PROCEEDINGS OF THE
NATIONAL SILVICULTURE
WORKSHOP

EUGENE, OREGON

OCTOBER 13-15, 1976

Density of Stocking Control

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

Introduction

The 1976 National Silviculture Workshop was held in Eugene, Oregon, on October 13-15, 1976. The objectives were to discuss second growth management of individual stands, with particular emphasis on the control of stand density.

These proceedings include papers that were available for publication and will be of future value. Two additional handouts that may be of interest are: (1) a brief synopsis of the field trip discussing each stop and (2) An Alternative for Managing West Side Douglas-fir Stands in the Cascade Range. The latter is a valuable publication for those interested in the use of silviculture to improve aesthetics. A limited number of copies are available from Region 6.

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Subject: 1976 National Silviculture Workshop

Chairman: Robert E. Gillespie

Time: October 13, 14, 15

Location: Eugene, Oregon - Valley River Inn - October 13 and 14
Field Trip October 14 and 15
End of Meeting October 15 - Portland, Oregon

Purpose of Meeting:
Second Growth Management - Stocking Levels by Age Class - Density Control - Yields

October 13

8:00 a.m.	Call to Order Introduction of Participants	Gillespie
8:05 a.m.	Welcome	Region 6
8:15 a.m.	Purpose of Meeting	Gillespie
8:30 a.m.	Reforestation and TSI Needs - Program Problem with Acreage - Definitions - Answers	Lamont Engle All Regions
9:30 a.m.	Control Systems and Their Importance to Silviculture Decisions - Acreage Controls - Data Compilation - Yield Accounting	Region 6
10:00 a.m.	BREAK	
10:15 a.m.	Yield Data - Provisions for Managed Yield Tables - Storage Change - Update, etc.	Daniel B. Jones
10:45 a.m.	Growth Committee What are we doing? The fit to Clark Row's program. Results - Progress - Future	Al Stage
11:00 a.m.	Stocking Levels - Guides and Fit to Management Plan	Roach and/or Marquis
11:45 a.m.	NOON	

1:00 p.m.	Stocking Levels - Yields and Guides	Gil Schubert Darrell Crawford
1:45 p.m.	Precommercial Thinning - Yields Costs and Benefits	Walter Fox
2:45 p.m.	Douglas-fir - What One Specific Thinning Requires Stocking Levels and Guides	Region 6
3:30 p.m.	Practical Application of Guides Discussion	Pearl All Regions
4:30 p.m.	END OF DAY PROGRAM	
6:00 p.m.	Night Meeting and Dinner Program Speaker - Regional Problems, etc.	

October 14th - Field Trip

October 15th

7:30 a.m.	Research Implementation	Dick Watt
7:45 a.m.	Research Needs	TMR - W.O.
8:15 a.m.	Wrap-up of Density Session	Gillespie
8:30 a.m.	Silvicultural Practices and Landscape	Twombly and Bacon
9:30 a.m.	Field Trip to Portland Speakers on bus and field trip to be provided by Region 6	
5:00 p.m.	AT PORTLAND, OREGON	

Register of Attendees

Name	Organization
John Alcock	Willamette, R-6
William R. Beaufait	Timber Management, R-1
Charles Bechtel	Kaibab, R-3
Bob Blomquist	Timber Management, R-9
Ron Bonar	R-10
Roy Bond	Regional Forester, R-8
Jim Bopes	Willamette, R-6
William D. Boyer	Auburn, Al., SO
William J. Bryan	Timber Management, R-4
Bill Chapparo	Timber Management, R-3
Mike Cole	Bozeman, Mt., INT
Darrell Crawford	Timber Management, R-3
Glenn R. Davies	Timber Management, R-5
Jerry L. Edwards	San Dimas Equipment Development Center, R-5
Gene Eide	Willamette, R-6
Orville Engelby	Timber Management, R-4
LaMont Engle	Timber Management, W.O.
Leonard Farr	Willamette, R-6
T. L. Figart	Gila, R-3
Walter Fox	Timber Management, R-8
Bob Gillespie	Timber Management, W.O.
Tom Greathouse	Timber Management, W.O.
Norm Grenell	Willamette, R-6
Ed Gryczan	Timber Management, R-2
Reid Jackson	Bridger-Teton, R-4
Ralph Jaszkowski	Willamette, R-6
Dave Johnson	Timber Management, R-10
Daniel B. Jones ?	Rocky Mountain Station
Wesley Kellie	Lolo, R-1
Walt Knapp	Timber Management, R-6
Mitch Knight	Timber Management, R-5
Peter Laird	R-1
Gale Larson	Willamette, R-6
Jim Laux	R-1
'Butch' Marita	Kootenai, R-1
Bob Mathison	Timber Management, R-2
C. D. McAninch	Timber Management, R-2
Gary Metcalf	Medicine Bow, R-2
John R. Milodragovich	Timber Management, R-1

Name	Organization
Wayne Orr	Willamette, R-6
Robert W. Pearl	Timber Management, W.O.
Carl Puuri	Timber Management, R-6
Donald Reukema	PNW, Olympia
Ben Roach	NE, Warren
Gilbert H. Schubert	RM, Flagstaff
Gene Sirmon	Mississippi, R-8
De Smith	Timber Management, R-9
Ed Smith	Timber Management, R-8
Al Stage	Moscow, INT
John Tephy	R-6
Jack Todd	R-6
Bill Tuttle	Timber Management, R-8
Bud Twombly	Timber Management, R-6
Stan Undi	Timber Management, R-5
Jack H. Usher	Timber Management, R-6
Bob Van Aken	Policy Analysis, W.O.
Peter Wagner	Timber Management, W.O.
Richard F. Watt	Cooperative Forestry, NA
Ham Williston	Jackson, Ms., SA

Control Systems - Their Importance in Silvicultural Decisions

Introduction

To begin with--let's define what we are talking about when we use the expression "control system".

In general, a control system may be defined as: "the formal processes and procedures which are used to measure and regulate accomplishment against planned goals or objectives."

In particular in this presentation I will be talking about those timber management control systems which are currently used in Region 6 and which directly or indirectly control the implementation of silvicultural activities, or monitor the effects of such activities.

In the planning and decision-making job--the development of adequate and workable control systems is often given rather cursory attention.

Control systems are often thought of as "bookkeeping" and "record keeping" procedures, and are often developed as a sort of "post-script" to the more interesting and imaginative conceptual phases of planning and decision-making.

Yet--as any planner or decision-maker would readily agree--the development of the most highly sophisticated and intensive silvicultural prescriptions--or intensive timber management plans--or finely tuned cultural treatment plans--are merely exercises in futility if they are not implemented on the ground with the same intensity and sophistication. It is the control system then, which finally determines whether or not plans and prescriptions are carried out.

They are important and they deserve careful attention and substantial effort, both in their development and in their execution.

In the next twenty minutes or so, I will try to cover three different types of controls which operate in Region 6 to influence and control silvicultural decisions and activities.

(1) Silvicultural standards, procedures, and techniques
(2) Silvicultural controls in the timber management plan
(3) Relationship of the budget process and silvicultural activities

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Presented by Jack H. Usher, U.S. Forest Service, Timber Management Unit, at the National Silvicultural Workshop, October 13-15 at Eugene, Oregon.

Discussion

Silvicultural Standards, Procedures, and Techniques

Silvicultural Activity Definitions -

The control and regulation of silvicultural activities begins in the Region with a set of silvicultural standards--or if you like--a set of standardized definitions, or criteria which define silvicultural activities. In your handout (1st 6 pages) packet you will find a list of definitions of harvest cutting practices, and cultural activities, used in the Region, and the letter code designation for each practice. These codes are universal throughout the Region and are a primary identifier for entry of planned or accomplished activities into our field data management system (TRI).

Since I am sure that each Region has a similar set of silvicultural activity definitions--I will not discuss them in detail--you can read the handout at your leisure.

Stocking Level Guides

Region 6 stocking level guides have been developed for each of the major species groups in the Region. They provide the basic guides for acceptable stocking levels in our stands. They consist of sets of coordinated stocking level curves and each table defines maximum, minimum, and recommended stocking levels by diameter class for a major species type age. Bud Twombly will discuss the construction and use of these tables in more detail this afternoon in his presentation. Suffice to say, for the purpose of my presentation, that the Regional stocking level guides are a primary control device intended to influence silvicultural decisions. Stands which are stocked below the minimum curve are so badly understocked that they should be replaced (i.e., Regenerated). Stands which exceed the maximum curve in stocking density are so badly overstocked that they also should be scheduled for early replacement. In our experience, stands which have been growing in this extreme condition of overstocking for a substantial period of time are not likely to respond adequately to stocking level control activities.

Stands which fall between the recommended and maximum curves may be candidates for thinning--precommercial or commercial, dependent upon the stand size and the numbers and volumes of excess trees.

Stands which fall between the minimum and recommended curve are candidates for interplanting, no treatment, or early replacement, dependent upon their age, size, tree condition, and management objectives.

Stand Examination

The technique which is used to inventory stand conditions preparatory to prescription is the Region 6 stand examination. Bud will also discuss this program in some detail this afternoon--and you will be exposed to it several times during the field trip--so I will not discuss it further here. Suffice to say that we find it invaluable as a basic tool in our silvicultural control and decision process.

Managed Yield Tables

The final silvicultural technique which I wish to mention is the Region 6 Managed Yield Table Program. The managed yield table is another and more specialized form of a stocking level guide. Managed yield tables are built to predict the stocking levels (in number of trees) and the intermediate and harvest yields which will be produced under various alternative silvicultural management alternatives. They are used as the basis for projecting growth and yields for regulated timber in the allowable harvest calculations in our timber management plans.

Again, Bud will discuss some of the details involved in building a managed yield table, so I will not discuss them here. We use the managed yield table concept as the basis for many important silvicultural and management decisions. By comparing managed yield tables for stands managed to maintain wildlife cover against a "standard" managed yield curve, we can determine the yield impact of preserving wildlife cover--or maintaining certain levels of wildlife snags for birds--or meeting the visual requirements--or maintaining stream temperatures.

By using these tables as the yield functions in allowable cut calculations in RAM--and comparing separate runs made with standard tables and with the special tables, we can determine the trade-off values (in terms of MMBF of allowable cut) of many different alternative multiple use management allocations.

By building managed yield curves for stands managed with and without a silvicultural practice, precommercial thinning for instance, and comparing the two RAM runs made using the different tables, we can determine the allowable cut gain from the practice.

Timber Management Plans

The primary control on silvicultural decisions in this Region is the 10-year timber management plan.

Under our system, the management plan and the allowable harvest calculations for each National Forest present a range of possible allowable harvest levels rather than a single allowable cut level as did previous plans. The upper limit of this range, <u>the potential yield</u>, is the highest allowable harvest level for the next decade that would be possible to reach and sustain with the most intensive silvicultural management that would be technologically feasible over the next ten years. It considers productivity of the land, the use of conventional and advanced logging technology, all technologically available intensive silvicultural practices, and the interrelationship or timber with other resource uses and the environment.

A level of allowable harvest is also calculated that is attainable if the currently funded level of silvicultural intensity were continued over the next decade. This level of yield defines the lower limit of the proposed allowable harvest range to be presented in each plan.

The difference between the potential sustainable allowable harvest and that which would be programed under current levels of management represents a harvest opportunity that could be realized and programed dependent upon the acres of silvicultural practices that are accomplished during the plan decade. A description of each such practice and the allowable harvest benefits and investment cuts of implementing each practice is a part of each new management plan. To illustrate this rationale and how it influences silvicultural activities--let's look at an example drawn from the Gifford Pinchot management plan. (Refer to handout.) First, however, some term definitions.

Intensive Silvicultural Practices

Stocking Level Control - This is a broad category of cultural activities that include thinning and afforestation practices in young stands aimed at keeping all commercial forest land stocking at an optimum level. The practices included on the Gifford Pinchot are precommercial thinning of overstocked stands below merchantable size; brush or other competing vegetation control in these stands (by herbicides or mechanical means), afforestation (through interplanting) to bring presently poorly stocked young stands up to recommended stocking levels), and reforestation of "backlog" nonstocked areas.

Planting Genetically Improved Stock - As a part of the Gifford Pinchot allowable harvest calculation, we have also calculated the potential allowable harvest level gains which would result if we were able to plant all regeneration (final harvest) acres to be cut over the next decade with first generation genetically improved nursery seedlings. The forest is well along with its tree improvement program and is presently beginning to produce a significant amount of nursery seedlings which have been produced from seed harvested from superior trees selected on the forest.

On the Gifford Pinchot, the annual programed harvest increase which could be taken upon accomplishment of these intensive practices would be:

1.	PCT, Interplanting, and Brush Control	1.169 million board feet annual yield increase per 1,000 acres accomplished
2.	Reforesting Nonstocked Backlog Acres	1.547 million board feet annual yield increase per 1,000 acres accomplished
3.	Genetics	0.239 million board feet annual yield increase per 1,000 acres accomplished

The preceding figures are a representation of the "allowable cut effect" of implementing each intensive practice. In essence, this rationale says, for example, that as soon as we have successfully reforested 1,000 acres of "backlog" nonstocked land, we could immediately increase the allowable harvest level by 1,547,000 board feet per year. This immediate increase in cut could not, of course, be harvested from the acres just planted, but rather would allow us to annually sell and harvest an additional 1,547,000 board feet of old growth. This immediate benefit, often called the allowable cut effect, is justifiable since by successfully reforesting this 1,000 acres, we have assured ourselves that an equivalent amount of additional volume will be sustainable in the future through growth on the 1,000 acres of plantation we have currently established. Similar assumptions are made for the other intensive practices except that the future benefits for P.C.T., IP, and genetics are the result of increased rates of utilizable growth on the same acres rather than the result of expanding the acre base. Parenthetically, it should also be noted that our ability to take immediate allowable harvest gains for accomplishment of these practices exists because we have "excess" old growth inventories on the National Forests--and if we were not operating under an "evenflow" sustained-yield charter, the benefits of these practices could not be taken until the increased growth produced by them had actually resulted in more trees growing to merchantable size.

The approximate direct cost per 1,000 acres of implementing each practice on the Gifford Pinchot is as follows:

1.	PCT and IP	$ 75,000 per 1,000 acres
2.	NS	$164,000 per 1,000 acres
3.	Genetics	$ 3,010 per 1,000 acres

Now, let's look at the handout. (Give corrections.) Essentially the format of this table is as follows:

1. The tree vertical columns define three possible levels of allowable harvest that could be programed from the Gifford Pinchot National Forest for the next decade--and which could be sustained for at least 30 decades into the future if the premises built into this decade's plan were to be projected for that period of time.

