, I will be referring

to some of the more important tables reproduced from our Draft Environmental Impact Statement.

Treatment Costs

The first step in the economic analysis was to identify the costs of the various vegetation management treatments. For site preparation and release, this data was obtained through a survey of silviculturalists at the Forest level. The results of the survey are summarized in Table 1. As you can see from the data, there is a wide range of treatment costs for individual treatments. Tom Mills may say more about this in his presentation later today. Costs for planting, precommercial thinning, and other timber costs such as sale preparation, sale administration, and roads were estimated directly from budget data.

Total Costs, Unit Costs, Present Net Value

Costs for individual treatments were used to develop total costs and cost per thousand board feet of timber for the alternatives (Table 10) and were used to calculate present net value and employment effects of the alternatives. Present net values for the alternatives (Table 11) come out relatively close together for all but two of the alternatives. There are a number of reasons why present net value changed little:

1. Timber yields changed little between all but two of the

alternatives.

2. Changes in timber yields were offset somewhat by changes in timber prices. (A downward sloping demand curve was used in the analysis)

3. The change in total cost of the alternatives was less than the change in vegetation management cost. (Vegetation management costs represent less than 25 percent of timber production cost in R-5)

The basic assumptions behind the present net value computations are shown in Table 12. Our analysis did account for real price and cost increases and the effect of timber output on price levels.

Employment

Effects on employment are shown in Table 13. Because the amount of employment in vegetation management activities was a public issue, we kept this type of employment separate from employment in timber harvesting and manufacturing. Vegetation management direct employment was estimated by estimating the wage cost portion of treatment costs and then converting to worker years by using average wage rates. Standard input-output modeling techniques were used for the remaining employment estimates. The basic employment assumptions are shown in Table 14.

Government Receipts

Effects on government receipts are shown in Table 16. Since California has a yield tax on timber harvested from all ownerships, effects on yield tax revenues were also estimated.

Conclusion

All of the economic analysis items I have discussed are covered in Chapter 4--The Environmental Consequences chapter of our Vegetation Management DEIS. These same economic analysis items are also covered in Forest Plan EIS's. How many of these same economic analysis items are included in other EIS's or EA's depends upon the nature of the decision, identified issues and concerns, and the significance of the anticipated economic effects. However, whenever analysis of this type is required, close coordination between the silvicultural and economic analysis work will be needed.

Table 1. Cost ranges and typical costs of site preparation and release treatments. Costs are dollars per acre, based on a 1982 survey of National Forests in R-5.

Treatment	Range	Typical
A. Site Preparation		
Tractor pile and burn.	50-370	200
Terracing	70-210	150
Discing	60-176	80
Machine mastication or mowing	10-390	180
Broadcast burn	35-750	140 Douglas-fir 200 Other cover types
Hand piling	-	200 ^{1/} Tractor ground 300 ^{1/} Cable ground
Burning piles	50-70	60
Hand cutting (brush)	100-1800	200 Small brush ~~500~~ Large brush
Hand felling (trees)	-	100 ^{2/} Tractor ground 150 ^{2/} Cable ground
Hand felling and daubing	-	150 ^{2/} Tractor ground 200 ^{2/} Cable ground
Herbicides, Aerial	30-125	90
Herbicides, Ground mach.	50-150	90
Herbicides, Hand	50-275	130

B. Release

Machine mastication or mowing	40-275	170
Hand weeding	-	150 ^{2/}
Hand cutting (brush or small trees)	30-1500	200 Small brush 300 Large brush or small trees
Herbicides, Aerial	30-125	70
Herbicides, Ground machine	30-80	80
Herbicides, Hand	20-295	130

1/ No recent costs reported in survey. An informal survey of silviculturists on the Klamath, Modoc, Six Rivers, Stanislaus, and Tahoe National Forests showed a range of estimated costs of \$200-350 per acre, depending on slope. The typical values were based on this information.

2/ No recent costs reported in survey. Typical values selected after informal survey described in 1/ above.

Table 10 - Average annual vegetation management costs^{1/} by alternative in current (1982) dollars.

Alternative	Average Annual Vegetation Mgm't. Cost		Vegetation Mgm't. Cost Per 1000 Board Feet	
	Million Dollars	Change From Current (%)	Dollars	Change From Current (%)
1. Current Policy	50	0	25	0
2. No Vegetation Management	15	-70	21	-16
3. No Application of Herbicides	61	+22	47	+88
4. No Aerial Application of Herbicides	54	+8	28	+12
5. Emphasize Timber Production	50	0	23	-8
6. Emphasize Nontimber Resources	56	+12	28	+12
7. Emphasize Cost Effectiveness	47	-6	23	-8
8. Emphasize Employment Opportunities	58	+16	29	+16

^{1/} Vegetation management costs include the cost of site preparation, planting, release, and precommercial thinning.

Projected Average Annual Vegetation Management Costs by Alternatives

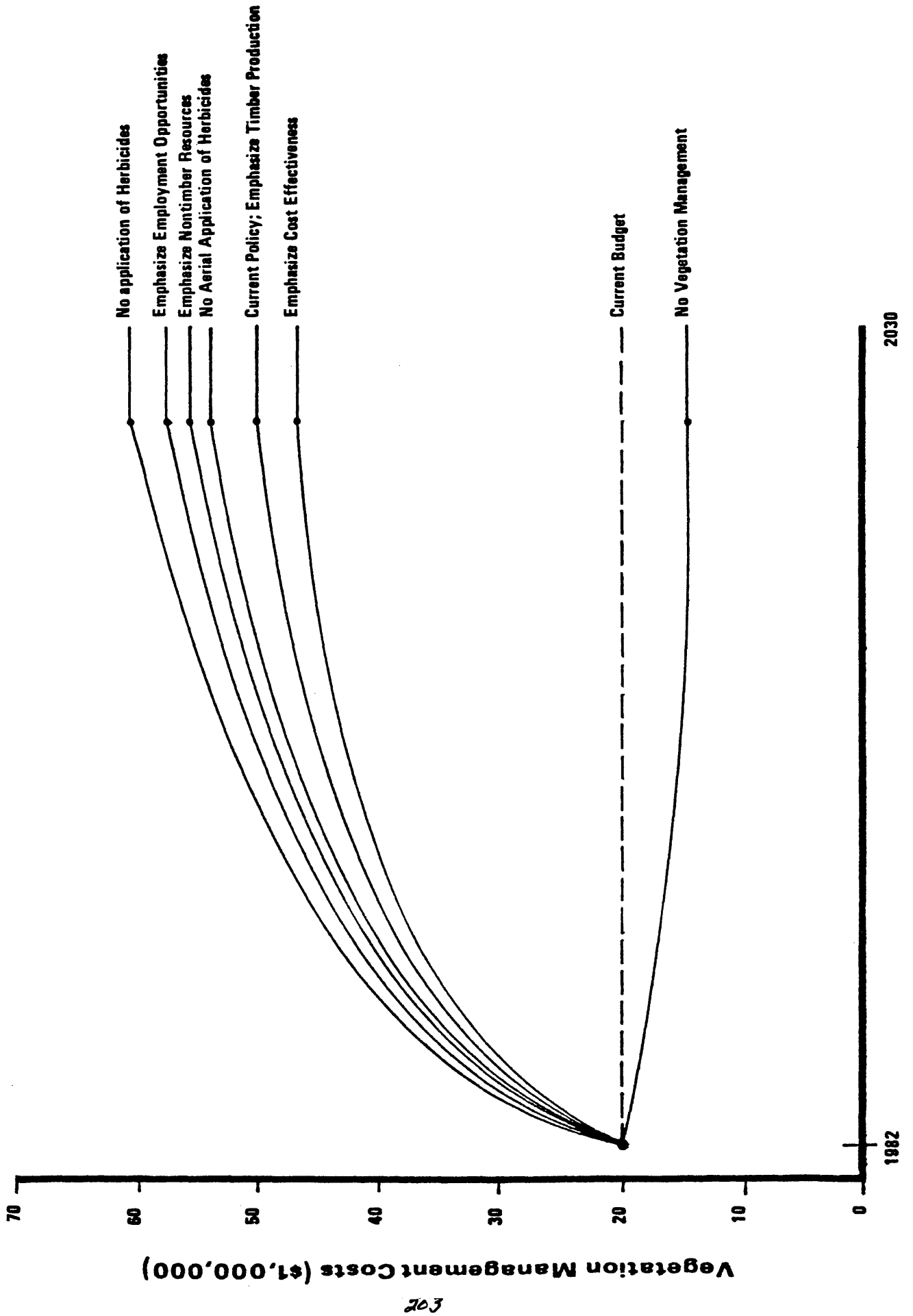


Table 11 - Alternatives ranked by present net value

Alternative Name	Rank	Total Discounted Benefits ^{1/} Billion \$	Total Discounted Cost ^{2/} Billion \$	Present Net Value	
				Billion \$	Percent Change From Current
7 Emphasize Cost Effectiveness	1	13.3	7.2	6.1	+2
1 Current Policy	2	13.3	7.3	6.0	0
4 No Aerial Application of Herbicides	3	13.1	7.2	5.9	-2
5 Emphasize Timber Production	4	13.4	7.6	5.8	-3
6 Emphasize Nontimber Resources	4	13.3	7.5	5.8	-3
8 Emphasize Employment Opportunities	6	13.3	7.6	5.7	-5
3 No Application of Herbicides	7	10.7	5.7	5.0	-17
2 No Vegetation Management	8	6.9	2.5	4.4	-27

See Table 12 for the analytical assumptions used in computing present net value.