2. The left hand column (1) indicates the sustainable allowable harvests for the decade if current budget levels (investments) were to be continued for the decade.

3. The right hand column (3) indicates the allowable harvest that could be programed if the budgets and technological constraints were overcome and we could manage the forest at the full potential yield levels.

4. The middle column (2) indicates the average annual programed harvest level that was proposed for the decade, and for which financing was reasonably assured, in the approved plan for the forest.

The horizontal line entries in each column indicate the technological constraints which must be overcome and the acres of each intensive practice that must be accomplished to reach the total programed cut as entered on the total line at the bottom of each column.

I will discuss each line entry very briefly.

Standard and Special

The first line defines a basic nonintensive management level based on prompt planting of regenerated areas, no stocking level control in young stands, prompt commercial thinning as soon as stands reach commercial thinning size, commercial thinning entries at 10-year intervals up until rotation age and then prompt regeneration harvest. This line assumes that this basic management intensity can and will be applied to all standard and special land components. It is essentially a "no investment" level of management insofar as appropriated funds are concerned (K-V pays for regeneration; CT and REGEN cuts are self-supporting operations, i.e., the return in stumpage receipts exceeds the costs of performing the operation.)

Programing Marginal Areas

Column

(1) 4,200 acres or 20 million board feet could be programed annually within the "present budget" limitations of money, men, and systems, providing the market price of timber remained at least as high as present, and the required harvesting systems were available for economic use.

(2) Same as 1.

(3) 8,100 acres of regeneration cutting and 4,000 acres of commercial thinning can be annually programed if the budget, economic, and technological constraints can be overcome.

Principal Technological Constraints
a. Improved reforestation techniques required to assure prompt regeneration on certain soils, aspects, and upper forest timber types.

Principal Economic Constraints
a. High road access costs
b. Logging costs of using advanced log suspension systems (long skyline, helicopter, perhaps balloon)

Basic Level
Sum of previous two lines. This line is the level of harvest which would be available at a nonintensive management level and presuming that the assumptions made in programing the marginal component were valid.

Intensive Management Levels
The remaining line entries show the effect on programed cut levels by application of the various intensive management practices.

Precommercial Thinning
(1) Thinning of 7,000 acres of highest priority stands. (total decade direct cost $780,000).

(2) Thinning 35,734 acres of presently accessible stands. (total decade cost $3,980,566)

(3) Thinning the total overstocked. (total decade cost $8,322,891)

Interplanting
(1) No interplanting

(2) Interplant all cutover areas. (total decade cost $1,928,865)

(3) Interplant all understocked areas. (total decade cost $3,063,120)

Planting of Nonstocked Backlog
(1) Plant all nonstocked backlog with a productivity greater than 30 CF/acre/year. (total decade cost $2,532,661)

(2) Same as Item 1.

(3) Plant all the nonstocked backlog. (total decade cost $2,567,661)

Planting of Genetic Stock

(1) Select 850 parent trees and plant 40,000 acres with progeny from the parent trees. (total decade cost $49,865)

(2) Same as Item 1.

(3) Plant 94,500 acres with seed from 2,000 selected trees. (total decade cost $284,865)

Mortality Salvage

This is salvage of normal endemic (as opposed to catastrophic) level of mortality--that occurs outside of scheduled sale areas during the decade. It is a minimum harvest level goal (not an upper limit) and may be expanded if markets and costs of recovering this type of scattered dead or dying trees make such expansion economically feasible.

Total Line - Total annual harvest which could be programed during the next decade under each of the column heading assumptions.

Budget

The ultimate control on silvicultural decisions and accomplishments is the budget process. Money and manpower are the final and vital factor which determines accomplishment of all management objectives. Unless our silvicultural techniques and plans can be tied firmly into the budget process, then they have indeed been wasted efforts.

In budget planning for fiscal year 1979 for Region 6, we have incorporated the rationale just illustrated for the Gifford Pinchot into developing Regional budget proposals for the timber system. The rationale used in this attempt to provide a direct tie between budget proposals and silvicultural objectives was as follows:

1. First we determined the land base which will be available for timber management in 1979 (in terms of acres of standard, special, and marginal) through predicting the changes in availability of the nonselected roadless areas which will likely occur by 1979 through the land use planning process.

2. Once the likely base has been determined in item 1 above--we then calculated the allowable harvest (sell) level range that could be justified through intensive management practices on the available land base. The upper and lower end of this range was defined as follows:

Management Intensity

Lower End - Commercial thinning plus stocking the nonstocked backlog.

High End - Commercial thinning plus stocking the nonstocked backlog plus precommercial thinning, plus genetic improvement.

3. Using timber management planning efforts currently in progress--and acre data from the Region-wide preliminary 10-year reforestation and TSI plans, we calculated the necessary ace factors needed to relate proposed sell levels to the acres of P&M reforestation, TSI, and genetic stocking required to support those levels.

4. Using the above determined items, we then prepared three trial target sets which would define three alternative timber system program levels which would be necessary to accomplish three trial program levels for fiscal year 1979. The three target sets to be defined are:

a. Low Level - Timber system output commensurate with operating at the commercial thinning and restocking of the nonstocked backlog level of management intensity.

b. High Level - Timber system output commensurate with operating at the precommercial thinning level of output (CT + nonstocked backlog + PCT).

c. Intermediate Level - Timber system output commensurate with operating at a management intensity level approximately halfway between the low and high level.

d. These three levels are divisions on a continuum that ranges from a low yield 3,800 MMBF to the highest possible yield, 5,000 MMBF. The low level encompasses yields from 3,800 MM to 4,200 MM; the intermediate level is from 4,200 MM to 4,600 MM; and the high level includes 4,600 MM to 5,000 MM. The trial target sets have been set at the lower level of each of these divisions: 3,800 MM, 4,300 MM, and 4,600 MM. Ultimately nine alternative target sets along the continuum will be costed out to provide a complete range of funding alternatives. Execution of the above objectives resulted in the following trial target sets and trial dollar levels.

(Refer to & discuss the last page of the handout packet)

33 - A METHOD OF ANALYZING. The following is a procedure which can be used for prescribing a silvicultural practice.

Check certain conditions which can qualify the stand for a particular practice. If these conditions do not qualify the stand for that practice, check other conditions which can qualify the stand for another practice.

Begin with a removal cut. Determine if the stand contains at least two distinct canopy levels. If it does, check on the stocking level of the highest or tallest level. If it does not, go to the commercial thinning practice and begin checking conditions which could qualify the stand for that practice. Continue this procedure until all the conditions for a stand will qualify it for a certain practice.

Following is a check list of some conditions which indicate that a stand may qualify for the silvicultural practice shown:

1. Silvicultural Practice: Removal Cut

   To qualify for this treatment, a stand should:

   a. Contain a salable quantity of merchantable timber.

   b. Contain at least two distinct canopy levels.

   c. The highest level must not exceed minimum stocking level.

   d. The highest level must be composed of mature or cull trees.

   e. The condition of trees in the highest level makes it undesirable to retain them in the stand until most of the trees in lower level(s) become merchantable. -*

*-f. Lower levels contain crop trees at or near recommended stocking level.

g. Crop trees are capable of attaining per acre volume production rate acceptable to management within an acceptable time period after stocking level of the manageable component is adjusted to the recommended level.

2. Silvicultural Practice: Commercial Thinning

To qualify for this treatment, a stand should:

a. Contain a salable quantity of merchantable timber in excess trees.

b. Contain crop tree stocking to the recommended level.

c. Have stocking in excess and cull trees dense enough to be inhibiting growth of crop trees.

d. Have crop trees whose characteristics indicate that increased growth will result in an acceptable time if stocking is adjusted to the recommended level, or

e. Have crop trees near rotation age whose characteristics indicate that growth can be maintained at an acceptable rate if stocking is adjusted to the recommended level.

3. Silvicultural Practice: Regeneration Cut

To qualify for this treatment, a stand should:

a. Contain a salable quantity of merchantable timber.

b. Have total live tree stocking either

(1) At or below the minimum stocking level (all tree classes), or

(2) Exceeding the minimum stocking level but trees are primarily mature or cull, or

(3) Which will soon be reduced to or below minimum stocking level by predictable mortality.

c. Contains crop tree stocking to recommended level but stocking in mature and excess does not permit expectation of retaining crop tree stocking following the harvest activity.-*

*-d. Be able to be reforested within the prescribed alloted time period shown in the manual.

4. Silvicultural Practice: Precommercial Thinning

To qualify for this treatment, a stand should:

a. Contain crop tree stocking to the recommended level.

b. Not contain mature trees eligible for removal cutting.

c. Contain dense enough stocking in excess and cull trees to be inhibiting growth of crop trees to the extent that trees will not reach merchantable size within an acceptable time span acceptable to management.

d. Most crop trees have characteristics which indicate that increased growth will occur in an acceptable time if stocking is adjusted to the recommended level. These characteristics include the following:

(1) Crown ratio greater than 40 percent.

(2) Free from serious mistletoe infection.

5. Other Practices: Salvage

To qualify for this treatment, a stand should:

a. Contain a salable quantity of salvable dead trees plus other trees which can be identified as certain to die before the stand becomes eligible for any other silvicultural treatment involving harvest of trees.

b. Be either

(1) Ineligible for other silvicultural treatment at the time, or

(2) Other treatment prescribed is to be deferred.

6. Sanitation

To qualify for this treatment, a stand must:

a. Contain a salable quantity of dead, damaged, or other trees the removal of which is necessary to prevent the spread of pests or pathogens.-*

*-b. Be either

(1) Ineligible for other silvicultural treatment at the time, or

(2) Other treatment prescribed is to be deferred.

7. No Treatment

a. Stand is healthy and crop trees do not or will not benefit from stocking level control.

b. Prescribed treatment needs to be deferred.-*

Field No. 33 (continued)

Timber Harvest Activities.

HCC Clearcut. (Group, patch, strip or stand.)

HCR Clearcut with Seed Trees Reserved. (Seed Tree Cutting.)

HCU Substandard (Cull) Timber removal. (Use when only substandard material is harvested, not in conjunction with harvest of standard material.)

HFR Final Removal Cut.

HPL Prelog or preparatory cut.

HPR Partial Removal Cut.

HRG Regeneration Cut Prescribed. USE ONLY IN PRESCRIBED ACTIVITY FIELD, NO. 33.

HRM Removal Cut Prescribed. USE ONLY IN PRESCRIBED ACTIVITY FIELD, NO. 33.

HSA Sanitation Cut.

HSH Shelterwood Cut. (Use only to describe the "Seed Cut" in the Shelterwood system, not the Preparatory or Removal Cuts.)

HSP Special Cut. (Refers to cutting of some trees from an area for other than silvicultural purposes, such as making a spot for picnic tables, etc. Must not be used when cutting reduces stocking below minimum stocking level. Does not apply to salvage or sanitation, even if conducted in a campground or in the Special Cut Component area designated in the TM Plan.)

HSV Salvage Cut.

HTH Commercial Thinning.

HTX Commercial thinning of Xmas Trees.

Field No. 33 (continued)

No Activity

NTM No Treatment Prescribed. USE ONLY IN THE PRESCRIBED ACTIVITY FIELD No. 33. (Use to show that an area has been examined for treatment needs, and a determination has been made that no vegetation management activity should be planned or conducted until conditions change.)

Reforestation Activities. Reforestation activities also include all related treatments planned and carried out as a part of the reforestation process, and recorded on the Reforestation Activity Record. (Site Preparation, Animal Control, Release, etc.)

RAS Artificial Seeding. USE ONLY IN COMPLETED FIELD, No. 39

REF Reforestation. (Normally all prescribed and active reforestation projects are identified by this code until reforestation is completed, and then the appropriate code to show type of reforestation actually done is entered in the Completed Projects Field, No. 39. If reforestation is accomplished by a combination of methods, REF may be used in the Completed Projects field to indicate this.)

RNP Natural Seeding with Site Preparation. USE ONLY IN COMPLETED FIELD, No. 39.

RNS Natural Seeding without Site Preparation. USE ONLY IN COMPLETED FIELD, No. 39

RPL Planting. USE ONLY IN COMPLETED FIELD, No. 39

I RSP Reforestation with Site Preparation Prescribed. (USE ONLY IN PRESCRIBED FIELD, No. 33. This code indicates that the site is occupied with non-tree vegetation which must be removed, such as old brushfields, etc.)

Stand Improvement Activites

SCN Cleaning.

SDR Destruction of noncommercial stand in order to regenerate with a more productive stand.

SFL Fertilization.

SPC Precommercial Thinning.

SPR Pruning.

SRL Release.

GIFFORD PINCHOT N. F. R-6

SUMMARY - ANNUAL ALLOWABLE HARVEST LEVEL ALTERNATIVES - AND ACRES OF INTENSIVE MANAGEMENT PRACTICES REQUIRED DURING THE NEXT DECADE TO JUSTIFY EACH HARVEST LEVEL

	Decade Acres	PROGRAMED HARVEST LEVEL (MM BD FT ANNUALLY) ① At Present Budget Levels	② At Planned Budget Levels	③ At Potential Yield Level
Standard & Special (Nonintensive Management Base Level)		255.08	255.08	255.08
Programed Marginal	1) 4,200 acres	20.00		
	2) 4,200 acres		20.00	
	3) 12,100 acres			41.67
Basic Level (Nonintensive Management Level)		285.08	285.08	306.75
Intensive Management Practices				
Precommercial Thinning	1) 7,000 acres	8.18		
	2) 35,734 acres		41.76	
	3) 74,981 acres			87.64
Interplant	1) 0 acres	ø		
	2) 29,301 acres		34.28	
	3) 38,289 acres			44.75
Planting of Nonstocked and Backlog	1) 21,628 acres	33.46		
	2) 21,628 acres		33.46	
	3) 21,768 acres			33.68
Planting of Genetic Stock	1) 40,000 acres	9.59		
	2) 40,000 acres		9.59	
	3) 94,500 acres			22.58
Mortality Salvage	1) 4,100 acres	10.00		
	2) 4,100 acres		10.00	
	3) 4,100 acres			10.00
Total		336.31	404.17	495.40

R-6 - FY 1979 BUDGET PROPOSALS - TIMBER SYSTEM

Total Forest Allocations

	Targets			M Dollars		
	Low Level	Int. Level	High Level	Low Level	Int. Level	High Level
031						
Timber Sale Offerings (MMBF)	3800	4200	4600	19950	22050	24150
032						
Management Plans and Inventories ($)				1713	1713	1713
033						
P&M Reforestation (M Acres)	8000	10600	21200	1460	1940	3880
034						
P&M Precommercial Thinning (M Acres)		22500	44900	300 1/	2750	5480
035						
Nursery Expansion ($)				1583	1989	2651
036						
Tree Improvement ($)				538	538	803
037						
Silvicultural Exams (M Acres)	472	566	689	1416	1698	2064
Timber System Support ($)						
Wildlife						
Range						
Minerals and Geology						
Recreation						
Soil and Water Management						
Fire Management and Lands						
Subtotal				3080	3415	3740
Engineering Support (FR&T $)				88315	97612	106909
			Total	118,355	133,705	150,590

1/ COR Costs 1978 Contracts

USING MULTIPLOY FOR EVALUATING SILVICULTURAL TREATMENTS

By Daniel B. Jones[1]

MULTIPLOY is a computer language used to simulate and evaluate investments in forestry. The computer program was developed by Clark Row (1975) and is documented by the two-part manual, System MULTIPLOY: A Computer Language to Simulate and Evaluate Investments in Forestry. Part 1, Introduction and Basic Manual (Row, 1976), contains detailed instructions for using the system; and Part 2, Training Guide (Row, et al., 1976), consists of a series of progressively more complex lessons which lead the user through most of the features and options of MULTIPLOY. Both manuals are presently in draft form, but should be published in the near future. The program has been used by several regions of the National Forest System on a limited basis with encouraging results. The program is operational at the USDA Computer Center in Fort Collins, Colorado (FCCC) to all who have access to the facilities.

Uses of MULTIPLOY

MULTIPLOY can be used to simulate timber and other inputs of forest land management regimes on single tracts or projects over the long time periods required to produce forest crops. It can also be used to evaluate financial returns of managerial options in terms of income per acre, rate-of-return on investment, long run average revenues and costs, and required capital expenditures. The primary uses of MULTIPLOY are: determining the effects of timber conditions, economic situations, and management decisions on financial returns (long range);

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and setting priorities by analysis of likely economic returns on a project-by-project basis (short range). Some other uses of the system are: estimating dollar-value increases attributable to gains from genetic improvement or fertilization; estimating the value productivity of land use; estimating dollar-values of fire, insect, or disease losses and riskiness of forest investment; and filling the analytical gap between yield tables and allocation models such as Timber RAM (Navon, 1971).

Specific Features of MULTIPLOY

MULTIPLOY uses individual or "custom" yield estimates, either in the form of externally supplied yield tables, internally generated simulations (either "canned" routines or user-provided equations), or a combination of both. The user has a virtually unlimited selection of costs and prices, ranging from fixed levels to variable levels determined by estimating formulae designed by the user. These formulae can vary with such factors as the difficulty of the situation, the intensity of treatments, and the amount of timber harvested (or yields simulated). The system allows for reduction in outputs from use of lands for alternate purposes or because of geographic features, fire, storm, insects, and diseases. It also allows for salvage of specified proportions of these losses. Allowance can be made for genetic and silvicultural growth gains when growth is estimated by simulation. Multiple use yields (grass and forbs, browse, water, and sediment) can also be included in the evaluations. Besides the above factors, additional financial or economic factors can be incorporated, such as the initial costs of land, the value of land in use after final harvest or loss, and the allowable cut effect. The alternative measures of economic returns that can be determined by the system are equivalent annual income, present net value, benefit/cost ratio, and rate of return on investment.

What MULTIPLOY Produces

The system produces four basic types of output. The Timber Stand and Output Table is a chronological record of the characteristics of the timber stand and harvests; the Trial Summary shows the results of each trial or evaluation; the Revenue and Cost Schedule shows an itemized cash flow schedule used to calculate the foregoing dollar values; and the Problem Summary lists the results of all trial runs in a problem (if more than one trial is performed).

Basic MULTIPLOY Instructions

MULTIPLOY utilizes a format-free input, i.e., the input instructions are in the form of basic English sentences and ordinary mathematical equations. The format was designed especially for people who are not primarily data processors and for those with only a keyboard terminal available to them. A complete cross-referenced list of all the allowed instructions is presented in the appendix of the Basic Manual (Part 1). This cross-referenced list allows the user to quickly find detailed descriptions of the instruction statements. One very convenient feature of the input form is that numbers (data) do not have to be in specific columns, but have only to be separated by commas or blank spaces, thus allowing quicker, less frustrating, and more accurate entry of the data.

The basic format of the instructions is a memo. The heading of the memo has TO, FROM, and SUBJECT lines. The main body of the memo contains the simulation commands and the reading and writing instructions. The closing section of the memo contains instructions for executing the problem. The memo allows for the insertion of comments, blank lines, continuation lines, and separation to make the memo easy to understand and interpret (especially after lying idle for several months).

Specific Features of MULTIPLOY

Probably the best way to illustrate the features of the program is through some examples. Figure 1 shows an input memo for a typical MULTIPLOY problem. In this example we'll examine an existing stand through its final harvest and then examine the subsequent stand through one rotation. We will test the sensitivity of the problem to the harvest age in the initial rotation. The memo contains instructions for evaluating the sensitivity of final harvest age on the management of an even-aged stand. You can see the form of the memo heading in the first three lines of the memo. Below the heading, in lines 5 through 15, is the management regime for the existing stand (initial rotation). Lines with an asterisk in column 1 are comment statements. The instructions are self-explanatory with the possible exception of the variables in the yield table (lines 10 and 11). The variables used in this yield table are: T -- average stand age, D -- average diameter breasthigh, N -- average number of trees per acre, Y -- average total volume per acre, O -- average merchantable volume per acre, YC -- average total volume yielded if cut, and OC -- average merchantable volume yielded if cut.

Lines 17 through 34 contain the management regime for the subsequent rotation. Note the different treatments specified for the subsequent rotation. Yield table 2 is used in this subsequent rotation.

Associated with the different treatments specified for both rotations are the different costs and prices depicted in lines 36 through 44. Note that some of the costs are specified as fixed (e.g., line 38) or variable -- specified as an equation or function of the yield table variables (e.g., lines 43). Included with the costs and prices is a statement REDUCE YIELDS FOR HOLES BY .01. This statement causes a reduction in yields for any number of reasons, such as non-stocked holes, roads, landings, administrative sites, ridge lines, stream courses, and rock outcrops. This instruction is not a cost but illustrates that MULTIPLOY instructions can be in any order (with a few minor exceptions).

Lines 46 through 49 contain the discounting instructions to be used by MULTIPLOY in the economic evaluations.

Since the objective of this problem was to test the sensitivity of harvest age on the yields (both biological and economic), lines 51 through 53 contain the instructions to perform this sensitivity test.

Figure 2 contains the Stand and Output Tables for this problem. This table is the one printed for harvest age = 60. Similar tables are printed for harvest ages 40 and 50. Notice that the tables display

```
TO: MULTIPLOY          'DATE'
FROM:    'ANALYST'S NAME'
SUBJECT: 'LESSON 4'

* MANAGEMENT REGIME FOR EXISTING STAND (INITIAL ROTATION)
SET PRESENT AGE AT 40 YEARS
REMOVE CULLS AT 40 YEARS IN INITIAL ROTATION
HARVEST FINAL YIELD AT AGE 60 IN INITIAL ROTATION
USE YIELD TABLE 1 IN INITIAL ROTATION
READ 3 YIELD CARDS INTO TABLE 1 WITH VARIABLES T, D, N, Y,
 O, YC, OC
40, 10.6, 200, 10, 9, 5, 3
50, 11.6, 150, 6, 15, 3, 5
60, 12.4, 100, 2, 20
USE YIELD TABLE 2 FOR SUBSEQUENT ROTATION

* MANAGEMENT REGIME FOR SUBSEQUENT ROTATION
CONTINUE TRIAL BEYOND FINAL HARVEST ONE ROTATION
PREPARE SITE FOR REGENERATION
PLANT 500 SEEDLINGS
LAG REGENERATION 4 YEARS
PRECOMMERCIAL THIN AT AGE 10 IN SUBSEQUENT ROTATION
PRESCRIBE BURN FROM 15 TO 40 AT 5 YEAR INTERVALS IN SUBSEQUENT
 ROTATION
THIN
HARVEST FINAL YIELD AT AGE 50 IN SUBSEQUENT ROTATION
USE YIELD TABLE 2 IN SUBSEQUENT ROTATION
READ 5 YIELD CARDS INTO TABLE 2 WITH VARIABLES T, D, N, Y,
 O, YC, OC
20, 8, 300, 10, 0, 3, 0
30, 9.2, 250, 12, 6, 4, 1
40, 10.6, 200, 10, 9, 5, 3
50, 11.6, 150, 6, 15, 3, 5
60, 12.4, 100, 2, 20

* COSTS AND PRICES
REDUCE YIELDS FOR HOLES BY .10
COST OF REMOVING CULLS IS $25
COST OF PREPARING SITE IS $40
COST OF PLANTING = $10 + $.01 * SEEDLINGS
COST OF PRECOMMERCIAL THINNING IS $15
COST OF PRESCRIBE BURN = $3 - $.04 * T
COST OF SALE PREPARATION = $1 * Y + $3 * OC
REVENUE OF TIMBER = $4.5 * Y + $60 * O

* DISCOUNTING INSTRUCTIONS
ASSUME DISCOUNT RATE OF .08
ASSUME REVENUE IN FURTHER USE OF $40
COMPUTE RATE OF RETURN

MAKE SENSITIVITY TEST
VARY FINAL HARVEST AGE FROM 40 TO 60 IN 3 STEPS
LABEL: HARVEST AGE
WRITE USING 80 COLUMN FORMATS
```

Figure 1. Sample input memo for MULTIPLOY, illustrating sensitivity testing.

yields for both rotations before and after all treatments. The user may specify different tables to be used before and after treatments and in initial and subsequent rotations. As we'll see in the next example each of these can be specified for treated stands and alternative base comparisons. Thus there are 8 situations for which different yields may be specified. Some of the columns in the tables may need explanation. There are two years specified (A and T). "A" is the investment age which runs from year 0 out to the planning horizon; "T" is the stand age and recycles for each rotation. Height, basal area, number of trees, diameter, total volume, and merchantable volume are self-explanatory. VAL is the value of the merchantable timber. Listed for the timber harvest are diameter, quality index, total and merchantable volume, value, and periodic revenues and costs. Note that for each year delineated there are two rows of numbers: the first row is for the standing timber before treatment and the second row is for the timber harvest.

Figure 3 presents the Revenue and Cost Schedule when harvest age = 40. This is an itemized list of all the revenues and costs and the year in which they occurred.

Figure 4 presents the Trial Summary Table for the trial where harvest age was 60. The trial summary presents the volume and value of the timber inventory and all cuts for the planning period. It also shows the combined values, both undiscounted and discounted, for the net and gross revenues and the costs. It also shows the present net value, equivalent annual income, benefit/cost ratio, and internal rate-of-return.

Figure 5 shows the Summary Table for the entire problem. It lists various factors achieved at the different harvest ages (the harvest ages are listed under the column labelled CASE). The columns in this summary table are the system's default headings -- the user may specify any factors he (she) wishes.

Sensitivity tests can be made on a variety of other factors such as allowable cut effect (duration, level, minimum cut), discount rate, establishment age, first and last thinning age, local cost or price modifier, minimum pulpwood or sawtimber diameter or volume, number of trees established, regeneration lag, site index, yield reduction for holes, etc.

Figure 6 shows the memo for another type of evaluation that MULTIPLOY can perform -- the case-by-case evaluation. The management regimes specified in this memo are basically the same as for the memo in Figure 1. Note, however, the cost of removing culls specification in line 37. It is specified by the equation COST = $1 * DIFF (where DIFF is a difficulty factor). Suppose that you wish to evaluate the effect of different difficulty factors on the outcome (both biological and economic) of the management strategy outlined in this memo. The instructions required to do this are found in lines 46 through 48 and lines 55 through 62. Note that the problem is to evaluate the effect of three difficulty factors or prices (20, 15, and 25) on the cost of cull removal. In addition, a with-and-without treatment comparison is to be made on cull removal. This means that for all three difficulty levels of cull removal, a comparison of the strategy with and without cull removal will be made. This results in the solving of six separate

'ANALYST'S NAME'
JUL 6, 1976, AT 17:3

'LESSON 4'

TRIAL 3 HARVEST AGE = 60.00

YIELDS USED IN ANALYSIS BEFORE THINNING DEVELOPED FROM --
YIELD TABLE 1

YIELDS USED IN ANALYSIS AFTER THINNING DEVELOPED FROM --
YIELD TABLE 1

YEAR		YIELD TABLE BEFORE/AFTER TREATMENT								TIMBER HARVEST				PERIOD	
A	T	HT	BA	NO	DBH	VOLY	VOLO	VAL	DBH	QI	VOLY	VOLO	VAL	REV	COST
0	40	0	123.	200.	10.6	10.0	9.0	585.							
		0	123.	200.	10.6	5.0	6.0	0.	.0	0.	5.0	.0	0.	0.	-25.
10	50	0	110.	150.	11.6	6.0	15.0	927.							
		0	110.	150.	11.6	3.0	10.0	613.	.0	0.	2.7	4.5	282.	282.	-19.
20	60	0	84.	100.	12.4	2.0	20.0	1209.							
		0	0.	0.	.0	.0	.0	0.	12.4	0.	2.0	20.0	1209.	1209.	-62.

YIELDS USED IN ANALYSIS BEFORE THINNING DEVELOPED FROM --
YIELD TABLE 2

YIELDS USED IN ANALYSIS AFTER THINNING DEVELOPED FROM --
YIELD TABLE 2

A	T	HT	BA	NO	DBH	VOLY	VOLO	VAL	DBH	QI	VOLY	VOLO	VAL	REV	COST
34	10	0	0.	0.	.0	.0	.0	0.							
		0	0.	0.	.0	.0	.0	0.	.0	0.	.0	.0	0.	0.	-55.
44	20	0	105.	300.	8.0	10.0	10.0	645.							
		0	105.	300.	10.6	7.0	7.0	451.	.0	0.	2.7	2.7	174.	174.	-23.
54	30	0	115.	250.	9.2	12.0	6.0	414.							
		0	115.	250.	10.6	8.0	5.0	336.	.0	0.	3.6	.9	70.	70.	-18.
64	40	0	123.	200.	10.6	10.0	9.0	585.							
		0	123.	200.	10.6	5.0	6.0	382.	.0	0.	4.5	2.7	182.	182.	-21.
74	50	0	110.	150.	11.6	6.0	15.0	927.							
		0	0.	0.	.0	.0	.0	0.	11.6	0.	6.0	15.0	927.	927.	-51.