^{1/} Benefits include anticipated real price increases. Benefits are based on average annual timber output levels for the alternatives. See Appendix.

^{2/} Costs include anticipated real cost increases. Total discounted costs include costs such as roads, sale preparation, sale administration, and support or mitigation costs for nontimber resources in addition to vegetation management costs. Costs are based on average annual timber output levels for the alternatives.

Table 12

Present Net Value Analysis Assumptions

Planning period 1982 - 2030

Real discount rate - 4.0 percent

Real cost increases for timber management activities: 1/

Decade	1980- 1990	1990- 2000	2000- 2010	2010- 2020	2020- 2030
Average annual increase %	3.1	2.4	1.9	1.6	1.6

Real price increases for stumpage, by species 2/

Decade	1980- 1990	1990- 2000	2000- 2010	2010- 2020	2020- 2030
Average annual price increase, %					
Douglas fir	4.53	1.04	1.97	1.50	1.81
Ponderosa pine	4.41	1.02	1.94	1.48	1.79
White fir	5.43	1.19	2.22	1.65	1.96
Mixed conifer	4.79	1.09	2.06	1.57	1.84

Base year stumpage prices (1979-1981 average) 3/

Species Group	Douglas Fir	Ponderosa Pine	White Fir	Mixed Conifer
Price, Dollars per MBF	174	214	106	205

Timber management costs, other than vegetation management costs 85/MBF 4/Timber price response per 100 MMBF change in output - 3.7 percent 5/

1/ Estimate based on projections of real disposable personal income per capita shown in Forest Service, USDA, An Assessment of the Forest and Range Land Situation in the United States, January 1980.

2/ Source: Haynes, Richard W, Connaughton, Kent P; Adams, Darius M.; Stumpage Price Projections for Selected Western Species, Forest Service, USDA November 1980.

3/ Region 5 averages based on data reported in Ruderman, Florence K., Production Prices, Employment, and Trade in Northwest Forest Industries, First Quarter 1982, Forest Service USDA, July 1982.

4/ Based on fiscal year 1983 budget relationships.

5/ Derived from data in "Projections of the Demand for National Forest Stumpage, by Region, 1980-2030" by Richard W. Haynes, Kent Connaughton, and Darias M. Adams, December 1980 (draft).

Table 13 - Average annual employment by alternative

1/

	Vegetation Management Employment	Timber Harvesting & Manufac- turing Employment	Total Direct Employment ^{2/}	Total Direct, Indirect, & Induced Employment ^{3/}
Thousands of Worker Years				
1. Current Policy	2.4	12.0	14.4	31.3
2. No Vegetation Management	1.0	4.2	5.2	11.2
3. No Application of Herbicides	2.9	7.8	10.7	22.2
4. No Aerial Application of Herbicides	2.7	11.4	14.1	30.3
5. Emphasize Timber Production	2.3	12.6	14.9	32.6
6. Emphasize Nontimber Resources	2.9	12.0	14.9	32.0
7. Emphasize Cost Effectiveness	2.2	12.0	14.2	31.0
8. Emphasize Employment Opportunities	2.9	12.0	14.9	32.0

1/ See Appendix and Table 14 for basic data and assumptions used for employment estimates.

2/ Total direct employment is the sum of vegetation management, harvesting, and manufacturing employment.

3/ Includes the effect of respending of income within the economy.

Table 14. -- Employment Analysis Assumptions

Direct Employment Coefficients - Vegetation Management ^{1/}

Discing	2.4 worker years per 1,000 acres	
Terracing	4.4	
Tractor pile and burn	7.1	"
Hand fell and daub	9.4	"
Aerial chemical	1.5	"
Hand applied chemical	6.5	"
Broadcast burn	8.5	"
Mastication	5.0	"
Hand grubbing	7.9	"
Hand cutting	10.6	"
Hand pile and burn	13.8	"
Planting and precommercial thinning	52.9 worker years per million 1982 dollars spent	

Direct Employment Coefficient - Timber Harvesting and Manufacturing ^{2/}
6 worker years per MMBF

Total Direct, Indirect, and Induced Employment Multipliers ^{2/}		
Vegetation management		1.4
Timber harvesting and manufacturing		2.33

^{1/} Estimates based on a treatment cost survey of Forests, estimates of the wage cost portion of total treatment costs, and average wage rates.

^{2/} Estimates developed using the input-output modeling technique. Total direct, indirect, and induced employment is obtained by multiplying direct employment by the appropriate multiplier.

Table 16. — Average annual Treasury returns, county receipt shares, and yield taxes by alternative (Million Dollars) 1/

Alternatives	Returns to the U.S. Treasury	County Receipt Shares	Yield Taxes ^{2/}	Total County Payments- Receipt Shares Plus Yield Taxes
- Million Dollars -				
1. Current Policy	628	157	51	208
2. No Vegetation Management	330	83	27	110
3. No Application of Herbicides	500	125	41	166
4. No Aerial Application of Herbicides	618	155	50	205
5. Emphasize Timber Production	632	158	51	209
6. Emphasize Nontimber Resources	628	157	51	208
7. Emphasize Cost Effectiveness	628	157	51	208
8. Emphasize Employment Opportunities	628	157	51	208

1/ Dollar amounts reflect real price increases anticipated over the planning period.

2/ Yield tax rates are changed frequently by the State. The current rate of 3.1 percent is used here.

Stratifying Sites By Productivity And Treatment Constraints For Reforestation

Introduction

This paper was prepared from work done while developing the R-5 draft Environmental Impact Statement for managing competing vegetation during reforestation. In order to analyze the effects on projected timber yields in the Region for alternatives that included various mixes of cultural treatments, some stratification of the suitable land base was necessary. Clearly the strata needed to be defined in terms that used the concepts of "benefits" and "costs".

The biological measure of "benefit" was defined to be the mean annual increment in board feet Scribner, which is influenced by rotation length, site quality, timber species, kinds of competing plants, and the treatments. As will be described below, production functions were developed for the major combinations of timber species and kinds of competing plants for "typical" prescriptions for each alternative.

The measure of "cost" was the total cost (excluding general overhead) of doing the prescribed treatments. This aspect is covered in more detail in the associated paper by Mike Skinner. However, certain topographic characteristics can strongly limit the options for cultural treatment practices (e.g., slope limitations on use of crawler tractors). Therefore, topographic measures were used as an indirect measure of "cost".

Each stratum was called a "Treatment Unit", which was a particular commonly occurring combination of vegetation and slope classes - analogous to the "Analysis Area" concept used in land management planning.

Treatment Units

A Treatment Unit (for the purposes of this analysis) is a class of land with certain similar slope and vegetation attributes (described below), that should have similar timber growth and survival responses to the same treatments. The Treatment Units were determined by combinations of selected forest cover types, competing vegetation, and slope classes. Differences in the kinds of reforestation treatment methods that could be used, and expected significant differences in treatment effectiveness (different timber yields) were the bases for determining the kinds of Treatment Units to be analyzed.

Forest cover types. Seven types were selected (see below) representing the major commercial tree species and brushfields scheduled for conversion to commercial timber species in the Region. Except for the White Fir type, these types correspond to inventory units used for timber management planning in the Region.

Slope classes. Three classes were selected because of treatment method considerations.

-- Tractor Ground. Slopes where track-laying and other tractor-like equipment can operate effectively - usually up to 20-40%, depending on the equipment.

-- Cable Ground, Less than 60% Slope. Steeper slopes than tractor ground, but less than 60%. Only ground machine operations are precluded from this terrain.

-- Cable Ground Greater than 60% Slope. Following the current practices on several National Forests, hand cutting of brush and hand application of herbicides to trees or brush taller than about 3 feet were assumed to be precluded from these slopes, primarily for safety considerations and ineffectiveness. Tree felling, scalping, planting, and grubbing of herbaceous plants were not assumed to be precluded.

Competing plant classes. Within the forest cover types the principle competing plants were grouped by expected similarity of competition severity, or by similarity of typical effective treatment methods, (such as hardwood felling and daubing with herbicides, brush cutting, hand grubbing, or application of particular herbicides). Competing plants occur in various combinations. However, for the purposes of this analysis, it was necessary to simplify the description of competing vegetation. So, classes were defined that identified the initial dominant competing plants.

-- Eastside Pine Type. Four competing plant classes were identified: sprouting manzanita, non-sprouting manzanita, other brush, and grass/forbs. Manzanita plants were estimated to be more severe competitors than other shrubs. Grass/forbs were put in a separate class because of differences in effective treatment methods. Sprouting and non-sprouting manzanita were identified as separate classes because hand cutting methods may be used to effectively control non-sprouting manzanita, but not sprouting manzanita.

-- Red Fir Type. Three competing plant classes were identified: sprouting manzanita, other brush, and grasses/forbs. Non-sprouting manzanita is not a significant competitor in the Red Fir type.