Figure 2. Stand and Output Table for the example described in Figure 1 when harvest age equals 60.

'ANALYST'S NAME'
JUL 6, 1976, AT 17:3

'LESSON 4'

TRIAL 1 HARVEST AGE = 40.00

REVENUE AND COST SCHEDULE

NO	UNITS	AMOUNT	TIME	SPAN	FREQ	DESCRIPTION
1	9.00	585.00	1.	1.	0.	FINAL TIMBER HARVEST REVENUE
2	.00	-37.00	0.	1.	0.	TIMBER SALE ADM COST
3	.00	-40.00	0.	1.	0.	SITE PREPARATION COST
4	.00	-15.00	0.	1.	0.	PLANTING COST
5	.00	-2.40	19.	1.	0.	PRESCRIBED BURNING COST
6	.00	-2.20	24.	1.	0.	PRESCRIBED BURNING COST
7	2.70	174.15	25.	1.	0.	TIMBER THINNING REVENUE
8	.00	-18.10	24.	1.	0.	TIMBER SALE ADM COST
9	.00	-2.00	29.	1.	0.	PRESCRIBED BURNING COST
10	.00	-1.80	34.	1.	0.	PRESCRIBED BURNING COST
11	.90	70.20	35.	1.	0.	TIMBER THINNING REVENUE
12	.00	-14.70	34.	1.	0.	TIMBER SALE ADM COST
13	.00	-1.60	39.	1.	0.	PRESCRIBED BURNING COST
14	.00	-1.40	44.	1.	0.	PRESCRIBED BURNING COST
15	2.70	182.25	45.	1.	0.	TIMBER THINNING REVENUE
16	.00	-18.10	44.	1.	0.	TIMBER SALE ADM COST
17	15.00	927.00	55.	1.	0.	FINAL TIMBER HARVEST REVENUE
18	.00	-51.00	54.	1.	0.	TIMBER SALE ADM COST
19	1.00	40.00	55.	1.	0.	LAND REVENUES IN CONTINUED USE
20	1.00	.00	54.	1.	0.	LAND COSTS IN CONTINUED USE

Figure 3. Revenue and Cost Schedule for the example described in Figure 1 when harvest age equals 40.

'ANALYST'S NAME'
JUL 6, 1976, AT 1713

'LESSON 4'

TRIAL 3 HARVEST AGE = 60.00

TRIAL SUMMARY

YIELDS	--------VOLUME--------		---------VALUE--------		UNIT
	TOTAL	PER YEAR	TOTAL	PER YEAR	VALUE
TIMBER INVENTORY		7.97		478.07	59.96
ALL HARVESTS	45.80	.62	2844.75	38.44	62.11
FINAL HARVEST	35.00	.47	2136.00	28.86	61.03
THINNINGS	10.80	.15	708.75	9.58	65.62

COMBINED VALUES	-----UNDISCOUNTED---		-DISCOUNTED AT .0800-	
	TOTAL	PER YEAR	TOTAL	PER YEAR
NET	2609.95	35.27	311.32	24.91
REVENUES	2884.75	38.98	371.89	29.75
COSTS	274.80	3.71	60.58	4.85

PRESENT NET VALUE	311.32
EQUIVALENT ANNUAL INCOME	24.91
BENEFIT/COST RATIO	6.14
INTERNAL RATE-OF-RETURN	27.16

Figure 4. Trial Summary Table for the example described in Figure 1 when harvest age equals 60.

'ANALYST'S NAME'
JUL 6, 1976, AT 17:3

'LESSON 4'
SUMMARY TABLE

CASE	AVG VOL	AVG COST	AVG REV	NET REV	ANN INC	PN VAL
40.	.56	3.80	36.64	32.84	39.43	492.87
50.	.57	3.82	36.26	32.44	27.48	343.49
60.	.62	3.71	38.98	35.27	24.91	311.32

Figure 5. Summary Table for the example described in example 1.

```
TO: MULTIPLOY          'DATE'
FROM:    'ANALYST'S NAME'
SUBJECT: 'LESSON 5'

* MANAGEMENT REGIME FOR EXISTING STAND (INITIAL ROTATION)
SET PRESENT AGE AT 40 YEARS
REMOVE CULLS AT 40 YEARS IN INTIAL ROTATION
HARVEST FINAL YIELD AT AGE 60 IN INITIAL ROTATION
USE YIELD TABLE 1 IN INITIAL ROTATION FOR TREATED ALTERNATIVE
READ 3 YIELD CARDS INTO TABLE 1 WITH VARIABLES T, D, N, Y,
 O, YC, OC
40, 10.6, 200, 10, 9, 5, 3
50, 11.6, 150, 6, 15, 3, 5
60, 12.4, 100, 2, 20
USE YIELD TABLE 2 FOR SUBSEQUENT ROTATION

* MANAGEMENT REGIME FOR SUBSEQUENT ROTATION .
CONTINUE TRIAL BEYOND FINAL HARVEST ONE ROTATION
PREPARE SITE
LAG REGENERATION 4 YEARS
PRECOMMERCIAL THIN AT AGE 10
PRESCRIBE BURN FROM 15 TO 40 AT 5 YEAR INTERVALS IN SUBSEQUENT
 ROTATION
THIN
HARVEST FINAL YIELD AT AGE 50 IN SUBSEQUENT ROTATION
USE YIELD TABLE 2 IN SUBSEQUENT ROTATION
READ 5 YIELD CARDS INTO TABLE 2 WITH VARIABLES T, D, N, Y,
 O, YC, OC
20, 8, 300, 10, 0, 3, 0
30, 9.2, 250, 12, 6, 4, 1
40, 10.6, 200, 10, 9, 5, 3
50, 11.6, 150, 6, 15, 3, 5
60, 12.4, 100, 2, 20

* COSTS AND PRICES
REDUCE YIELDS FOR HOLES BY .10
COST OF REMOVING CULLS = $1 * DIFF
COST OF PREPARING SITE IS $40
COST OF PLANTING = $10 + $.01 * SEEDLINGS
COST OF PRECOMMERCIAL THINNING IS $15
COST OF PRESCRIBE BURN = $5 - .05 * T
COST OF SALE PREPARATION = $3 * OC
REVENUE FOR TIMBER = $4 * Y + $60 * O
COMPUTE RATE OF RETURN

MAKE CASE BY CASE EVALUATION OF 3 CASES
COMPARE WITH-WITHOUT TREATMENT TRIALS
OMIT CULL REMOVAL IN BASE TRIAL
USE YIELD TABLE 3 IN INITIAL ROTATION FOR BASE ALTERNATIVE
READ 3 YIELD CARDS INTO TABLE 3 WITH VARIABLES T, D, N, Y,
 O, YC, OC
40, 10.6, 200, 10, 9, 5, 3
50, 11.0, 175, 8, 12, 3, 4
60, 11.8, 140, 5, 14
READ 3 CASE CARDS WITH VARIABLE ORDER
VARIABLE ORDER IS DIFF OF CULL REMOVAL

WRITE USING 80 COLUMN FORMATS
RUN PROBLEM PLEASE
N01 20
N02 15
N03 25
STOP
```

Figure 6. Sample input memo for MULTIPLOY, illustrating case evaluations.

simulations (the without cull removal, or base trial, will be the same for all three cases). Note that since yields will be different when cull removal is performed, two different yield tables can be used in the initial rotation -- table 3 is used for the base alternative (no cull removal) and table 1 is used for the treated alternative (cull removal). All the output tables are produced for each case and the summary table includes all six evaluations (the with/without comparisons at all three difficulty levels). A problem can include up to 100 cases, and instructions can be included or changed for each case. This makes for an orderly analysis of different projects and the problem Summary Table presents a summary of each case.

Besides reading in a complete yield table, MULTIPLOY allows the user to read in a partial table and then complete the table with user-specified yield and growth equations. In fact, the user may not want to read in any tables at all and specify all the equations for completing a stand table. An example of this latter feature is shown in Figure 7. The general form of the simulation command in line 8 is:

SIMULATE TIMBER GROWTH BY (method) (BEFORE, AFTER) THINNING FOR
(INITIAL, SUBSEQUENT) ROTATION IN (TREATED, BASE) ALTERNATIVE

There are seven programmed growth procedures (methods) that can be used in simulation: return to normal stocking, return to normal basal area, return to normal volume, growth equation for basal area, growth equation for volume, growth equation for diameter, and plantation distribution function.

If the user so desires, he (she) can use one of the canned simulators programmed into MULTIPLOY. There are presently simulators for four species: loblolly pine, slash pine, ponderosa pine, and Douglas fir.

Planned future additions to the choice of simulators include Rocky Mountain spruce-fir, lodgepole pine, yellow-poplar, shortleaf pine, longleaf pine, red pine, Eastern white pine, and oak-hickory. The detailed descriptions and sources of the canned simulators are given in the Basic Manual (Part 1).

As mentioned previously, MULTIPLOY can evaluate non-timber inputs as well. These are: grass and forbs, browse, water, and sediment. Including these variables in a problem results in an expanded stand and output table and trial summary. An example of a problem using these will not be presented here, but the output tables are very similar to the tables shown previously -- with the non-timber inputs and outputs included.

Some Further Options and Uses of MULTIPLOY

There are some other features in MULTIPLOY which might be of interest to this group.

The system includes an option which allows the user to vary a number of factors to simulate approximately the variation in financial returns that owners can expect. This is done through random variation tests. The user can: specify how many stochastic tests are to be made; randomly vary height growth, diameter growth, prices, or costs; specify the coefficient of variation; and randomly vary the regeneration success, fire loss probability and pest loss probability.

MULTIPLOY can be instructed to print the special activities cards for Timber RAM. These cards include the volume yields and associated economic values for the stand being evaluated.

```
TO: MULTIPLOY       'DATE'
FROM: 'ANALYST'S NAME'
SUBJECT: 'LESSON 6B'

* MANAGEMENT REGIME
PREPARE SITE FOR REGENERATION
PRECOMMERCIAL THIN AT AGE 10
SIMULATE TIMBER GROWTH BY GROWTH EQUATION FOR BASAL AREA
ASSUME ESTABLISHMENT AGE IS 20
ASSUME 300 TREES ESTABLISHED
ASSUME 90 SQUARE FEET OF BASAL AREA ESTABLISHED
THIN TO 80 SQUARE FEET BASAL AREA
HARVEST FINAL YIELD AT 60 YEARS

* EQUATIONS FOR COMPLETING STAND TABLE
ASSUME SITE INDEX IS 80
HEIGHT = 10 + SI - 800 / T
VOLUME IN TOTAL CUBIC FEET = .00008 * D ** 2 * H
ASSUME MINIMUM PULPWOOD DIAMETER IS 4.5 INCHES
VOLUME RATIO IN MERCHANTABLE CUBIC FEET = 1 - .8 / D
ASSUME MINIMUM SAWTIMBER DIAMETER IS 8 INCHES
VOLUME RATIO IN MERCHANTABLE BOARD FEET = .07 - .12 / D

* GROWTH EQUATIONS
GROWTH IN BASAL AREA = 15 * SI / T
MORTALITY IN NUMBER OF TREES =  - .05 + 3 / T

* COSTS AND PRICES
COST OF PREPARING SITE IS 40
COST OF PRECOMMERCIAL THINNING IS 15
COST OF PRESCRIBE BURN = 5 - .05 * T
COST OF SALE PREPARATION = 3 * OC
PRICE OF PULPWOOD IS $5
PRICE OF SAWTIMBER IS $60

WRITE USING 80 COLUMN FORMATS
```

Figure 7. Sample input memo for MULTIPLOY, illustrating growth and yield simulation.

The program can also read and write standard yield files. These yield files will be discussed by Al Stage during his presentation. Just let me say that the files are similar to those shown in Figure 8, and are compatible with the tables developed by the Growth Committee.

Another option that the program has is the feature of reading and writing revenue and cost input files.

In Summary

MULTIPLOY should be a valuable tool for silviculturists in evaluating the effects of different treatments on a timber stand, both in biological and economic terms. The system is relatively simple to use because it uses English control statements and format-free data inputs. It is useful for determining the sensitivity of a timber stand to different management strategies and for making different case studies on a given stand. It allows for growth simulation and random variation of certain parameters. Finally, it provides a link between yield tables and allocation models such as Timber RAM and can readand write standard yield table files as developed by the Growth Committee.

* YIELD PER ACRE OF EVEN-AGED STANDS OF DOUGLAS-FIR
*
* DEVELOPED FROM A SIMULATION ROUTINE BY DAVE BRUCE, PNW, PORTLAND
* NO PRECOMMERCIAL THINNING
* MINIMUM OF MERCHANTABLE PORTION OF STAND BEFORE FIRST THINNING
*   CUBIC FEET -- TREES OVER -INCH DBH TO 4-INCH TOP
*   BOARD FEET -- TREES OVER -INCH DBH TO 6-INCH TOP
*
*

SI - 80.

* T	H	G	N	D	Y	CO	BO	NC	DC	YC	COC	BOC
68.	67.	171.	636.	7.0	45.5	38.1	64.4	134.	8.0	12.9	11.3	27.7
75.	72.	137.	430.	7.6	38.1	33.1	43.8	44.	8.5	5.2	5.6	22.9
88.	76.	132.	355.	8.3	34.2	34.2	35.5	25.	9.0	3.3	3.0	9.3
98.	79.	134.	304.	9.0	36.4	36.4	30.4	20.	9.4	1.0	.7	9.9
108.	82.	136.	267.	10.7	38.6	38.6	26.7	16.	10.9	2.5	2.3	8.3
118.	84.	139.	238.	10.3	40.8	40.8	23.8	13.	10.3	2.2	2.0	8.7
128.	87.	142.	215.	11.0	42.9	42.9	21.5	0.	.0	.0	.0	.0
1.	0.	0.	0.	.0	.0	.0	.0	0.	.0	.0	.0	.0
1.	0.	0.	0.	.0	.0	.0	.0	0.	.0	.0	.0	.0

SI - 110.

* T	H	G	N	D	Y	CO	BO	NC	DC	YC	COC	BOC
47.	73.	172.	630.	7.1	48.5	41.0	74.0	135.	8.0	13.8	12.1	30.1
57.	84.	147.	380.	8.4	46.0	41.4	122.0	66.	8.9	9.2	41.4	26.6
67.	92.	153.	265.	10.0	42.3	45.0	169.0	35.	9.7	6.4	6.0	22.0
77.	99.	147.	206.	11.5	53.0	50.1	216.0	26.	11.0	5.4	5.1	21.0
87.	104.	154.	167.	13.0	57.5	55.1	260.0	19.	1.1	.5	4.3	19.0
97.	109.	161.	140.	14.5	62.3	60.0	301.2	14.	12.4	3.8	3.6	17.1
107.	113.	168.	121.	16.0	67.0	64.0	340.3	0.	.0	.0	.0	.0
1.	0.	0.	0.	.0	.0	.0	.0	0.	.0	.0	.0	.0
1.	0.	0.	0.	.0	.0	.0	.0	0.	.0	.0	.0	.0

SI - 140.

* T	H	G	N	D	Y	CO	BO	NC	DC	YC	COC	BOC
36.	79.	171.	639.	7.0	46.5	40.7	71.8	402.	82.0	41.1	40.8	71.8
46.	92.	158.	339.	9.2	53.3	49.3	169.3	85.	9.2	13.5	49.0	42.6
56.	105.	157.	211.	11.7	59.4	56.5	252.5	45.	10.5	10.0	9.4	36.3
66.	116.	166.	152.	14.1	67.7	65.3	333.3	23.	12.6	8.1	7.8	34.2
76.	125.	176.	118.	16.6	76.2	74.0	409.3	19.	14.0	6.9	5.6	30.7
96.	138.	194.	81.	21.1	92.2	90.0	544.4	0.	.0	.0	.0	.0
9.	0.	0.	0.	.0	.0	.0	.0	0.	.0	.0	.0	.0

SI - 170.

* T	H	G	N	D	Y	CO	BO	NC	DC	YC	COC	BOC
30.	71.	173.	617.	7.2	48.9	41.5	7.9	37.	8.1	14.1	12.4	31.1
40.	99.	172.	306.	10.2	62.0	58.0	22.7	268.	9.5	18.7	17.4	64.0
50.	118.	174.	175.	13.5	72.1	69.5	35.0	48.	11.3	13.6	13.9	59.2
60.	139.	187.	125.	16.9	85.0	83.0	47.0	27.	13.7	11.3	11.0	58.0
70.	146.	201.	91.	20.1	97.4	95.3	58.0	17.	9.3	94.0	9.2	53.0
80.	155.	214.	74.	23.1	109.3	107.1	68.1	11.	18.6	7.7	7.5	46.0
90.	162.	220.	63.	26.0	121.0	118.5	77.5	0.	.0	.0	.0	.0
9.	0.	0.	0.	.0	.0	.0	.0	0.	.0	.0	.0	.0
9.	0.	0.	0.	.0	.0	.0	.0	0.	.0	.0	.0	.0

Figure 8. An example of a standard yield table file which can be read or written by MULTIPLOY.

LITERATURE CITED

Navon, Daniel I. Timber RAM...a long range planning method for commercial timber lands under multiple-use management. USDA Forest Service Research Paper PSW-70. 1971.

Row, Clark. Objectives and features of MULTIPLOY: a forest investment simulation language. Presented at the annual meeting of Western Forest Economists, Wemme, Oregon, May 7, 1975.

Row, Clark. System MULTIPLOY: a computer language to simulate and evaluate investments in forestry. Part 1, introduction and basic manual. USDA Forst Service, Washington, D.C. Revised 1976 (draft).

Row, Clark, Dan Jones, and Terry Raettig. System MULTIPLOY: a computer language to simulate and evaluate investments in forestry. Part 2, training guide. USDA Forest Service, Washington, D.C. June, 1976 (draft).

Growth Processor Committee

A. R. Stage
Silv. Workshop
Eugene, Oreg.
Oct. 16, 1976

The WO Growth Processor Committee is charged with two major responsibilities:

1. To make recommendations to National Forest Systems on how to collect and how to process growth data for timber management planning.

2. To assemble existing growth information in a form that makes the data readily available for use in a common format.

Progress on Recommendations for Growth Data Specifications

During the past year a first draft of recommendations for methods of growth data collection has been prepared. These recommendations are intended to provide a minimum standard to be followed in conducting silvicultural research and administrative studies of stand response, and in the sampling of growth in timber management planning inventories. The scope of these recommendations includes sampling methods, specification of site, stand, and tree variables to be recorded, and specification of measurement standards.

Action Needed

After these standards have been adequately reviewed and revised, they should be implemented through appropriate manual and handbook revisions, and through incorporation in the review phase of all study plans that collect quantitative data on growth responses of trees.

Progress on Yield Files

During the past year the committee has established files of yield tables and yield simulators at the Fort Collins Computer Center. This collection of data is organized in two files. The first is the index to the data. Characteristicis of the data described in the index include:

Forest type

Species

Author-date

Title of publication

Abstract

Recommendations on scope of applicability

Geographic location of source data

Location of tabular data in FCCC system

Location of instructions for executing yield simulators in FCCC system

Variables described in data

This file is in the format of the FAMULUS information storage and retrieval system to permit ready search and cataloging of the yield data.

The second file contains yield tables formated for direct access by the MULTIPLOY program for comparing economic characteristics of the yield sequences.

A report on the current content of these yield files with instructions on how to access them on the Fort Collins Computer System has been prepared. This report has been sent to the Regional Representatives to the Growth Processor Committee for review and to solicit comments on needed revisions of the report. Suggestions of additional data to be added to the files are welcome as well.

Action Needed

Responsibility for adding new entries and for maintenance of the computer files and programs for accessing them has not been clearly defined at this time (October 1976). One approach to file updating would be to recognize these files as one form of publication of yield-study research. Research Branch should consider requiring this form of publication by the original investigator of all applicable studies.

STOCKING LEVELS --

GUIDES AND FIT TO MANAGEMENT PLAN

by

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Presented at the National Silviculture Workshop

Eugene, Oregon, October 13-15, 1976.

STOCKING LEVELS --

GUIDES AND FIT TO MANAGEMENT PLAN

I was asked to discuss three things:

(1) Guides to evaluate present stocking and to determine appropriate residual stocking in second growth stands.

(2) How to get the proper stocking established in the woods.

(3) How to get the control of stocking tied in with the management plan.

I am going to change the order around and talk about the management aspects first.

I have changed the order of presentation because control of stand density is a silvicultural operation, and each silvicultural operation is specific to a particular stand at a particular time.

The dominant objective of our management is to achieve even-flow sustained yield from our forest. Because a silvicultural operation is specific to a specific stand, silviculture, per se, has nothing to do with sustained yield except by implication. We can't just set out to practice "good" silviculture and expect that sustained yield will automatically result.

That's where the management plan comes in. In the management plan we set up a schedule of cutting such that the forest will sooner or later attain a regulated structure and provide regular yields. The volume attainable under this schedule, during the management plan period, is the allowable cut.

Before I go on to show how the control of stand density fits into the management plan, I want to discuss briefly the determination of the allowable or the potential cut. It may seem that I am straying from my assigned topic, but bear with me and see where I go wrong.

It is generally accepted that we get sustained yield by cutting only the growth from a forest--assuming that we're somewhere close to a regulated structure. If the structure is too far from the regulated condition, we adjust the rate of cutting to achieve a regulated condition, then cut the growth.

Traditionally, we make periodic inventories, usually based on permanent sample plots, to determine volumes and acreages by types and species on the different sites. We have the same kind of information from previous inventories. We can add up or estimate what was cut or died in the meantime, and then calculate what the periodic growth has been. We project the appropriate rate of growth for the next period, and calculate an allowable cut on that basis.

In an oversimplified way this is how our annual cuts have traditionally been determined, at least in our second growth eastern hardwood forests. On a national basis, Forest Survey figures have been used in somewhat similar fashion to estimate volumes available to meet national needs for various future periods.

Am I still on relatively safe ground? OK, then I will proceed to get into trouble.

This traditional method doesn't work. In fact it can be very dangerous as markets improve to where actual cuts approach the full potential or allowable yield. The reason it does not work is because it can only monitor, but cannot predict, and certainly cannot control, changes in forest structure. These are the changes in age-class or size-class distribution that result from growth, mortality, and cutting.

I am not saying that periodic inventories based on permanent sample plots are not worthwhile. In fact they are very useful. They tell us with good accuracy what is actually in our forest today, and how the situation has changed since the last time. Such inventories are particularly valuable for keeping a handle on unusual mortality caused by fires, windstorms, epidemics, and natural or man-made catastrophes of one kind and another. And they provide at least some check on volume, cut, and growth projections determined by other methods.

My charge is that such inventories, and growth models based on them, are very dangerous as a basis for future volume, growth, and allowable cut projections.

I realize that this is a serious charge and people might worry about it except that I am so obviously crazy. But let me give you a quick example.

I spent some years in Ohio and became fairly well acquainted with its hardwood forests. In these forests it takes about 100 years to produce sawtimber yields on natural rotations, but you could do it in 60 or 70 years with periodic thinnings or improvement cuttings, if these are properly applied.

Regardless of the type of management or the rotation length, to achieve a sustained yield of sawtimber-size products, you would need to keep 20 to 25 percent of the forest area in seedlings and saplings, 35 to 40 percent in poletimber, and 35 to 45 percent in sawtimber.

In 1952, the Forest Survey in Ohio showed the following distribution of forest area by size-classes:

Ohio Forest Area, 1952 - - M acres (percent)

Sawtimber	Poletimber	Seedl. and Sapl.
2679 (50%)	1978 (36%)	739 (14%)

In trying to compare these figures with the next Forest Survey in 1967, we run into a problem caused by changes in classification standards between inventories. I was able to determine that on the basis of 1967 standards there would have been 607,000 fewer sawtimber acres in 1952, but I don't know how these would have been split between pole stands and sapling stands. I suspect that they would have been classified as seedling and sapling stands representing the results of heavy high-grading cuts that left sparse overstories of low-grade sawlogs over young stands of reproduction. If I throw those 607 M acres into the sapling stand class, in 1952 Ohio would have had an ideal distribution of acreage for sustained yield. To be conservative, let's split the acreage between saplings and poletimber.

Ohio Forest Area, 1952 adjusted -- M acres (percent)

Sawtimber	Poletimber	Seedl. and Sapl.
2072 (38+%)	2282 (42+%)	1042 (19+%)

This is not quite ideal, but close. If it were feasible for an entire state to go on sustained yield, in 1952 Ohio was in excellent shape to achieve it.

By 1967, Ohio had an increase of 933,000 acres of forest land. These were acres of old fields reverting to forest, and they had to be classified as seedling and sapling stands. I subtracted this amount from the 1967 s. and s. acreage to put the figures on the same basis as would have been used for planning in 1952. The results are:

Ohio Forest Area, 1967 adjusted -- M acres (percent)

Sawtimber	Poletimber	Seedl. and Sapl.
1948 (36%)	690 (13%)	2758 (51%)

Because of the scarcity of pole stands, by 1967 there was no way that Ohio could go directly on even-flow sustained yield without going through a lengthy period of reduced yields. This is because there is simply no way to get saplings to sawtimber size without going through a lengthy poletimber stage.

In the meantime, according to the Outlook for Timber in the United States (1973. USDA Forest Serv. Forest Res. Rept. 20, 367p.), sawtimber volume increased by 3 billion board feet.

If, in 1967, the sawtimber growth rate were used to project an allowable cut, the situation would rapidly get worse.

Another example of this phenomenon occurred in the early 1960's, in the oak forests in the southern part of old Region 9. They were just starting on the third round of improvement cuts on those forests and discovered that, in many stands, although the total volume was there, there weren't enough big trees to provide an operable cut.

I have other examples of this phenomenon, some based on personal experience, that I won't take your time on. But it may be instructive to examine why this phenomenon occurs.

It occurs because, in our management planning, we assume that a board foot is a board foot is a board foot, and therefore 8 or 10 small trees equal 1 big one.

For example, let's consider an oak stand that is growing 250 board feet per acre per year, based on periodic inventories of permanent sample plots. The sawtimber growth rate is determined by the rate of increase in size of all trees 11 inches and larger plus ingrowth into the 11 inch class. The 11 inch diameter represents our minimum merchantability specification for sawtimber.

Unfortunately, the market wants 18 to 24 inch trees, will readily accept 14 to 16 inch trees, but will take only a limited number smaller than that, and then only when forced. Therefore, to get an operable sale, we've got to have relatively more cut volume in big trees than in small ones. Now, we can cut all of that 250 board feet per acre by cutting 1 big tree. The stand grows that amount back again next year, but it spreads that growth in little chunks over a lot of small trees. And there are a great many more small trees than there are big ones. So as this process continues eventually we end up with all our sawtimber volume clustered in a narrow range of diameters just above the threshold of merchantability.

If I may coin a principle here, it is this: If there is a differential between the threshold diameter for merchantability and the minimum diameter the market will freely accept, both human nature and economics force us to cut proportionately heavier among the large diameters than we should. In doing so we change the structure of the forest, and therefore we change the distribution of growth among size classes.

Or, stated in more positive fashion, if we plan to grow products of a certain minimum size on an even-flow sustained yield basis, the periodic growth must be cut from each diameter class, down to and including the smallest diameter that we wish to regulate, in direct proportion to the amount that occurs there.

This is another way of saying that to achieve even-flow sustained yield, we must cut in such a way as to establish the desired forest structure, and thereafter cut in such a way as to maintain that structure. Which means that we must control the cutting not by the apparent forest growth rate in product classes, but according to the distribution of size classes that we want to regulate. This statement holds, of course, whether you plan to use even-aged or uneven-aged management.

As a tool for management planning, the traditional method of basing growth projections and allowable cuts on periodic inventories of permanent sample plots falls down in several respects. First, it doesn't tip you off as to what is happening to forest structure until after it has happened, by which time it may be too late. Second, it doesn't tell the manager what stands need to be treated, in what fashion, nor where the volume is located that is available for cutting.

These two objections might have been overcome when we were using uneven-aged management--if we had used it correctly, or could have used it correctly, to maintain the same regulated reverse J-shaped diameter distribution in each and every stand. But I see no way in the world of using it to control the rate of cutting in forests of even-aged stands in which the structures not only vary widely among stands but must also change constantly as the stands get older.