-- Mixed Conifer Type. Six competing plant classes were identified: sprouting manzanita, non-sprouting manzanita, bearclover, other brush, tanoak/madrone, and grass/forbs. Bearclover and tanoak/madrone were put in separate classes because of different effective treatment method options than for the "other brush" class, and because bearclover, tanoak, and madrone plants are stronger competitors than the "other brush" plants.

-- Westside Pine Type. Five competing plant classes were identified: the same classes as for the Mixed Conifer type, except for the tanoak/madrone class. The extent of tanoak/madrone is not sufficiently great (<10,000 acres) in this type for use in this analysis.

-- Douglas-fir Type. Four competing plant classes were identified: tanoak/madrone trees, snowbrush, other brush, and grass/forbs. Snowbrush plants in this cover type are more severe competitors than other shrubs.

— White Fir Type. Only two competing plant classes were identified: sprouting manzanita and other brush. The extent of other competing plants such as grasses or hardwood trees is too limited (<10,000 acres) for this analysis.

-- Brushfields. Based on Regional Reforestation Backlog data, the brushfields to be converted to timber were assumed to be sprouting manzanita.

Acreage estimations for the Treatment Units. The number of acres in Region 5 were estimated for each combination of the 7 forest cover types, 3 slope, and competing plant classes. First, the number of acres in each cover type that are expected to be managed intensively for timber during reforestation, were estimated from the available land management planning (preferred alternative) or current Timber Management Plan data from each National Forest (on file at the Regional Office). Then, the fractions of the cover types in each combination of competing vegetation class and slope classes were estimated based on informal consultation with the timber management staffs of most of the National Forests. Finally, total acreages were computed for each combination of the classes. If the total acreage in the Region was less than 10,000 for a given combination, then that combination was eliminated or merged into another Unit for further analysis. At the completion of this process, 53 Treatment Units were identified for the analysis of effects on yields, total acreages had been computed for each Treatment Unit, and the average site quality (Dunning Site Class) had been estimated for each Treatment Unit.

Reforestation Prescriptions

For each Alternative, typical prescriptions were written that specify how the competing vegetation could be treated. These prescriptions are "typical" in the sense that they represent the most probable sets of treatments that would be used in the Treatment Units for the Alternatives. THERE IS NO INTENTION OF CONVEYING THE IDEA THAT THESE TREATMENTS WOULD OR SHOULD BE THE ONLY ONES USED. Many kinds of treatments are being used besides those identified as "typical" for the Current Policy Alternative. Likewise, many kinds of treatments would be used besides the indicated typical treatments for the other alternatives.

Assumptions.

1. All of the acres would be planted (except for the regeneration of red or white fir stands under the "No Vegetation Management " alternative). Since the subject of the EIS is control of competing vegetation during reforestation, the use of either artificial or natural regeneration is not an issue. As artificial regeneration is expected to be used far more often than natural regeneration, it was assumed that, for the purposes of this yield analysis, all of the acres would be planted (except as noted above).
2. All sites are being reforested after a regeneration harvest, and there was no, or sparse densities of, competing shrubs, forbs, or grass in the understory of the harvested stand. The hardwood tree component of the harvested stand was assumed to be less than 10% cover.
3. The number of release treatments was limited to two. It was estimated

that, on the average, no more than two release treatments are feasible due to administrative constraints.

4. To simplify the yield analysis, it was assumed that every acre would be precommercially thinned to appropriate stocking levels, except for those acres where seedling survival is expected to be sufficiently low such that precommercial thinnings would not be beneficial.

5. No treatments were prescribed for controlling vegetation where the primary objective would be to reduce the availability of habitats for vertebrate animal pests (e.g., pocket gophers or rabbits). In some circumstances, particularly in the Red Fir Type, intensive control of competing plants often is needed to control damage from vertebrate pests.

Selection of site preparation and release treatments. The selection of treatments for the "typical" prescriptions was based on two considerations. First, what are typical prescriptions now ("Current Policy"), and what would the probable typical prescriptions be for the other Alternatives? Current practices vary considerably, depending in part upon geography. For example, in recent years the aerial application of herbicides has been practiced more frequently in the northern Coast Range and in northeastern California, than on the west slope of the Sierra Nevada, where hand applied herbicides have been used more frequently. It was assumed that such geographical patterns of relative treatment uses would continue.

Second, treatments were prescribed which are most commonly believed by silviculturists in this Region to be the most cost effective, within the constraints of each Alternative. For example, ground-applied herbicides are regarded as being more effective in controlling competing shrub plants than hand or machine cutting. Therefore, the prescriptions for the "No Aerial Herbicides" Alternative usually are for hand-applied herbicides, rather than hand or machine cutting.

For the "Emphasize Non-Timber Resources" Alternative, hand control methods were selected instead of machine methods wherever possible because of the potential for greater discrimination as to which competing plants needed to be controlled. This would increase the opportunities for achieving many non-timber resource management objectives. For example, hand cutting was selected rather than machine mastications for controlling non-sprouting manzanita, and hand applied herbicides were selected rather than ground machine-applied or aerially-applied herbicides for controlling sprouting manzanita. Broadcast burning and hand pile and burning have different effects on non-timber resources such as certain wildlife populations, soils, and visual quality. The selected mix of broadcast burning and hand pile and burn was 50:50 on slopes too steep for ground machines, but less than 60% slope. It was estimated that this mix would provide for a good combination of desired non-timber resource objectives.

Yield Model Assumptions

1. Even-aged management would be used in all Treatment Units, with a rotation age of 85 years. Almost all of the suitable land base probably will be managed by an even-aged system, or, if uneven-aged systems are used, by the group selection system (to which even-aged yield models can be applied), according to the draft land management plans of the National

Forests in California. An 85-year rotation is typical of the rotations used in land management planning for estimating timber yields from suitable lands.

2. Commercial thinning treatments are approximately equivalent to those used in the timber management planning models (RAMPREP). Harvesting occurs at 10-year intervals after the stand stocking reaches 90% of normal basal area stocking (as shown in the appropriate normal yield table), the average tree height is 50 feet, and the mean diameter at breast height (4' 6") is 13 inches. The residual stocking (basal area) after each commercial thinning is the value from which the stand basal area can increase to 90% of the normal basal area at the end of 10 years.

3. The timber yields will be identical to the RAMPREP model projections if the regenerated stands meet the first commercial thinning criteria (see assumption #2 above), in the specified period.

4. The maximum yields per acre (with the constraint of 2 release treatments) exceed the RAMPREP yields by about 10 to 20% on Dunning Sites A to III. This assumption is based on estimates for ponderosa pine plantations growing with no, or very few, manzanita or bear clover plants, and an 85-year rotation (Fiske, 1982). On Dunning Sites IV and V, the maximum yields per acre should be about 105 to 110% of the RAMPREP yields.

5. The yields for white fir on Dunning II sites (the estimated average site index for the white fir type defined in this analysis) would be equivalent to the RAMPREP yields for red fir Dunning II sites. The white fir yields should be about the same as the red fir yields since the stocking levels for normal stands at ages 50-80 years are comparable (Schumacher, 1926 and 1928).

Yield Reductions Due to Competing Plants

Introduction.

Generally, accurate estimations of conifer timber yield reductions over a rotation in California, due to effects of competing vegetation, are difficult to make. The major reason is that quantitative relationships have been established for only a few cases in California, so estimations for other situations must be based on interpolations between and extrapolations from these cases, and by using silvical and ecological characteristics of the plants.

The general method used in this analysis was to estimate the "worst case" mean annual board foot growth reductions (no vegetation management), for which the most data exist, and then to estimate the reductions due to lesser average densities of competing vegetation expected after the prescribed treatments are implemented for each alternative for each Treatment Unit.

The worst case growth reductions were estimated by comparing the estimates from two methods that are described below. The relative weighting given each of the two estimates varied, depending on the silvical characteristics of the commercial tree species and the potential competitiveness of dense stocking of the competing plants.

The first method was to increase or reduce the estimated yield reduction from the approximate 70% reduction calculated by Fiske (1982) for ponderosa pine on Dunning III sites growing with dense manzanita, depending on the silvical characteristics of the tree species being considered, and the potential competitiveness of the other plants relative to manzanita.

The second method was to estimate the mean annual stand growth at age 85 years (by projecting average tree and stand growth for two periods within the 85-year period), and comparing the result with the RAMPREP values for the appropriate Dunning Site. The first period is when average tree growth is substantially slowed by the effects of the competing plants, and when almost all of the tree mortality is expected - about 1 to 5 decades, depending the kind of competing plants present. The second period starts when the average potential crop tree is dominant over the competing plants - height and diameter growth losses, and tree mortality, would be low or negligible. The second period ends at the first commercial thinning, if any, or at 85 years.

The sizes of the average potential crop trees (height and diameter at breast height, dbh) at the end of the first period were estimated, and the approximate numbers of trees were estimated. Then, the changes in stand structure and volume, was projected for the second period using FEWTREES, and unpublished variable density growth model developed by Glenn Davies, Region 5 Timber Management Staff. The central feature of FEWTREES is a set of diameter growth relationships for dominant trees as functions of the stand basal area at the start of the growth projection period, usually 10 years. FEWTREES is based on LOGS plots data and published growth data. Height growth follows, or parallels site index curves.

In each case, the sensitivity of the growth reduction estimate to changes in the estimates of: 1) the length of the first growing period, 2) the average tree dbh at that time, and 3) the numbers of potential crop trees per acre; was tested by running the FEWTREES model for the probable ranges of these three input variables. The results were used to estimate the value range of the growth reduction for the stand.