The only alternative I see is to go to individual stand data obtained from permanent and periodically updated stand records. During the next management plan period, a certain acreage of older stands will be regenerated, and will yield so much volume. A certain acreage of immature stands will be thinned. These will yield certain volumes depending on their stocking, their structure, and their composition. The management plan must set the amount of acreage to be treated in the various categories and indicate the appropriate treatment for each category. This is so that each stand will fit into its proper place in the hierarchy. I foresee that the stand records will be maintained by computer, programmed to update them periodically as needed. The updates will be corrected by fresh data gathered during stand examinations either prior to or just after treatment.

And now I've come full circle on the management planning. It is not just a case of fitting stand density control in with the management plan. Rather, the management plan is the instrument that must control stand density. But there's more to it than just the control of stand density; we must also control stand structure, and in many types, composition. And then we must get the control applied on the ground.

Since these operations must be performed on an individual stand basis, let's leave the subject of management planning for a while, and go to the first topic I was assigned: Guides for stocking levels. Because of my broad ignorance of most types, I will merely cover what we consider necessary in one specific type: the Allegheny hardwoods.

The forest type that we fefer to as the Allegheny hardwoods is, for a natural type, somewhat unnatural. It developed following the heavy cuttings that removed the beech-hemlock forest between about 1880 and 1930.

The Allegheny hardwoods consists of sugar maple, beech, and some remnant hemlock with varying admixtures of black cherry, red maple, yellow and sweet birch, white ash, yellow-poplar, cucumbertree, and half a dozen others.

The yellow-poplar is very intolerant and very fast growing. It is either dominant or absent. The black cherry is also intolerant and also fast growing, but not quite as much as yellow-poplar in either category. White ash is moderately intolerant and grows well, though not quite as fast as the cherry. The birches may be a little more tolerant than the ash, but still are usually classed as moderately intolerant. They grow slower than most of the other species and unless released are overwhelmed by about the middle of the rotation.

Red maple and cucumbertree are intermediate in tolerance, but both grow nearly as fast as the black cherry. Red maple responds well to release, at least in the intermediate and higher crown classes.

Sugar maple, beech, and hemlock are all very tolerant--sugar maple a little less so than the other two. All three grow very slowly when crowded or when under a canopy, but will survive for decades in the understory. All respond well to release at any age, and will grow very well until they again become crowded.

The intolerant species do not respond well to release, so they must be managed as dominants and codominants. When these intolerants are mature, which means a maximum age of 90 to 100 years (80 years is safer), the stand must be regenerated, or else we must be satisfied to manage the next stand as only sugar maple or beech, or a combination of the two, with a consequent loss of value, yield, and variety.

Thinnings must be heavy enough to get enough growth response from the sugar maple and beech for these species even to make merchantable pulpwood by the end of the rotation. This means also that thinnings must begin no later than a stand age of 55 to 60 years, preferably much earlier. But we dare not thin too heavily or we lose production and reduce the value of the final yield of the highly valuable intolerants.

We also have problems getting natural reproduction due largely to the termendous populations of whitetail deer, which range from 60 to 100 animals per square mile--pre-fawning. Unless we fence them out, which is both difficult (Did you ever try to chase all the deer out of a 25-acre area?) and very expensive, about the only way we can beat them is to overwhelm them with tree reproduction. When a stand is to be regenerated we must have enough advance reproduction, of a size and vigor to grow fast enough, over a large enough area, that the deer can't possibly eat it all within the time it takes for some of it to grow out of reach.

Since new germinants can't compete in the new stand with vigorous advance reproduction, this means that advance reproduction of all species desired in the new stand must be present when the regeneration cut is made. And in turn this requires that representatives of all species desired in the new stand be retained in the old stand right up to the time of the final harvest.

Even having advance reproduction isn't adequate to ensure that beech and sugar maple will have a place in the new stand. These species lag so far behind the new crop of intolerants that they must have a head start--as large saplings or small poles--if we want them to reach sawtimber size in the next stand. But we mustn't leave too many maple and beech saplings and poles or they seriously reduce the percentage of intolerants in the next stand and may retard the development of the ones that do make it.

So the Allegheny hardwood type poses some interesting silvicultural and management problems. But the purpose of the foregoing is not to impress you with our problems,--everybody has problems. What I want to get across is that, with us, the control of stand density is not just another moot academic exercise that would be nice to do if we had the time and money. For us, the need to control not only stand density but also stand structure and species composition is an unavoidable fact of life. Either we do it or we les the type.

The control of stand density requires that there be some stocking standards to serve as the basis for adjustment. I set out to determine if our stands would reach some average maximum level of stocking, and if so, if it could be described mathematically.

I collected data on 106 natural undisturbed stands. Stand ages ranged from 18 to about 100 years; basal area from 75 to 175 square feet per acre. Altogether I had diameter tape measurements on about 125,000 trees. I used these data in multiple regression analysis to derive a tree-area ratio equation (Chisman, H. H. and Schumacher, F.S., 1940. On the tree-area ratio equation and certain of its applications. J. Forest 38: 311-317).

The best regression that I found is one based on six species groups. It is highly significant with a coefficient of multiple determination (R^2) of 99 1/2 percent, and a standard error of about 5 percent of the mean value of the plots.

The good precision of the tree-area ratio equation lends a pleasing amount of confidence that Allegheny hardwood stands do indeed achieve a maximum degree of crowding--or stocking--and that it can be described mathematically. The next problem was to find a way to display the relationship graphically based on stand parameters for which data could be easily obtained in the woods. I hoped that I could develop a chart similar to the one Gingrich developed for the oaks (Gingrich, Samuel F., 1967. Measuring and evaluating stocking and stand density in upland hardwood forests in the Central States. Forest Sci. 13: 38-53).

When I tried a regression using the same variables Gingrich did (basal area per acre plotted over number of trees per acre), my R^2 dropped to 34 percent, and the standard error increased to 16 percent.

Species composition was the major point of difference between my tree-area ratio equation and the stocking equation. The former was broken down into six species groups while the latter had all species lumped together. It seemed obvious that I had to find a way to account for composition.

To shorten a long story somewhat, I found that the percentage of stand basal area contributed by various species worked very well. And I could determine the percentages of basal area by species groups simply by tallying the groups separately during the wedge prism cruise.

However, I couldn't figure out any practical way to show more then two species groups on a two-dimensional stocking chart. The combination that gave the best accuracy (R^2 of 70%, standard error of 10%) was one group comprising cherry, ash, and yellow-poplar, which I shall hereafter designate as CAPs, and the other group containing all other species. Then I was able to prepare the stocking chart (figure 1). We have been field testing this guide for about three years, and so far it seems to be working very well.

The A-lines on the chart show the average maximum basal areas that will be attained by stands of given average diameters when certain percentages of the total basal area are contained in the CAP group. For example, a stand with an average diameter of 8 inches that contains no cherry, ash, or yellow-poplar will normally have about 114 square feet of basal area per acre. But if an 8-inch diameter stand has 80 percent of its basal area in CAPs, the basal area will be about 170 square feet per acre.

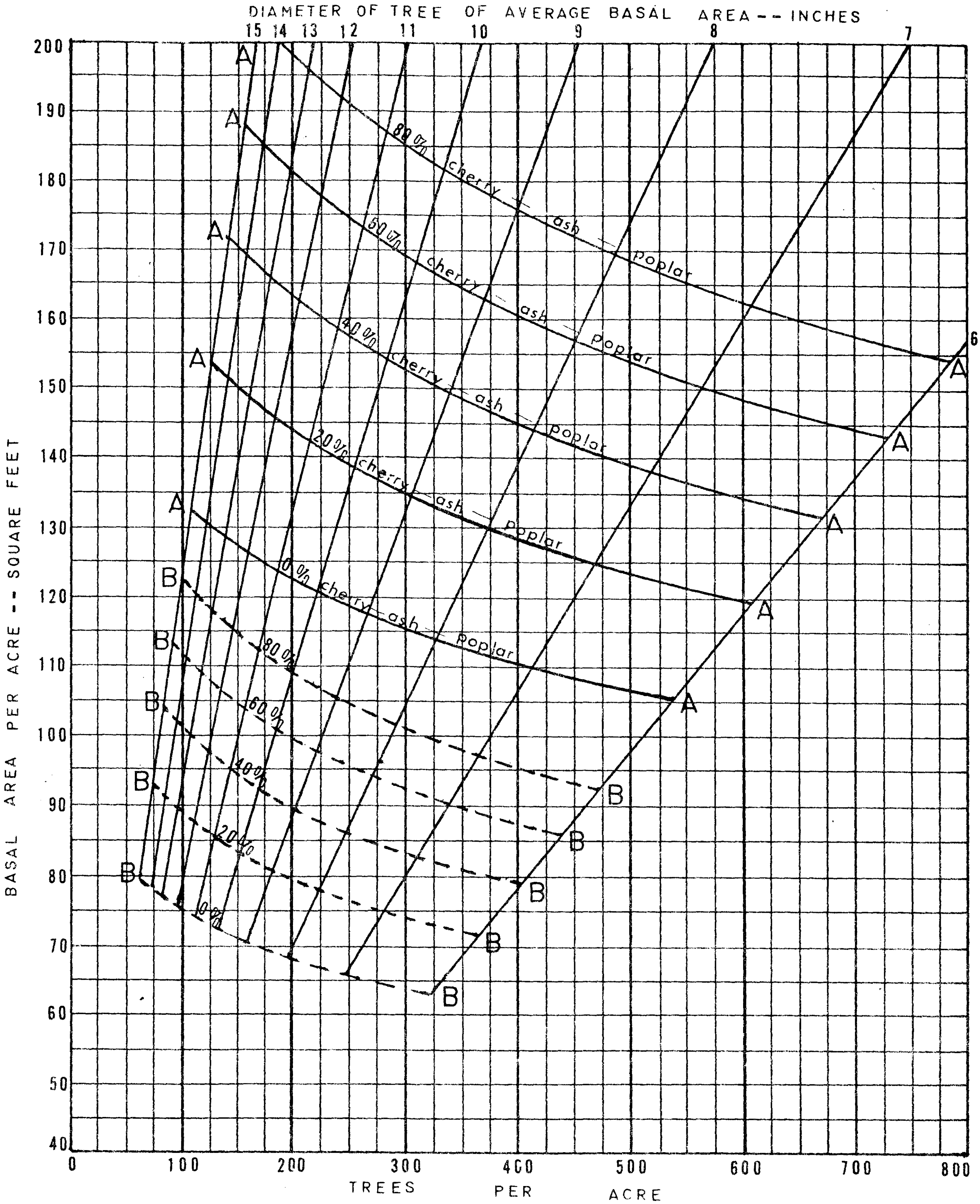

Figure 1. STOCKING GUIDE FOR ALLEGHENY HARDWOODS

The B-lines on the chart indicate our best guess at the minimum stocking necessary to use all the growing space, for stands of a given average diameter and percent CAPs. For the two stands mentioned above, the first should be thinned to leave at least 68 square feet per acre; the second to leave at least 102 square feet--if the average diameter and percent CAPs remains the same.

Using the stocking chart requires three pieces of data: the stand basal area, the percentage of the stand basal area contained on the CAP group, and the stand average diameter. These data are obtained during stand examination, using point samples for the basal area tally and 1/20-acre plots for the tree count (Figure 2).

The basal area tally is broken down by the two species groups and by four size classes based on ocular estimates of the diameters of the sample trees. Tallying by the two species groups reveals the percent CAPs; tallying by the four size classes gives a good quick picture of stand structure and is most helpful in revealing the size classes that must be favored to provide the final crop and, by elimination, the size classes that should be marked heavily to increase the stand diameter and push the stand along toward maturity.

Kane Exp. For.	Cherry-Maple	4/17/75
UNIT	TYPE OF SPECIES	DATE
Bl. II, Plot I, 10 ac.	54	BR
STAND AREA	AGE	

BASAL AREA AND TREE TALLY

Sample Point Number	LARGE SAWT. 17+		SMALL SAWT. 11 – 16		POLES 6 – 10		SAPLINGS 1 – 5		TREE COUNT 1/20 acre	
	CAPs	Other	CAPs	Other	CAPs	Other	CAPs	Other	CAPs	Other
1			4		4	3	1	1	6	34
2	1		2	1	1	5		5	3	39
3			5		2	4		1	5	43
4			6		3	1		1	7	36
5			3	2	3	3			4	49
6			3		2	4		4	4	39
7			2		2	3	1	4	4	35
8	1		1	3	2	2		5	3	45
9			3	1	3	3			5	41
10			4	1	3	3		1	6	41
11										
12										
13										
14										
15										
TOTAL									47	402
TOTAL per acre	2		33	8	25	31	2	22	94	804
TOTAL per acre	2		41		56		24		898	

DISTRIBUTION OF THE CUT

	LARGE SAWT.		SMALL SAWT.		POLES		SAPLINGS	
	CAPs	Other	CAPs	Other	CAPs	Other	CAPs	Other
Cut Basal Area			6		11	6	2	13

STAND CALCULATIONS

	Trees per acre	Basal Area per acre TOTAL	Basal Area per acre CAPs	Basal Area per acre Other	Percent CAPs	Average Stand Diameter	Basal Area for 100 % Stocking	Stand Stocking Percent
ORIGINAL Stand	900	123	62	61	50	5.0	129	95
RESIDUAL Stand	390	85	43	42	50	6.4		60
CUT Stand	510	38	19	19				35

Figure 2. Stand tally sheet showing determination of basal area to cut by species groups.

When the basal area and tree tally are completed, the nature of the original stand can be calculated. The percent CAPs is determined by dividing the basal area in CAPs by the total basal area. The stand average diameter is determined from the stocking chart by using the total basal area per acre and the number of trees per acre. Using the stand average diameter and the percent CAPs, the chart is entered to find the A-level basal area that would be expected in a normally stocked stand. Dividing this basal area into the actual stand basal area shows the percent stocking in the original stand--that is, how well the present stand is stocked compared to the average maximum found in nature for a stand of the same average diameter and composition.

Next, the chart is used to determine the minimum residual stand to leave. The prescriber must decide three things: the percent stocking desired in the residual stand, the percent composition that he wants in the residual stand, and the probable average diameter of the residual stand. From our thinning and cutting method studies, we have developed guides to show the extent to which composition can be changed, and the direction and amount by which the average diameter will change for a particular kind of cutting. Then using the residual stand diameter and the residual percent CAPs, the prescriber can enter the stocking chart, using the B-level curves, to determine the minimum residual basal areas to leave. Subtracting the residual stand from the original shows the basal areas that may be cut by species groups. Then the prescriber distributes these basal areas by size classes to conform to his intended treatment. This distribution of the cut then becomes the marking prescription. The marking crew can compare the amount to be cut in each size class and species group with what the basal area and tree tally show to be present, and they can tell what proportions to mark in each class.

This is a very brief excursion through the procedure. A manuscript now in the publication process explains it thoroughly, and we fully expect it to be printed long before the turn of the century. So I will not go into more detail here except to note several significant points.

You will notice that there is more involved than simply the control of stand density. The procedure provides also for some regulation of both species composition and stand structure. Second, because emphasis is placed on determining the desired residual stand, the stand prescribers can operate on a higher professional level. They can exert some deliberate control in guiding the stand some known distance toward maturity, rather than let the stand push them around so to speak. Third, rather than just going out looking for merchantable trees to cut, the marking crew has definite guidelines as to the proportions of various size classes to look for. And finally, the good documentation permits checking the process at any level, in the field or in the office. It provides substantiation for decisions made or gives an objective basis for questioning them.

Initially the procedure may seem complex, but it has not proved to be so in practice. We have conducted 8 training sessions so far, and a two-day session has been adequate to get a good job done in the field. Ironically, most of the difficulty comes, and most of the training time has to be spent on, getting reliable stand data. Every forester automatically assumes he knows how to conduct a good stand cruise, but it seems that only about 60% do a consistently good job. And if you don't get adequate stand data, you're just kidding yourself.

Last spring we had a training session for District TMA's and stand examiners on the Allegheny National Forest. Then the Forest gave it a three month trial on each district, and have since adopted it for forest-wide use.

The next question we faced was whether the marking crews could mark according to the prescriptions.

In September we held a training session for the Allegheny's timber marking crews, using 100 percent inventoried plots to check stand tallies and residual stands after marking. Seven out of eight crews came within 5 percent of the desired residual stocking on the first try. The removals by species groups and size classes were very close to the prescriptions--within 1 or 2 square feet--except for the poletimber category in the "other" species group, where they tended to undermark by 3 to 6 square feet. At least part of this was probably due to the fact that our inventories included in the pole class some trees smaller than the merchantability standards for pulpwood. So probably they didn't find all the poles that we said were there.

All crews agreed, without any pressure or leading questions, that the prescriptions caused very little change in their normal procedure, and also that the prescriptions were very helpful in focusing their attention on the size classes that were to be marked heavily or that were to be favored and retained.

The jury is still out, of course, as to how well the marking will work on an operational basis, but the initial trial was promising.

So far I've discussed in general how the management plan should control the silviculture. Then I discussed stocking levels for Allegheny hardwood stands. Then I told you how we are going about the problem of getting physical control of stocking on the ground. Now I'd like to revert back to the first topic and explain more specifically how the whole business is dovetailed together.

Usually when we talk about even-aged management, we talk in terms of using it to control age-class distribution. This is convenient because it makes the concept easier to understand. Also, of course, if we regenerate a certain portion of the acreage each period--and get prompt reproduction--it goes a long way toward ensuring that we have a reasonable distribution of age-classes to work with.

But actually, we don't need to care about stand age, at least on the Allegheny Plateau. What we're really interested in is tree-size. We want to grow some standard volume of products of a certain size and species, in the shortest time feasible, with no loss of production in the meantime. When a stand has that volume in those products, the stand is mature regardless of its physical age. And the average stand diameter is a most useful guide to setting that point of maturity, or for estimating how far a given stand is from it.

Table 1 shows, for unmanaged stands, the increase of average stand diameter with age, and also the increase in average diameter of each species group with age. You will note that the average diameter of stands of average composition increases at the rate of about 1 1/8 inches every 10 years.

Dave Marquis and a graduate student have developed equations that do a good job of predicting stand volumes for a given average diameter, percent composition, and percent stocking. From this we should be able, with some economic analyses, to select an average stand diameter that represents maturity for any given intensity of management.

Now there are several ways to increase the average stand diameter faster than the norm of 1 1/8" per 10 years, or decrease it if desired. From our cutting experiments we can estimate reasonably well how much the average diameter will shift upward or downward as a result of cutting from above, cutting from below, or cutting in the middle. From our thinning studies, we can predict, a little tenuously yet I admit, how rapidly a stand will increase in average diameter and stocking after thinning to any particular level.

Table 1. Diameter of tree of average basal area (quadratic mean diameter) in fully stocked, even-aged, and previously unmanaged stands of Allegheny hardwoods.

Stand Age (years)	Yellow-poplar	Black Cherry	Pin Cherry	White Ash	Red Maple	Yellow and Sweet Birch	Sugar Maple	Beech	Entire Stand
	(Average diameter in inches)								
10									1.04
20	2.9	3.3	2.9		2.4	2.5	1.2	1.1	2.16
30	5.3	5.5	4.1	3.5	3.7	3.7	1.9	1.6	3.30
40	8.1	7.7	5.2	4.8	5.0	4.8	2.4	2.0	4.46
50	11.4	10.1	6.5	6.5	6.4	5.9	3.0	2.4	5.64
60	14.9	12.6		8.6	7.8	7.0	3.6	2.7	6.83
70		15.2		11.1	9.2	8.0	4.1	3.1	8.04
80		17.8		13.9	10.6	9.0	4.7	3.4	9.25
90		20.6		17.2	12.0	10.0	5.3	3.8	10.46
100		23.4		20.8	13.5	11.0	5.8	4.1	11.69
Number of stands	16	97	28	23	84	79	101	63	101
R^2	93%	79%	54%	92%	73%	77%	59%	52%	80%

(All regressions were highly significant. R^2 is the coefficient of determination--the percentage of the variation in mean diameter associated with stand age. Lowest ages and crosslines show limits of data).

For example a 50-year-old stand that is 100 percent stocked, with a composition of 40 percent CAPs, will have an average diameter of about 5.6 inches, and it will contain a certain volume. If this stand is left alone, in 10 years it will still be 100 percent stocked, with an average diameter of about 6.8 inches, a composition of 41 or 42 percent CAPs, and it will contain a certain amount more volume.

However, if that 50-year-old stand is thinned back to 60 percent stocking, and the marking removes about 2/3 of the cut basal area from below the mean diameter in each species group, the average diameter will increase to about 6.4 inches as a result of cutting, and during the next 10 years it will increase an additional 1.4 to 1.5 inches, instead of 1 1/8 inches, as a result of faster growth on individual trees after the thinning. In 10 years that stand will be between 72 and 75 percent stocked with an average diameter of 7.8 or 7.9 inches, and its volume will be a certain amount. In effeet this stand will be very close to the characteristics of a 70-year-old stand even though it is only 60 years old, and it can be considered as a 70-year-old stand if the management plan is based on age-class distribution.

However it should be much more convenient to base the management plan on size classes. The stand average diameter is readily available from stand examination data, and the use of average diameter eliminates the practical difficulties of determining stand age in the field or trying to decide the proper stand age for stands containing more than one age class.

Within 10 years this kind of information should be available for most of the stands on the Allegheny National Forest. The data will be in the computer on a stand by stand basis, together with the programs for updating them up to 20 years or so at a stretch. And the next time the Allegheny TM staff prepares a management plan, they should be able to project a pretty realistic potential cut, by products, <u>and know what specific stands the cut will come from</u>. And they should be able to specify the silvicultural treatments needed for any particular stand, or for a proportionate area of any particular class of stands, to adjust their forest structure toward the desired fully-regulated goal.

There are some other fringe benefits on the horizon. The stocking chart that I showed you hasn't been published yet, but already I feel it is obsolescent. Rather than fool with the chart in the woods, the Allegheny is providing their stand examiners and prescribers with programmable pocket calculators--the kind that save the program even when the calculator is turned off. The calculators are pre-programmed with an equation that, once the appropriate stand data are plugged into it, gives the average stand diameter, percent CAPs and percent stocking, for the present stand and for any desired residual stand. This permits the prescriber to explore the effect of various cutting prescriptions, and the resulting distribution of cut basal areas, right in the field if he wishes.

These calculators are most convenient because we are no longer limited by the two-dimensional chart to only two species groups. The calculator will be able to handle as many species groups as can be readily tallied in the field. This will permit us to measure and control stocking levels more accurately and to develop better volume estimates. Further we plan to explore the possibility of equations that will tell the prescriber what volumes per acre he should obtain with any particular type of cut. This should help ensure operable sales, or conversely help prevent stands from being cut where overcutting would be necessary to provide an operable volume. And, of course, it should provide a much better basis for sales and project planning than now exists.

Now, having painted that rosy picture, I need to back down some and enter a disclaimer.

What I have described is not all available yet. The stocking guide seems to be working well and is being used. But we cannot yet predict with confidence what the 10 year growth will be in either stocking percent or average diameter, let alone volume. Our density studies are only four years old, and I have a great distrust of early growth data. Our data have been pleasingly consistent over the past three growing seasons though, and I'm getting increasingly optimistic. Dave Marquis's volume tables and equations have agreed remarkably well with determinations made by conventional means in several stands. But they need much more checking, and of course we have had no opportunity yet to check growth projections against actual stand growth.

So, we're not as far along as I may have implied. But I feel pretty confident that we're well on the way.

In summary, during this session I have tried to explain my ideas on why and how silvicultural prescriptions must be tied to management plans. I have explained why I distrust current methods of projecting growth and allowable cuts, and I have tried to explain how I think it must be done--namely, by building projections up from individual stand data. I have described our stocking guides: how they are used to evaluate stocking in present stands; how they are used as a tool to manipulate not only stand stocking, but also stand structure and composition, along a deliberate course toward maturity; and how this control is applied on the ground. And I have looked into the crystal ball to show how, as our growth data accumulate, more accurate or detailed stocking guides might be used as a tool, together with other stand data, to estimate present stand volumes, potential cut volumes, and growth projections following treatment.

APPENDIX I

USE OF STOCKING GUIDE FOR ALLEGHENY HARDWOODS

(Determining initial stocking)

1. Decide on stand boundaries, and plan cruise route.

2. Make stand inventory:

   a. Wedge prism cruise (10 plots minimum) for basal area, tallying sample cruise by two species groups and four size classes (estimate size class by eye).

   b. Tree count of all trees 1.0 inch dbh + on 1/20 acre plots (26 1/3 ft. radius) using same plot centers as used for wedge prism cruise.

3. Summarize columns on tally form to determine:

   a. BA/acre in CAPs and "Others" for each size class.

   b. BA/acre in CAPs and "Others" (totals by species groups)

   c. Total BA-acre

   d. Number of trees per acre.

4. Determine percent CAPs: $\frac{\text{BA in CAPs}}{\text{Total BA}}$

5. Determine average stand diameter from chart. (Use total BA/acre and trees per acre).

6. Determine BA for 100% stocking. (Use average stand diameter and percent CAPs--A curves).

7. Determine percent stocking in stand: $\frac{\text{Stand BA}}{\text{A-level BA}}$

8. Determine size class (or classes) for future management. (What size class or classes contain bulk of basal area? Generally favor larger size classes.)

APPENDIX II

USE OF STOCKING GUIDE FOR ALLEGHENY HARDWOODS

(Determining desired residual basal area)

1. Decide on percent stocking desired in residual stand.

2. Decide on percent CAPs desired in residual stand.

3. Estimate average diameter of residual stand.

4. Determine BA/Acre needed in residual stand (from chart).
   a. If 60% stocking: use estimated residual average diameter and residual % CAPs, get basal area from B curves.
   b. If other than 60% stocking: use estimated residual average diameter and % CAPs; determine A-level basal area; multiply A-level basal area by stocking percent desired.

5. Determine number of trees per acre in residual stand. (Use residual basal area and average diameter of residual stand.)

6. Determine BA in CAPs in residual stand. (Multiply residual BA/Acre by % CAPs desired.)

7. Determine "Other" BA/Acre. (Subtract CAP BA/Ac. from Total BA.)

8. Determine "cut" stand. (Subtract residual stand from original stand)

9. Distribute cut BA in CAPs among CAP size classes. (Assign 2/3 of cut basal area to the two smaller size classes.)

10. Distribute cut BA in "Others" among "Other" size classes. (Assign 2/3 of cut basal area to the two smaller size classes.)

11. For each species-size class, compare cut BA with original BA to determine proportion of trees to mark.

YIELDS AND GUIDES RELATED TO
STAND DENSITY IN THE SOUTHWEST

by

Gilbert H. Schubert and Darrell W. Crawford[1/]

Forest managers in the Southwest have noticeably shifted their emphasis to more intensive practices, particularly on the more productive lands and lands with special qualities. Managers are now faced, however, with an increasing demand to improve their forestry practices, particularly on Federal and State lands. These demands stem from a need for more timber and other forest-related resources, and a need to produce these goods and services without irreparable environmental damage or visual degradation.

There are many ways to increase forest productivity without damaging the land. Last year at Tucson, Arizona, I presented a paper on "Silvicultural Practices for Intensified Forest Management." The silvicultural practices discussed were focused on stand manipulation to: (1) improve growth rates by controlling stand density, (2) accelerate replacement by prompt reforestation and increased rate of ingrowth, (3) reduce mortality by removal of high-risk trees, (4) maximize yields by improvement of stocking and by frequent stand re-entry to maintain growth rates, reduce

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loss, and improve utilization, (5) improve quality by removal of inferior trees, (6) fertilization to improve tree survival and growth, (7) tree improvement to increase growth rates and tree quality or resistance to tests, and (8) cultural work to protect the site and to enhance other forest-related resources.

The basic goal of management is to keep forest lands productive. In the past, the forests have been under extensive management. The silvicultural practices were limited generally to sanitation-salvage cuttings. The intensity of management gradually increased as we spent more effort to protect the forest. The annual net growth per acre was often less than 70 board feet. This has been increased to about 100 board feet today, largely due to more frequent cuts in the mature and overmature stands. But the productive capacity of these lands ranges from an annual net growth of 150 to 350 board feet. In my opinion, we can make the greatest gains to achieve full growth capacity by controlling stand density.