The most probable mean annual volume growth reduction value was estimated within each range, rounded to the nearest tenth percentile. These values are shown in the Table.

At the end of this stratification process we had production functions for various combinations of vegetation and treatments, and estimates of the land base, for each stratum. From there, effects on yields for the Region due to the alternatives could be computed easily.

Literature Cited

Fiske, John N. 1982. Evaluating the need for release from competition from woody plants to improve conifer growth rates. In Proc. Third Annual Forest Vegetation Management Conference, Nov. 4-5, 1981, Redding, Calif. pp. 25-44.

Schumacher, Francis X. 1926. Yield, stand, and volume tables for white fir in the California Pine Region. Bull. 407. Univ. of Calif. College of Agriculture, Berkeley. 26 pp.

Schumacher, Francis X. 1928. Yield, stand, and volume tables for red fir in California. Bull. 456. Univ. of Calif. College of Agriculture, Berkeley. 29 pp.

Table 1. Average estimated percentage reductions from R-5 timber management objectives (board feet Scribner, on a per acre basis), for an 85-year rotation, by timber type and relative average density of specific plants that are the primary initial competitors on the site. Heavy (H) and moderate (M) densities mean crown covers of greater than about 30 to 50%, at least 20% respectively. Reductions due to light densities were estimated to be negligible. Other combinations of competing plant and commercial tree species were not sufficiently extensive in R-5 to be included in the analysis. Data are from the R-5 DEIS for vegetation management during reforestation.

Competing Plants and Density		Timber Type					
		Eastside Pine	Red Fir	Mixed Conifer	Westside Pine	Douglas- Fir	White Fir
Sprouting Manzanita	H	50	70	60	70	N/A	60
	M	20	20	30	30	N/A	20
Non-sprouting Manzanita	H	50	N/A	60	70	N/A	N/A
	M	30	N/A	30	30	N/A	N/A
Bearclover	H	N/A	N/A	70 ^C	70 ^C	N/A	N/A
	M	N/A	N/A	30	30	N/A	N/A
Snowbrush	H	b	b	b	N/A	30	b
	M	b	b	b	N/A	20	b
Other Brush	H	30	20	20	40	20	20
	M	<----- Negligible ----->					
Tanoak/ Madrone	H	N/A	N/A	70	a	70	N/A
	M	N/A	N/A	40	a	40	N/A
Grass/Forbs	H	50 ^C	50 ^C	50 ^C	50 ^C	50 ^C	a
	M	30	20	30	30	30	a

- a Not sufficiently extensive to be included in the EIS analysis.
b Included in the "Other Brush" category of competing vegetation.
c Only if effective site preparation - otherwise not suitable for timber management.

Causes of Variation in the Direct Cost of
Silvicultural Treatments on National Forest Land

by
Thomas J. Mills*

Abstract: The direct cost of silvicultural treatments accomplished on National Forest lands from 1975 to 1978 through service contracts varied considerably. Much of the variation cannot be explained by treatment, site, or contractor characteristics. This leads to the hypothesis that managerial differences among contractors and among local Forest Service units may be important sources of cost variation. The real direct cost per acre of the silvicultural service contracts rose significantly during the study period for most treatment categories. Treatment costs for areas smaller than 100 to 150 acres were higher than the costs for larger areas. The sizeable real cost increases, the major economies-to-scale that are possible for larger treatment areas, and the cost variation not related to site, all suggest that the influence of managerial decisions on silvicultural treatment costs warrant detailed review and further study. The inability to explain much of the cost variation with treatment and site characteristics may imply nonstandardized management objectives and erratic silvicultural program performance capabilities that in turn could lead to a misallocation of silvicultural investment funds.

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INTRODUCTION

Silvicultural treatments are applied extensively throughout the nation. For example, in 1977, 1.9 million acres were reforested and 1.3 million acres received various intermediate treatments, such as precommercial thinning. The U.S. Department of Agriculture, Forest Service, with a \$118 million appropriation in the fiscal year 1982 for reforestation and stand improvement, is a major participant in this treatment activity. It was recently estimated that an additional 168.2 million acres could be treated in the entire nation, at a cost of \$15.2 billion and earn a real return of 4 percent (U.S. Department of Agriculture, Forest Service 1981).

A number of studies of silvicultural costs are available that provide reasonable cost estimates (Worrell 1953, Yoho and Fish 1961, Somberg and others 1963, Wikstrom and Alley 1967, Hilliker and others 1969, Conkin 1971, Yoho and others 1971, Moak and Kucera 1975, Moak and others 1977, Olson and others 1978). With the exception of Row's (1971) study, however, these are regional studies and they do not analyze many of the major causes of treatment cost variation. This study was designed to estimate direct silvicultural treatment costs on National Forest lands nationwide and determine the variation in these costs. An overview of the findings and implications is reported here. A more detailed discussion is given by Mills and others (1982).

STUDY METHODS

Data for this study were drawn from silvicultural service contracts awarded on National Forests. These contracts represent actual transaction evidence, which gives a more accurate separation of direct and indirect costs than is usually possible with accounting records. This advantage must be balanced against the fact that treatments performed under the service contracts may not be entirely representative of treatments performed with

Forest Service personnel and equipment, so extrapolation of results to the total silvicultural treatment program on the National Forests is hazardous.

Forms were sent to all National Forests, requesting data on all silvicultural service contracts successfully awarded and completed during 1976 and 1977. Data were also volunteered from some contracts completed in 1975 and 1978. The voluntary reports were retained to increase the total number of observations. We compiled 2650 usable observations, the majority of which were from 1976 and 1977 contracts. Some of the retained observations had missing values in some variables, such as the number of trees planted or treated per acre. Those missing values caused some problems with the development of cost prediction equations, but did not affect the estimation of cost per acre.

The direct treatment cost was estimated by adding the cost of materials supplied by the Forest Service to the contract bid value. The costs were then deflated to 1978 dollars, using the producer price index. The cost of time spent by Forest Service personnel in the field administration of the contracts was calculated but not included in the direct cost estimate. Some of that time could logically be labeled "direct cost."

The 2650 observations were stratified by silvicultural treatment category and groups of forest types. Average costs and cost prediction equations were then developed from the observations in each strata. Total direct cost of the contract was regressed against treatment variables (such as acres treated and basal area per acre treated), site variables (such as slope, elevation, and the presence of obstacles), and contract variables (such as number of vendors bidding on the contract). Only variables commonly available prior to treatment were included in the equations.

After excluding variables that had high simple correlations with retained variables (0.80 or higher), all-possible regression equations were estimated from the covariance matrix, using the P9R subroutine in the BMD statistical package (Dixon and Brown 1979). Once the most significant variables were identified, using Mallows' C_p index of unexplained variation, the selected equations were reestimated, using only observations that had no missing values in the retained variables.

RESULTS

Treatment Composition

Fifty-eight percent of the observed contracts called for some form of stand establishment, such as site preparation, reforestation-- or a combination of both--, as opposed to intermediate treatments, such as precommercial thinning, timber stand improvement, or release, and slash disposal (Table 1). This treatment composition contrasts sharply with an earlier study of silvicultural treatments on National Forests that were capable of earning a 5 percent rate of return (U.S. Department of Agriculture, Forest Service 1973). Eighty-four percent of the treatment acreage that could pass the financial return test involved intermediate treatments, rather than stand establishment treatments. This variance in treatment composition could result from a difference between the service contracts and the total silvicultural program or it could imply that the service contract dollars are not being allocated so as to maximize financial return.

Site preparation and reforestation were seldom combined in the same contract. Instead, the stand establishment contracts were awarded for one or the other of the two treatments. The 7-month mean elapsed time between the site preparation and reforestation treatments is generally a short enough period, however, to avoid competition from revegetation of the site. The

Table 1--Mean direct cost per acre of silvicultural service contracts accomplished on National Forest land from 1975-1978, by silvicultural treatment and forest-type group (1978 dollars)¹

Forest-type group	Site Preparation			Reforestation ²			Site preparation and reforestation ³			Intermediate ³ treatment			Slash disposal			All treatments ⁴		
	Cost			Cost			Cost			Cost			Cost			Cost		
	(number)	(dollars)	(number)	(number)	(dollars)	(number)	(number)	(dollars)	(number)	(dollars)	(number)	(dollars)	(number)	(dollars)	(number)	(dollars)	(number)	(dollars)
Northern conifers ⁵	16	36 (23)	71	50 (18)			22	19 (12)							116	40 (22)		
Southern pines ⁶	126	46 (18)	74	36 (11)			28	37 (17)							232	42 (17)		
Central hardwoods ⁷	68	47 (26)													77	45 (25)		
Northern hardwoods ⁸	88	19 (17)	50	56 (24)			36	17 (10)							176	30 (26)		
Douglas-fir	95	62 (48)	256	75 (29)			55	90 (50)			235	52 (31)	13	99 (93)	664	66 (39)		
Ponderosa pine and white pine	105	47 (30)	131	73 (31)			59	95 (54)			440	32 (23)	61	28 (25)	804	45 (36)		
Mixed spruce ⁹	78	60 (40)	87	65 (25)			17	76 (41)			108	65 (31)	11	43 (39)	304	63 (34)		
Lodgepole pines	41	42 (17)	24	71 (28)			28	52 (22)			105	55 (25)			205	55 (26)		
All forest types	619	46 (33)	701	65 (29)			167	83 (49)			982	42 (29)	90	43 (51)	2588	52 (35)		

¹Values in parentheses are standard deviations.

²Includes planting and seeding.

³Includes control of undesirable vegetation, cleaning, individual tree or area release, and precommercial thinning.

⁴The total includes cases for all treatments, including miscellaneous categories not shown separately for pruning, fertilization, development of timber management plans and inventory, compartment examination, and fire prevention activities. The grand total does not add to the number of cases retained (2650) because of some missing values in these practices.

⁵Includes red-white-jack pine and spruce-fir.

⁶Includes longleaf-slash pine, loblolly-shortleaf pine, and oak-pine.

⁷Includes oak-hickory, oak-gum-cypress, and elm-ash-cottonwood.

⁸Includes maple-beech-birch, and aspen-birch.

⁹Includes fir-spruce, hemlock-Sitka spruce, and larch.

majority (83 percent) of intermediate treatments were precommercial thinnings. The mean diameter of treated trees was 3.7 inches and the mean number of trees treated per acre was 766.

The preliminary estimate of mean contract acreage was 240 acres, and the mean number of separate, contiguous treatment blocks per contract was 4.23 (Table 2). The corresponding mean size of the contiguous treatment areas was 56 acres which is less than the maximum size of clearcut blocks set by the National Forest Management Act regulations (U.S. Department of Agriculture, Forest Service 1979). The regulations were established after these treatments were installed. The treatment block sizes under these contracts are larger than the acreage of similar treatments on nonindustrial private lands initiated under the 1978 Forestry Incentives Program (FIP)¹, where site preparation averaged 39 acres, reforestation 33 acres, and timber stand improvement 34 acres.

Mean Treatment Cost

The mean treatment cost across all observations was \$52 per acre (Table 1). The reforestation treatments, at \$65 per acre, and the combined site preparation and reforestation treatments, at \$83 per acre, had the highest mean costs. Interestingly, the mean cost of the combined site preparation and reforestation treatment was \$28 per acre less than the sum of the two treatments applied separately. It wasn't possible from the data available in this study to determine whether this lower cost implies some economies-to-scale or differences in the areas treated by the different types of contracts. The mean intermediate treatment cost, at \$42 per acre, and mean slash disposal cost, at \$43 per acre, were both somewhat lower than the cost of stand establishment treatments.

¹ Personal communications with Chris Risbrudt, Cooperative Forestry Staff, U.S. Department of Agriculture, Forest Service, Washington, D.C., December 15, 1980.

Table 2--Mean and standard deviation of selected silvicultural service contract characteristics

Contract characteristic	Mean	Standard Deviation	Number of Observations
Bids received	5.09	3.55	2,143
Contractor time doing silvicultural contracts (percent)	60.0	35.4	2,266
Contractor's experience on silvicultural treatments (years)	7.17	6.52	2,257
Duration of contract (months)	2.57	3.33	2,631
Multiple areas ¹	4.23	6.62	2,650
Distance between multiple areas ¹ (Miles)	8.53	10.2	1,448
Seedlings planted per acre ²	481.	234.	879
Time between site preparation and reforestation (months) ²	7.16	9.75	782
Basal treated area per acre ³ (square feet)	41.9	45.7	998
Trees treated per acre ³ (number)	766.	999.	1,182
Average d.b.h. of treated trees ³ (inches)	3.70	2.48	1,328

¹Number and distance between separate contiguous treatment areas within the same service contract.

²Reforestation and site preparation, and reforestation cases only.

³Site preparation, site preparation and reforestation, and intermediate treatment cases only.

The cost of Forest Service materials and supplies was less than 5 percent of the direct cost in all except the reforestation treatment, where it was 34 percent, and the combined site preparation and reforestation treatment, where it was 17 percent. The Forest Service contribution in those cases was primarily tree seedlings.

The cost of these treatments done under contract on National Forest lands were roughly comparable to the cost of treatments installed on nonindustrial private lands under the FIP. The 1978 FIP costs were \$55 per acre for site preparation, \$72 for reforestation, and \$31 for intermediate treatments, versus \$46, \$65, and \$42, respectively, for these service contracts.

The field time of Forest Service personnel spent in the preparation, supervision, and inspection of the service contracts averaged 1.03 hours per acre treated (Table 3). At the cost of salary, plus benefits, for the most commonly reported grades (GS-5 to GS-9) of personnel conducting this field work, the cost of field time was equivalent to 10 to 20 percent of the direct cost. Additional hours of contract administration spent in the District Rangers' offices, the Forest Supervisors' offices, and the Regional offices were not tabulated. The mean field time per acre treated dropped steadily from 1.44 hours for contracts less than 50 acres to 0.54 hours for contracts greater than 450 acres, although the downward trend was not statistically significant.

The amount of Forest Service field time spent on contract administration varied a great deal among contracts. The standard deviation of hours spent per acre was always more than half of the mean, and it occasionally exceeded the mean.

Table 3--Mean Forest Service field time spent on the preparation, supervision, and inspection of service contracts by silvicultural treatment and forest type group¹

Forest-type group	Site Preparation			Reforestation			Site Preparation and reforestation			Intermediate ³ treatment			Slash Disposal			All practices ⁴		
	Cases	Time	Per acre	Cases	Time	Per acre	Cases	Time	Per acre	Cases	Time	Per acre	Cases	Time	Per acre	Cases	Time	Per acre
	(number)	(hours)	(number)	(number)	(hours)	(hours)	(number)	(hours)	(hours)	(number)	(hours)	(hours)	(number)	(hours)	(hours)	(number)	(hours)	(hours)
Northern conifers ⁵	16	.32 (.47)	68	.72 (.80)			22	.52 (.40)								112	.64 (.71)	
Southern pine ⁶	124	.47 (.45)	72	.56 (.74)			27	.56 (.54)								227	.51 (.56)	
Central hardwoods ⁷	68	.78 (.62)														77	.80 (.64)	
Northern hardwoods ⁸	87	.60 (.78)	48	1.07 (1.28)			35	1.29 (1.06)								172	.87 (1.03)	
Douglas-fir	94	1.43 (1.32)	253	1.28 (1.13)	54	1.72 (1.38)	233	1.13 (1.14)	12	1.26 (1.68)						656	1.28 (1.20)	
Ponderosa pine and white pine	104	.88 (1.23)	129	1.53 (1.37)	55	1.69 (1.55)	428	.73 (.87)	58	.54 (1.07)						781	.94 (1.14)	
Mixed spruce ⁹	76	1.03 (1.12)	86	1.61 (1.48)	17	1.78 (1.70)	104	1.24 (1.23)	11	.72 (.78)						297	1.30 (1.32)	
Lodgepole pine	41	.54 (.40)	24	1.40 (.98)	28	.97 (1.12)	102	1.38 (1.36)								202	1.19 (1.25)	
All forest types	612	.81 (.98)	688	1.23 (1.21)	162	1.52 (1.44)	959	.97 (1.08)	86	.81 (1.36)						2,534	1.03 (1.15)	

¹Values in parentheses are standard deviations.

²Includes planting and seeding.

³Includes control of undesirable vegetation, cleaning, individual tree or area release, and precommercial thinning.

⁴The total includes cases for all treatments, including miscellaneous categories not shown separately for pruning, fertilization, development of timber management plans and inventory, compartment examination, and fire prevention activities. The grand total does not add to the number of cases retained (2650) because of some missing values in these practices.

⁵Includes red-white-jack pine and spruce-fir.

⁶Includes longleaf-slash pine, loblolly-shortleaf pine, and oak-pine.

⁷Includes oak-hickory, oak-gum-cypress, and elm-ash-cottonwood.

⁸Includes maple-beech-birch, and aspen-birch.

⁹Includes fir-spruce, hemlock-Sitka spruce, and larch.

Increase in Real Cost

The mean real cost across all observations rose by \$8 per acre per year, or roughly 20 percent per year, from 1975 to 1977 (Fig. 1). The trend of mean costs continued to rise through 1978 for all treatment categories except the combined site preparation and reforestation treatment, where the cost declined slightly. The reforestation cost rose from \$55 per acre in 1975 to \$91 in 1978, an increase of 65 percent in 4 years. These cost increases far exceed the 1 to 3 percent per year projected long-term increases in real stumpage prices (U.S. Department of Agriculture, Forest Service 1981).

Data collected by Moak and others (1980) on silvicultural treatments in the South also displayed real cost increases. They concluded the higher costs were the result of higher energy and labor costs. Whether the real cost increase in the Forest Service contracts was caused by those factors, or by changing managerial standards for treatment intensity, could not be determined from this data set.

Cost Variability

The direct treatment cost of the silvicultural treatments varied substantially among the service contracts, even when the observations were stratified by treatment and groups of forest types or by treatment and administrative region. The standard deviation of the treatment cost was usually greater than half the mean cost.

The cost variation was not great enough to seriously invalidate case study estimates of the financial return potential of silvicultural treatments, such as the Douglas-fir investment guide prepared by Beuter and Hardy (1974), (Mills and others 1976). The variation was great enough, however, to affect the validity of budget estimates prepared from aggregate cost averages, especially if the likely real cost changes were not incorporated.

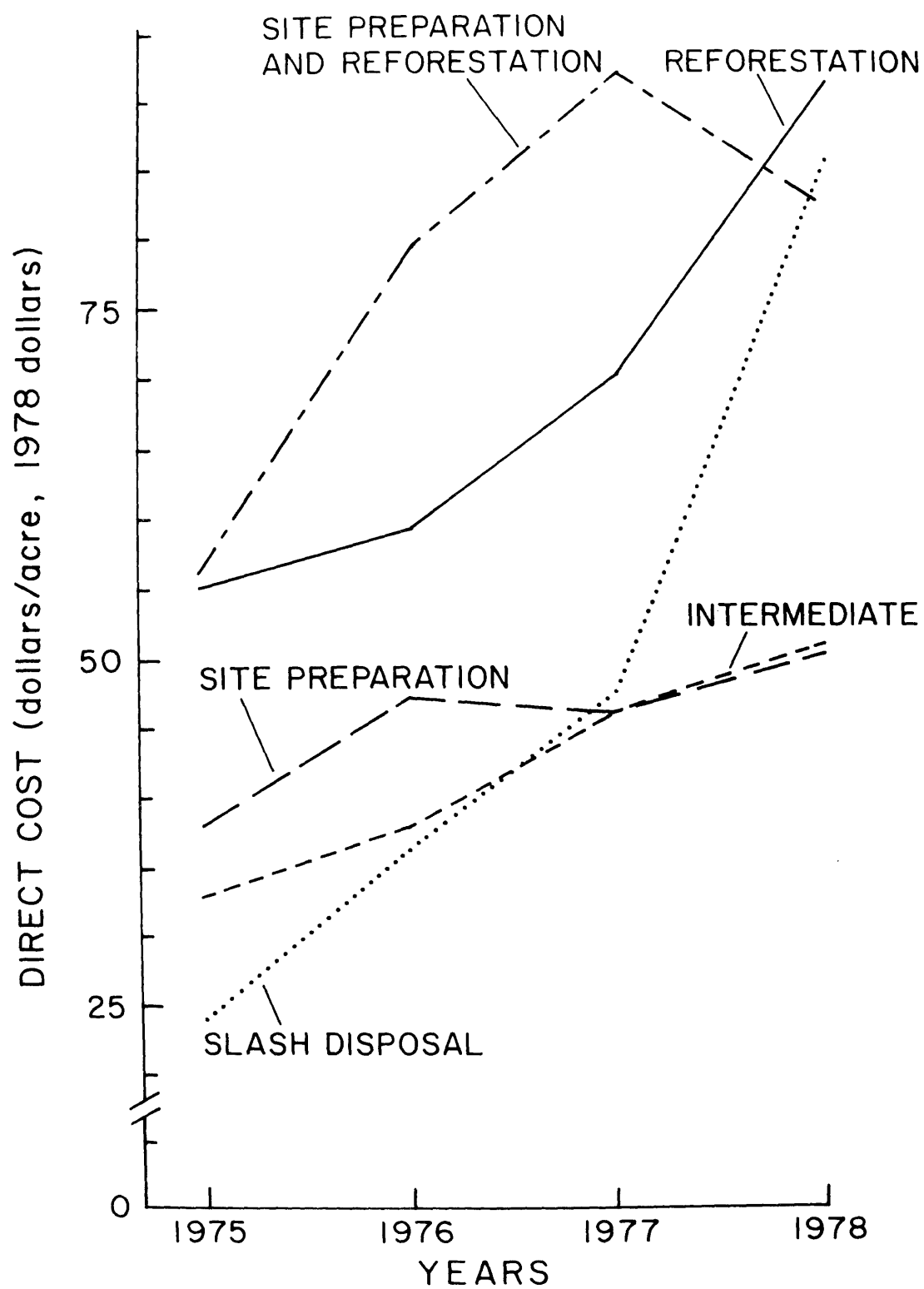


Figure 1--Real treatment costs per acre rose from 1975 through 1978 for almost all treatments.

The regression equations that expressed cost per contract as a function of site and treatment variables were developed in an effort to explain the cost variation, but the approach was only partially successful. The equations generally only explained between 40 and 80 percent of the cost variations. Unmeasured factors, such as contractor proficiency, true bidding competition, contract specification, and contract enforcement may be additional sources of variation. Loveless and others (1982) found evidence that local management characteristics influenced the cost of prescribed burning for wildlife management in the Forest Service's Northern Region, and McKetta (1983) found similar evidence in a study of fuel treatment costs in the same Region.

Economies-to-Scale

Although the regression equations did not explain all of the cost variation, they did show how much economies-to-scale exist in silvicultural treatments. After holding all the nonacreage variables in the equations at their sample mean values, total direct cost was estimated for several contract acreage sizes. The resulting total cost estimates were then divided by the corresponding contract acreage, yielding estimates of average treatment cost per acre for each of the contract acreages.

The economies-to-scale, as measured by a declining average cost per acre as the contract acreage increases, were substantial in some treatment and forest-type group strata (Fig. 2). Average cost per acre declined up to acreages of 100 to 150 acres, especially in the Douglas-fir type. The costs were substantially higher for areas less than 75 acres. Therefore, significant economies-to-scale will be lost if contracts are restricted to the size of the clearcut block restrictions in the National Forest Management Act regulations. The mean number of separate areas in the sampled contracts was 4.2 and they were separated by a mean distance of 8.5 miles (Table 2). The

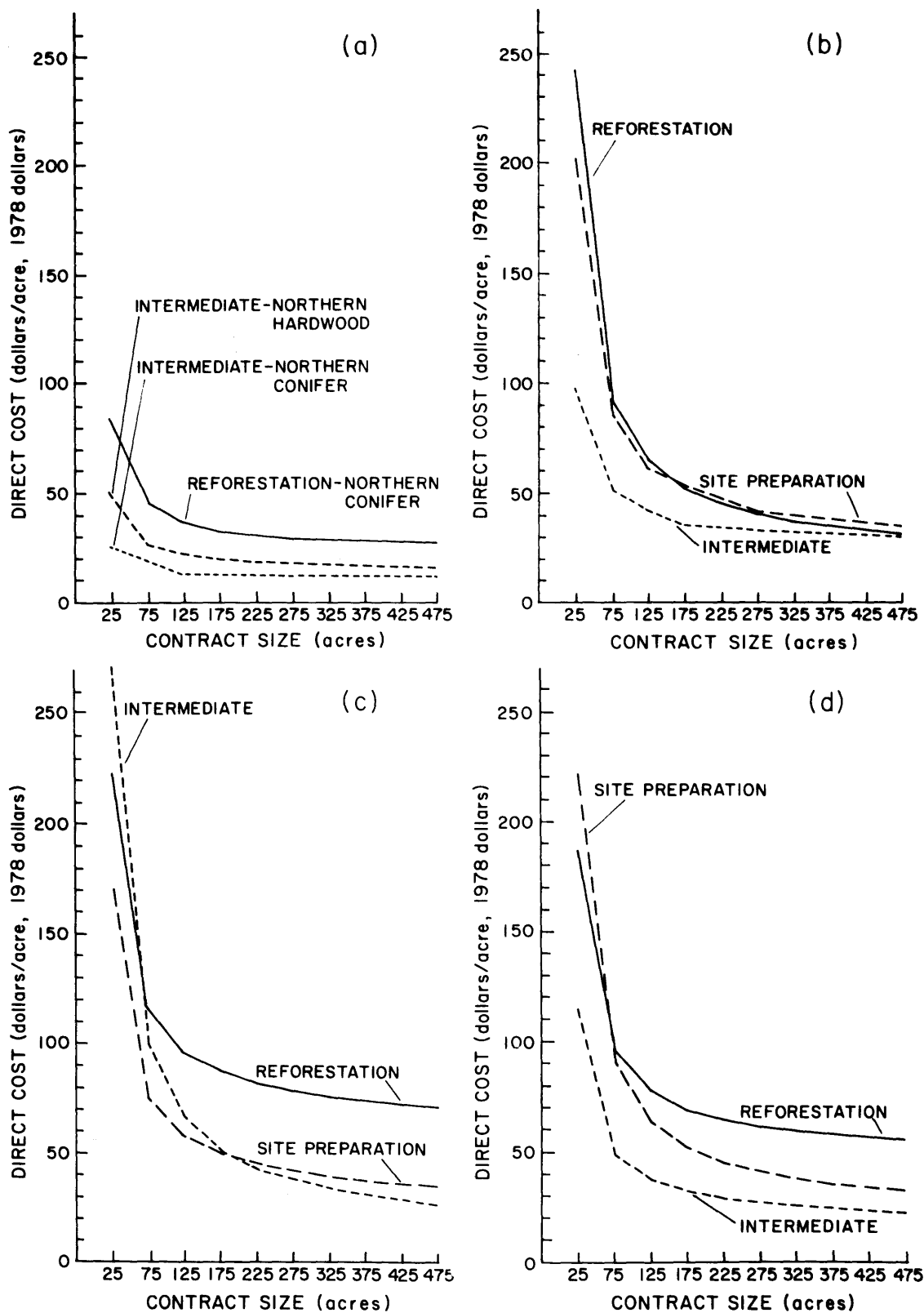


Figure 2--Average per acre cost for silvicultural contracts decreases as the contract acreage increases: (a) Northern conifer and Northern hardwoods, (b) Southern pine, (c) Douglas-fir, and (d) ponderosa and white pine.

subdivision of contracts into separate contiguous treatment areas occasionally increased the average treatment cost per contract acre, but the relationship was not consistent in all the regression equations. Row (1974) found that similar economies-to-scale of silvicultural practices were important in affecting the financial return from silvicultural investments.

CONCLUSIONS

Findings of this study lead to a hypothesis that the cost of silvicultural treatments on the National Forests will increase, and possibly substantially, during the 1980's. A corollary hypothesis is that much of the likely cost increase is within the control of management. The significant real cost increases from 1975 to 1978 that are not all explained by energy and labor costs; the treatment cost variation that could not be explained by site and treatment characteristics; and the diseconomies of small scale that will result if contracts are let for individual cutting blocks are all indicative of the influence that management decisions have on costs and cost trends.

These findings suggest that further study of silvicultural treatments on National Forests should concentrate on the causes of cost variation and especially the implications of management decisions on cost variation. If management knowledge and decisions are found to be responsible for a major portion of the cost variation and increase, a responsive strategy may be to more aggressively develop general treatment specifications and contracting guidelines. Without such an effort to manage costs, the financial return of National Forest silvicultural treatments will decline. Further, the comparative advantage in timber growing that the Forest Service has enjoyed over the nonindustrial private landowner will erode even further at a time when public assistance programs directed toward those landowners are intentionally targeting investments to improve efficiency.

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Problem Solving and Decision Analysis

in Silviculture

by

John H. Beuter ¹ /

Much effort is being expended these days to teach silviculturists how to do economic analysis and how to use stand growth computer models to maximize a desired criterion such as volume yields or present net worth. Some computer models combine stand growth models with optimization algorithms such as linear or dynamic programming.

As a result, silvicultural prescriptions are becoming more comprehensive and complete in terms of analysis. A few years ago it was rare to find reference to economics in one; today it is rare to find a prescription without economic analysis.

But have we made real progress in terms of what we are trying to accomplish? Are our plans and actions silviculturally sound? Can we defend them if challenged by forestry critics? Does this increasing use of computer models foretell the day when forestry decisions will largely be made by machines? Will silviculturists become obsolete?

My presentation to the National Silviculture Workshop touched on all these questions. In addition, it offered suggestions of alternative ways to solve silvicultural problems and analyze options for decisionmaking. Finally, it raised questions about the value of information and whether large forestry organizations are organized for effective silviculture.

The following is a synopsis of my presentation.

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What Is Silviculturally Sound?

Over the years I have polled professional silviculturists for their opinion of what constitutes silviculturally sound. The majority of responses key on biological capability and environmental protection. A suprisingly large number ignore owner objectives and cost-effectiveness.

The following outline shows two approaches for testing "silviculturally sound." The first refers to planning, i.e. the silvicultural prescription; the second refers to judging the soundness in terms of results on the ground.

- I. Silvicultural planning (prescription) -- Soundness can be judged by considering:
 - A. Owner's objective : Was it specified and considered in the analysis?
 - B. Biological considerations : Does it consider problems now and in the future? Are opportunities and limitations specified?
 - C. Environmental considerations : Is preservation of site productivity addressed? Are potential environmental problems, opportunities and limitations explicitly addressed?
 - D. Laws and regulations : Are limitations specified and considered in the analysis?
 - E. Cost-effectiveness : Are economic criteria specified and considered in the analysis?
 - F. Implementation feasibility : Is it clear the prescription can be implemented? Are there contingencies for when something goes wrong?
- II. Results -- soundness can be judged in terms of whether the owner's objectives were achieved without violating any of the constraints. Note that time is an important variable: concepts of soundness change over time. For example: Was terracing on the Bitterroot National Forest

silviculturally sound? It probably was given the objective to get regeneration at the time the problem was first addressed. However, in retrospect, it probably wasn't because environmental perceptions and public opinion changed over time.

How Do We Defend Our Silvicultural Prescriptions?

The key to defending a silvicultural prescription or decision is to prove one's expertness. This is done by providing an analysis that a dispassionate judge can agree is prudent and complete. The expert shows a thorough understanding of what he or she presents.

Simon (1977) sums it up in this way: "We choose among experts by forcing the experts to disclose how they reached their conclusions, what reasoning they employed, what evidence they relied upon. Having made their disclosure, they have exposed their assumptions and reasoning to the scrutiny and challenge of other experts. We do not have to be championship boxers to referee a fight."

Simon goes on to describe the relationship between one's expertness and the ultimate defense or justification of opinions or conclusions: "When [an expert] claims his expertness as the direct source of his conclusions, we are reluctant to challenge them. But we are prepared to examine and judge for ourselves those tenuous paths of common sense dialectic that commonly connect a specialized fact with a general consequence in the real world. We can do this if the paths are revealed."

In other words, the ultimate test is the ability to "duplicate the experiment." How do the conclusions match what can be independently observed? If the seedlings die, can we tell what went wrong?

Will The Forest Be Managed By Machines?

Can Silviculturists Be Eliminated In The Future?

The year is 1990. A new computer model has just been announced and its developers claim it will revolutionize forest management by making silviculturists obsolete.

The model is called SIMOPT-DF, an acronym for Simulated Yields--Optimized Management for Douglas-fir. Unlike the models of the 1980's, SIMOPT-DF uses site-specific variables to predict yields e.g. soil type, soil depth, aspect, elevation, rainfall. Furthermore, it is hooked to a region-wide monitoring system that evaluates past forest management practices and develops probability distributions for their success or failure. For example, the model knows the effectiveness of various vegetation management schemes and is able to instantly prescribe an optimal regeneration package, given the site-specific variables.

Furthermore, the model is capable of processing the landowner's objectives and constraints into its analysis to tailor-make prescriptions for the person's unique situation.

Though expensive to run, the model is purported to be cost-saving in two ways. First it eliminates the need for high-paid silviculture analysts. Technicians can gather biological and physical variables and low-paid social scientists can ferret out objectives and constraints. Second, the model considers so many options that it is much more likely than a silviculturist to choose the optimal one. This, in effect, instantly increases the landowner's present net worth.

Will such a model and information base exist? What effect would its existence have on the silviculture profession?

There is little doubt that the described situation is feasible. Furthermore, if and when it comes to pass, better silvicultural decisions will be made. An analog to this is the use of a world-wide information network by medical doctors to record

symptoms, treatments and results. Decisions based on the analysis of such information have a higher probability of being correct.

The described model and information base will not make silviculturists obsolete--it will help them to do their jobs more effectively. Silviculturists will earn their pay solving unique problems, not churning out programmed decisions from canned computer models.

Simon (1977) distinguishes between "programmed" and "nonprogrammed" decisions. The latter are unique, ill-structured, one-shot, novel policy decisions that are handled by general problem solving processes. These processes are a combination of routine analytics, creative thinking, intuition, inspiration, emotion and other ingredients of inspired problem solving. Somebody has to link site-specific observation to the objectives of the landowner and specify constraints. Somebody has to prepare contingency plans for things likely to go wrong.

The silviculturist provides the link between the real world and the model. Included are the calibration needed to validate the model, the assessment of existing and potential problems and the choice of the type of analysis needed to solve existing problems, avoid future ones and effectively achieve the owner's objective. The comparative advantage of the silviculturist over the machine is his ability to describe, analyze and solve problems. The machine is merely a tool to help do so.

An Overview of Problem Solving

A problem exists when the desired state is different from the existing one.

Example - I am at point A and want to be at point B.

A - - - - - → B

Example - I am at point C and should have been at point D.

• - - - - - → C
- - - - - → D

Example - I am hungry.

All these examples have in common a deviation from a desired state that requires action: get from A to B; get to D from C or figure the best way to cope with being at C; satiate my need for food. Finding the optimal act and successfully implementing it is the solution to the problem.

Some problem solving falls under the heading of trouble-shooting. In these cases, something has gone wrong, e.g. all the seedlings died, and the challenge is to find out why. Once the cause is determined, the problem can be eliminated in the future. Kepner and Tregoe (1976) present a structured approach to trouble-shooting that requires focussing on a deviation that specifies the problem. Once the problem is specified, the problem solver separates "What is" from "what is not", thereby making it possible to narrow the search for causes to the intersection of observations that apply to the specified problem. The procedure goes on to determine what is distinctive about "what is" and what may have changed and thereby caused the problem. The sifting process eventually leads to a set of possible causes which are further analyzed to determine a most likely cause. The most likely cause then becomes an input to decision analysis to determine that best means of eliminating the cause of the problem or working around it.

Rubinstein (1975) presents a more generalized approach to problem solving. He distinguishes between problems requiring synthesis and those requiring analysis. In synthesis problems, the answer (desired state) is known and the solution is the discovery of the best path to reach the desired state. An example would be a timber stand of specified stocking and tree size as the desired state.

Analysis problems, in contrast, involve using known procedures to find an unknown state (the answer). An example would be the determination of optimal thinning regimes.

Many problems in silviculture require both synthesis and analysis. Harvest

schedules to achieve specified amounts of wood over time are classic examples. We use analysis to determine optimal timber management regimes and synthesis to bring together the resources needed to implement silvicultural prescriptions

Rubinstein (1976) prescribes a general approach to problem solving that should be useful regardless of the type of problem one encounters. Following is a checklist of significant points:

- I. Have the right attitude -- One has to want to solve the problem, which means committing time and effort to doing so.
- II. Don't ignore known information -- For example, don't ignore site-specific information. Foresters sometimes use generalized growth models for timber stand projection without calibrating them to known information about a specific site. This can lead to erroneous assumptions about future outcomes.
- III. Avoid unnecessary constraints -- Some constraints are more perceived than real. Sometimes we constrain ourselves by association, e.g. a Forest Service employee may limit himself to a Forest Service approach to solving a problem when the use of a private sector approach might be more effective.

Another type of unnecessary constraint might be a narrow view of function. For example, timber harvesting may be viewed as an activity only concerned with removing trees when, in fact, it can play an important role in site preparation and regeneration if done properly.

World-view constraints limit our perspective for solving problems. The main purpose of an electric drill is to make holes. Once we recognize holes as the objective, the electric drill may or may not be the best way to make them. Likewise, not every forestry problem can be solved with a linear programming approach. We should focus on what we want to accomplish and find the best means for doing it.

- IV. Adopt an approach to problem solving -- Some guidelines are:

- A. Try to get the total picture -- don't jump to conclusions; withhold judgment.
 - B. Discuss your problem with others -- Talk, listen, ask the right questions.
 - C. Have the will to doubt -- There is a probability distribution associated with everything we do. Rarely is there only one way to accomplish something. Some forestry problems occur as a result of controversial activities and practices that aren't absolutely necessary. Less controversial means may be available. Solving these problems requires an open mind.
 - D. Use models; change the representation -- Models are abstractions of the real world that portray the essential elements and linkages related to a problem. For ease of understanding it is sometimes desirable to change how linkages are portrayed, e.g. transforming curvilinear relationships to linear ones. Mathematical models need not be exact to be useful. They need only result in better decisions on the average.
- V. Be aware of alternative paths to the solution of problems -- There is no universally best path to solving problems, although ongoing research aims to find a general problem solving approach using the artificial intelligence of computers. Such research has identified several paths to solutions used by human intelligence. Consider the following paths (not mutually exclusive):
- A. Work backwards : Start with what you are trying to accomplish and develop the feasible paths to get there from where you are. An example is the solution to a decision tree where the anticipated payoffs are traced back through the various branches to determine the highest expected value.
 - B. Generalize or specialize : At times it helps to work out a small, simplified version of a complex problem. Solving it may reveal the path

to solving the larger problem. At other times it helps to use a general formula or model to find the path to solving a specific problem.

- C. Explore Directions that appear plausible : Often problems are solved by linking together several approaches or models. It pays to have an open mind and not limit oneself to a single, conventional (safe?) approach.
- D. Develop stable substructures : Problem solving can be like a house of cards--it is possible to be successful up to some point and then have the whole approach collapse, requiring a new beginning. It is desirable to break a complex problem into modules which can be preserved as the work proceeds on different components of the problem. It is better to develop a stable structure with variable coefficients than to hard-wire all the relationships as if they represent ultimate truth.
- E. Use analogies and metaphors : It is well-known that many great discoveries were made on the periphery of the discoverer's main discipline or specialty. Often inspiration comes from observing something not seemingly related to the problem at hand, as when Einstein gained inspiration for his theory of relativity by observing the relationship of a fixed signpost to the moving bus he was riding. Try to relate your problem to familiar things in everyday life.
- F. Don't ignore your emotions : For whatever reason, many seemingly insoluble problems are overcome by following a tenuous path defined by a strong feeling within the individual. Usually success based on an emotional response is preceded by considerable thought and analysis, and the emotion may be a subconscious distillation of the payoffs and probabilities into the expected value believed best. As with any path to solving problems, it works better for some people than others.

The Value of Information -- A

Case Study In Decision Analysis

One of the most difficult things to determine in silvicultural analysis is the value of information. There is often a feeling that not much time nor resources are available--or, perhaps, should be allocated to--analyzing silvicultural alternatives. As one wag put it: "We never have time to do it right the first time, but we always have time to do it over."

Limited time and resources for analysis lead to blanket prescriptions and generalized conclusions. Two case studies will illustrate this.

Conventional wisdom held that the loss of phenoxy herbicides from a certain western national forest would drastically affect timber harvest schedules in the future. Based on the public pronouncements of some foresters, the loss of this important silvicultural tool was a disaster that had to be forestalled at any cost.

Taking a more reasonable approach, some foresters analyzed the situation (USDA, Forest Service, 1980). The analysis focussed on the real issue: vegetation management. The following steps were undertaken:

1. Determine exactly which acres fell into various vegetation management risk classes. It was determined that the key variables for predicting problems with undesirable vegetation were aspect and existing timber cover type. The forest was stratified into six classes.
2. Determine the payoffs for various timber management regimes, with and without phenoxy herbicides. Six treatments were identified ranging from no vegetation management of any kind, to all tools available, including phenoxy herbicides.
3. Determine the probability of various outcomes given a specific treatment. This reflects the probability that herbicides sometimes don't work as intended, as well as the probability that they do. Likewise, when no

treatment occurs, there is some probability that acceptable results will occur, though, for high risk areas it is more likely poor results will occur.

The probabilities were determined from regeneration records on file with the forest and from research results.

4. Determine expected values (payoffs weighted by probabilities) for the various alternatives. This was done for both volume and present net worth, in dollars.

The results of the study showed that the forest as a whole could produce 99 percent of the potential volume and 98 percent of the potential present net worth, even if phenoxy herbicides weren't available. It made visible which strata of the forests were at highest risk without vegetation management and showed the cost of the other treatment alternatives. For example, if no chemicals at all were available, the forest would be expected to produce only 63 percent of the potential volume and 35 percent of the potential present net worth.

The analysis presented useful information, but was it worth the time and resources it took to do it? Only time will tell.

Another case study offers a clearer picture of the value of information. Schöne (1983) investigated how much a public forest manager could afford to spend for site-specific information. The starting place was the agency's blanket prescription:

1. Plant 450 trees per acre
2. Regeneration surveys at one, three and five years after planting
3. Interplant if less than 300 trees per acre; replant if less than 100 trees per acre.
4. Precommercial thin if more than 500 trees per acre to residual of 450 trees per acre.

A model was built to accommodate possible outcomes, payoffs and probabilities

determined from observing regeneration records and survival in the field. It was found that an optimal blanket prescription was to plant 650 trees per acre instead of 450 trees per acre. The expected savings, over the entire forest, for adopting the revised blanket prescription was over \$50 per acre in present net worth.

The analysis went on to determine the value of gathering more specific information about site class and survival-related variables. The optimal prescriptions for the lowest and highest site classes were to plant 850 trees per acre, however because of the relatively few acres in these site classes it wasn't worth much to try to find them. If they could be identified inexpensively, e.g. by inspecting an existing soils map, it would be worthwhile to do so and adopt the optimal site-specific strategy.

Both of these case studies were accomplished in the mode of nonprogrammed problem solving and decision analysis. They contributed useful information which may lead to cost saving and better silvicultural results. Opportunities for similar problem-solving approaches abound in silviculture.

Organizing For Effective Silviculture

We have come full circle in the discussion of problem solving and decision-making in silviculture. We have discussed "silviculturally sound" the elements of problem solving and decision analysis and the value of information. None of this means much if our forestry organizations are not set up to encourage creative problem solving and do not have performance standards to insure high quality planning and results.

The basic issue is: Who is responsible? In large forestry organization there tends to be division of labor: harvesting specialist, site preparation and regeneration specialist, timber stand improvement specialist, and so forth. Furthermore, there are resource specialties that intersect with silviculture:

timber, recreation, wildlife, range and water. It is easy to find someone with a title that implies responsibility in each of these areas, but it is often unclear who has the overall responsibility for what happens on a specific site. Who brings together all the information into a cohesive plan? Who contracts and follows-up on contract performance? Who get rewarded if standards are exceeded? Or punished if something goes wrong?

Little research has been done on forestry organizations per se , however general organizational theory should apply. We should be concerned with how managerial functions are divided, span of control, employee motivation, accountability and so forth. Specifically, can we identify an organization that enhances silvicultural performance?

I have nothing to contribute to this question except a hypothesis that there is something to be learned by observing situations where a forest manager has total responsibility for a forest of say 10,000 to 15,000 acres. Given that this forest is reasonably productive, it is large enough to generate income needed to manage it, and small enough that the forest manger can be expected to be sensitive to what is on the ground anywhere on the forest.

Assuming good training in forest biology, the social sciences and analytical skills it seems reasonable to hold our forester responsible for everything that happens on his forest. I have observed some such situations and found the management to be biologically sound, environmentally sensitive, cost-effective and politically acceptable. The owner's objectives were being achieved in a manner that most would consider "silviculturally sound".

A clear advantage to this situation is that everybody, including the manager, knows who is responsible. If a problem arises, everyone knows who is supposed to solve it. If a good or a dumb decision is made, everyone knows who made it. There is no batting the ball around amongst specialists and teams to find responsibility. It is clear. Shouldn't we start thinking about organizing for more efficient silviculture?

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