In 1962 we installed a set of growing stock level (GSL) plots in a young even-aged stand on the Fort Valley Experimental Forest near Flagstaff, Arizona. These plots, known as the Taylor Woods GSL plots are one in a series of study plots in ponderosa pine stands in Western United States. We are testing 6 growing stock levels: 30, 60, 80, 100, 120, and 150. These GSL's are the square-foot basal areas per acre the residual stands have, or will have when the stand diameter is 10 inches or more. The

10-year response to thinning has been recently analyzed. I will use these data to show: (1) relationship of stand density to diameter growth, (2) diameter growth to site index, (3) years to grow trees to specific diameter sizes, (4) estimated yields of a managed forest, and (5) a simplified guide to aid in treating stands to various stand densities.

DIAMETER GROWTH

We know two important facts about our southwestern ponderosa pine which may also be true for other tree species. First, trees up to at least mature age classes can grow at about the same ring width provided basal area is held constant. This implies that decreased growth rates which others have considered to be age-related are really stand density related. Secondly, southwestern ponderosa pine remains physiologically young up to an age of at least 200 years. This means that our trees will respond to thinning up through maturity provided the tree remains undamaged. Intensive silvicultural practices can help us achieve these two important responses.

Diameter growth for our Taylor Woods plots was strongly correlated with stand density (Figure 1). For the 10-year period after thinning 98 percent of the variation in annual diameter growth was associated with stand density. The periodic annual increment (PAI) for the different stand densities can be closely estimated by the regression equation: $y = 0.037 + 0.448e^{-.015x}$ where y = diameter increment in inches, x = residual basal area

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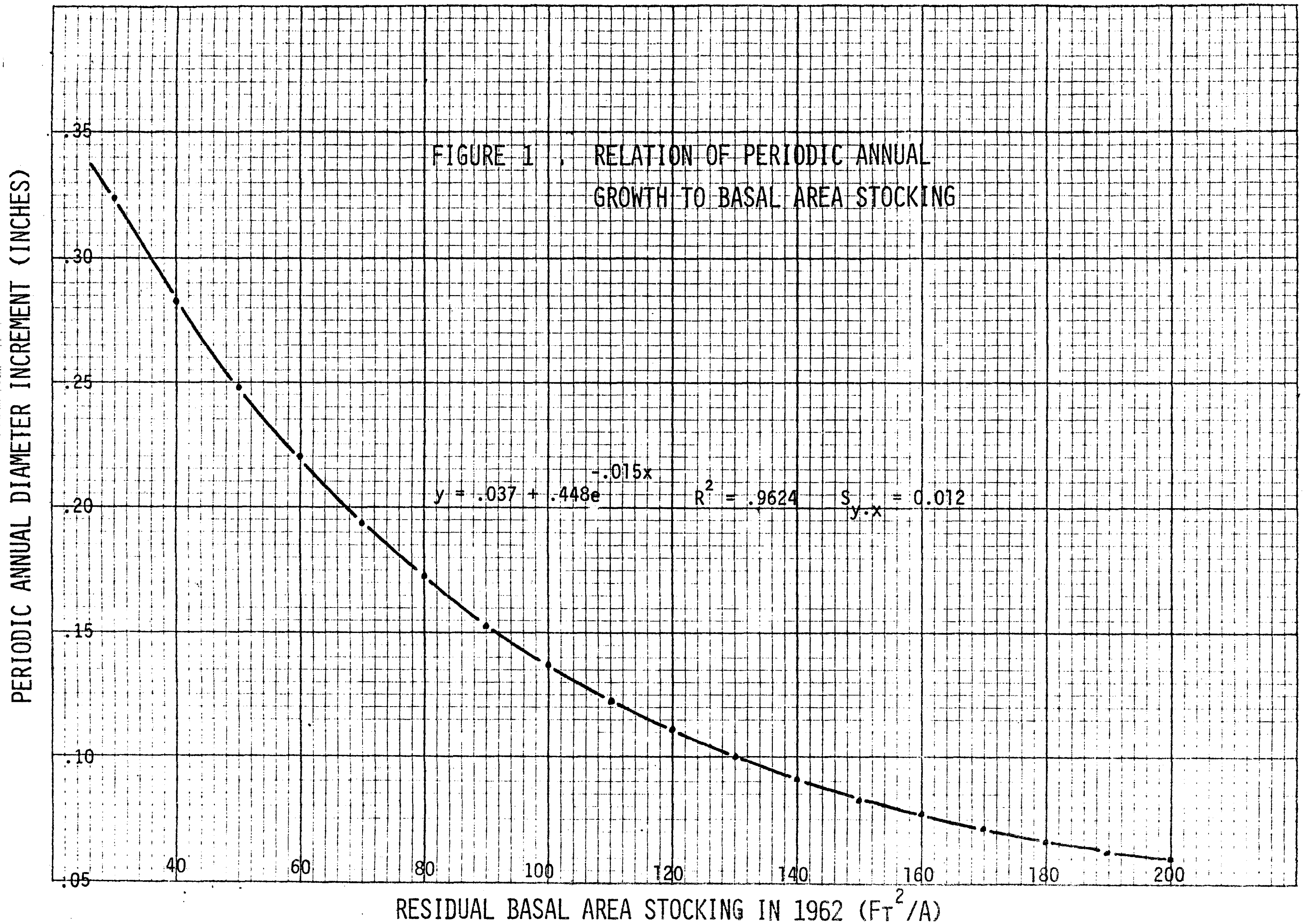

FIGURE 1 . RELATION OF PERIODIC ANNUAL GROWTH TO BASAL AREA STOCKING
y = .037 + .448e^-.015x
R^2 = .9624
S y·x = 0.012
PERIODIC ANNUAL DIAMETER INCREMENT (INCHES)
.05
.10
.15
.20
.25
.30
.35
40
60
80
100
120
140
160
180
200
RESIDUAL BASAL AREA STOCKING IN 1962 (FT^2/A)

immediately after thinning in square feet, and e = 2.718...... the base of hyperbolic logarithms.

The PAI diameter growth was greatest at the lowest GSL tested (Table 1). At GSL-30 the PAI was 2.3 times that at GSL-150. The trees at GSL-30 increased 3.1 inches in diameter compared to 1.4 inches at GSL-150. And growth at GSL-150 was twice that of the unthinned stand.

DIAMETER GROWTH RELATED TO SITE INDEX

At present, the GSL study has been installed in only one location in the Southwest. Therefore, the Taylor Woods study represents only one stand size and one site quality. Assuming that average ring-width growth remains nearly constant as stand density is maintained within relatively narrow limits, diameter can then be related to age. This assumption permits an estimate of years required to grow a tree of specified diameter size. Using the equation for Figure 1, we calculated the mean annual diameter growth for GSL's from 20 to 210. It must be remembered that the generated data at the upper and lower GSL's exceed the limits of the basic data and may be in error, but can serve as a first approximation. These data are shown under Site Index 90 in Table 2.

The MAI's for Site Index 90 and GSL's 20 to 210 were set as a base for computing similar data for Site Index (SI) 40 through 100. With SI 90 set as base 1.0000, conversion factors were

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Table 1.--Diameter growth of southwestern ponderosa pine related to growing stock levels (GSL) for the Taylor Woods plots in northern Arizona, 1962-1972

Growing stock level	Plot	Average diameter 1962	1967	1972	Periodic annual growth 1962-1967	1967-1972	1962-1972
Index 1/	No.			Inches			
30	7	5.36	6.81	8.51	0.290	0.340	0.315
	16	6.12	7.49	9.25	.274	.352	.313
	18	5.56	6.86	8.60	.260	.348	.304
	Av.	5.68	7.05	8.79	.274	.348	.311
60	3	5.18	6.37	7.52	.238	.230	.234
	15	5.49	6.47	7.65	.196	.236	.216
	17	5.89	6.88	8.18	.198	.260	.229
	Av.	5.52	6.57	7.78	.210	.242	.226
80	6	5.18	6.19	7.11	.202	.184	.193
	11	6.16	7.13	8.07	.194	.188	.191
	14	5.46	6.42	7.54	.192	.224	.208
	Av.	5.60	6.58	7.57	.196	.198	.197
100	1	5.67	6.61	7.43	.188	.164	.176
	9	4.84	5.69	6.62	.170	.186	.178
	13	5.28	6.12	7.00	.168	.176	.172
	Av.	5.26	6.14	7.02	.176	.176	.176
120	2	5.55	6.36	7.14	.162	.156	.159
	5	4.80	5.59	6.43	.158	.168	.163
	12	6.04	6.79	7.62	.150	.166	.158
	Av.	5.46	6.25	7.06	.158	.162	.160
150	4	4.76	5.34	6.07	.116	.146	.131
	8	4.72	5.36	6.05	.128	.138	.133
	10	4.44	5.14	5.87	.140	.146	.143
	Av.	4.64	5.28	6.00	.128	.144	.136

1/ Basal area in square feet per acre that will remain after thinning when diameter breast height is $\geq$ 10.0 inches.

computed based on data from Table 9 in Meyer's (1961)[2/] "Yield of even-aged stands of ponderosa pine at base age of 150 years." These conversion factors were then used to compute the MAI's for SI 40-100 and GSL 20-210. An examination of growth data from other Fort Valley plots indicate close agreement.

The data in Table 2 permit us to make rough comparisons of how many years may be required to grow a tree to specified diameters under different stand densities on site class various ~~lands in~~ the Southwest.

ROTATION PERIODS

Several factors have a bearing on the rotation period. Other speakers today have expressed their views on regeneration problems and the time required to get an established replacement stand. Growth of these replacement stands are also affected by a number of conditions. I have shown how stand density affects growth. Animals may retard growth through browsing. Several insects also affect growth. Some of the stands which we are cutting today took from 30 to 60 years just to reach pulpwood size. Fully managed stands should require much less time from seedling stage to maturity.

Data presented in Table 2 can be used to compute the number of years required to grow a tree to specific size and to set

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[2/] Meyer, Walter H. 1961. Yield of even-aged stands of ponderosa pine. U.S. Dep. Agric. Tech. Bull. 630, 59 p.

Table 2.--Computed mean annual diameter increment of young-growth southwestern ponderosa pine by site index and growing stock level (GSL)

GSL	Mean annual diameter increment by site index[1/]												
	40	45	50	55	60	65	70	75	80	85	90	95	100
Index	- - -	- - -	- - -	- - -	- - -	Inches	- - -	- - -	- - -	- - -	- - -	- - -	- - -
20	.196	.216	.236	.253	.269	.283	.298	.316	.334	.352	.369	.386	.404
30	.171	.189	.207	.221	.236	.248	.260	.277	.293	.308	.323	.338	.353
40	.150	.166	.181	.194	.206	.217	.228	.242	.256	.270	.283	.296	.310
50	.132	.146	.160	.171	.182	.191	.201	.213	.226	.237	.249	.261	.272
60	.116	.128	.140	.150	.160	.168	.177	.188	.198	.209	.219	.229	.240
70	.103	.114	.124	.133	.142	.149	.156	.166	.176	.185	.194	.203	.212
80	.092	.102	.112	.119	.127	.134	.140	.149	.158	.166	.174	.182	.190
90	.081	.089	.097	.104	.111	.117	.123	.130	.138	.145	.152	.159	.166
100	.073	.080	.088	.094	.100	.105	.110	.117	.124	.131	.137	.143	.150
110	.065	.072	.079	.084	.090	.094	.099	.105	.112	.117	.123	.129	.134
120	.059	.065	.071	.076	.081	.085	.090	.095	.101	.106	.111	.116	.121
130	.054	.059	.065	.069	.074	.078	.082	.086	.092	.096	.101	.106	.110
140	.049	.054	.059	.063	.067	.071	.074	.079	.083	.088	.092	.096	.101
150	.045	.049	.054	.058	.061	.064	.068	.072	.076	.080	.084	.088	.092
160	.041	.046	.050	.053	.057	.060	.063	.067	.071	.074	.078	.082	.085
170	.038	.042	.046	.049	.052	.055	.058	.062	.065	.069	.072	.075	.079
180	.036	.039	.043	.046	.049	.051	.054	.057	.061	.064	.067	.070	.073
190	.033	.037	.040	.043	.046	.048	.051	.054	.057	.060	.063	.066	.069
200	.031	.035	.038	.040	.043	.045	.048	.050	.054	.056	.059	.062	.064
210	.030	.033	.036	.038	.041	.043	.045	.048	.051	.053	.056	.059	.061
Conversion factors[2/]	.5304	.5856	.6409	.6851	.7293	.7679	.8066	.8564	.9061	.9531	1.0000	1.0470	1.0938

1/ Mean annual increment (MAI) SI-90 used as base where $Y=.037+0.448e^{-0.015x}$ for Taylor Woods GSL plots.

2/ Conversion factors derived from Table 9 in Meyer's (1961) "Yield of even-aged stands of ponderosa pine". Tech. Bull. 630.

rotation age (Table 3). These data include the impact of site and stand density for established seedlings but do not include the years needed to get seedlings established. For example, to grow a tree from seedling stage to a diameter of 24 inches would be about 124 years at GSL-70 on SI-90 lands. A tree of the same size would take 2 to 3 times longer at GSL's above 180 on SI-90 lands and longer yet on lower quality sites.

A 24-inch tree was once the target size in the Southwest. Future demands may indicate a different optimum size tree. The lower GSL's will produce a larger tree sooner than the higher GSL's. A 24-inch tree on a short rotation would satisfy timber-oriented managers. But a short rotation would not satisfy the needs of a recreationist who wants "yellow pines". To produce a "yellow pine" requires at least 200 years. Therefore, land managers need to select a rotation that yields trees that meet many needs. Figure 2 allows a manager to determine rotation ages on SI-75 lands for several GSL's. Similar curves can be constructed to correspond to his other SI.

TIMBER YIELDS

One of the prime objectives of timber management is to maximize timber production. Timber yields in the Southwest have been low compared to other regions and also when compared to the land potential. The reasons have been many. Some are: (1) unstocked and poorly stocked lands, (2) overstocked stands,

Table 3.—Estimated time required for southwestern ponderosa pine to attain a diameter of 24 inches by growing stock level on land of different site quality

GSL	SI-90	SI-75	SI-60
Index		Years 1/	
30	74	87	102
40	85	99	117
50	96	113	132
60	110	128	150
70	124	145	168
80	138	161	189
90	158	185	216
100	175	205	240
110	195	229	267
120	216	253	296
150	286	333	393
180	358	421	490

1/ Based on response to thinning on Taylor Woods plots for Site Index 90 with adjustment for Site Index 75 and 60 based on Table 9 in Meyer's (1961) "Yield of even-aged stands of ponderosa pine" Tech. Bull. 630.

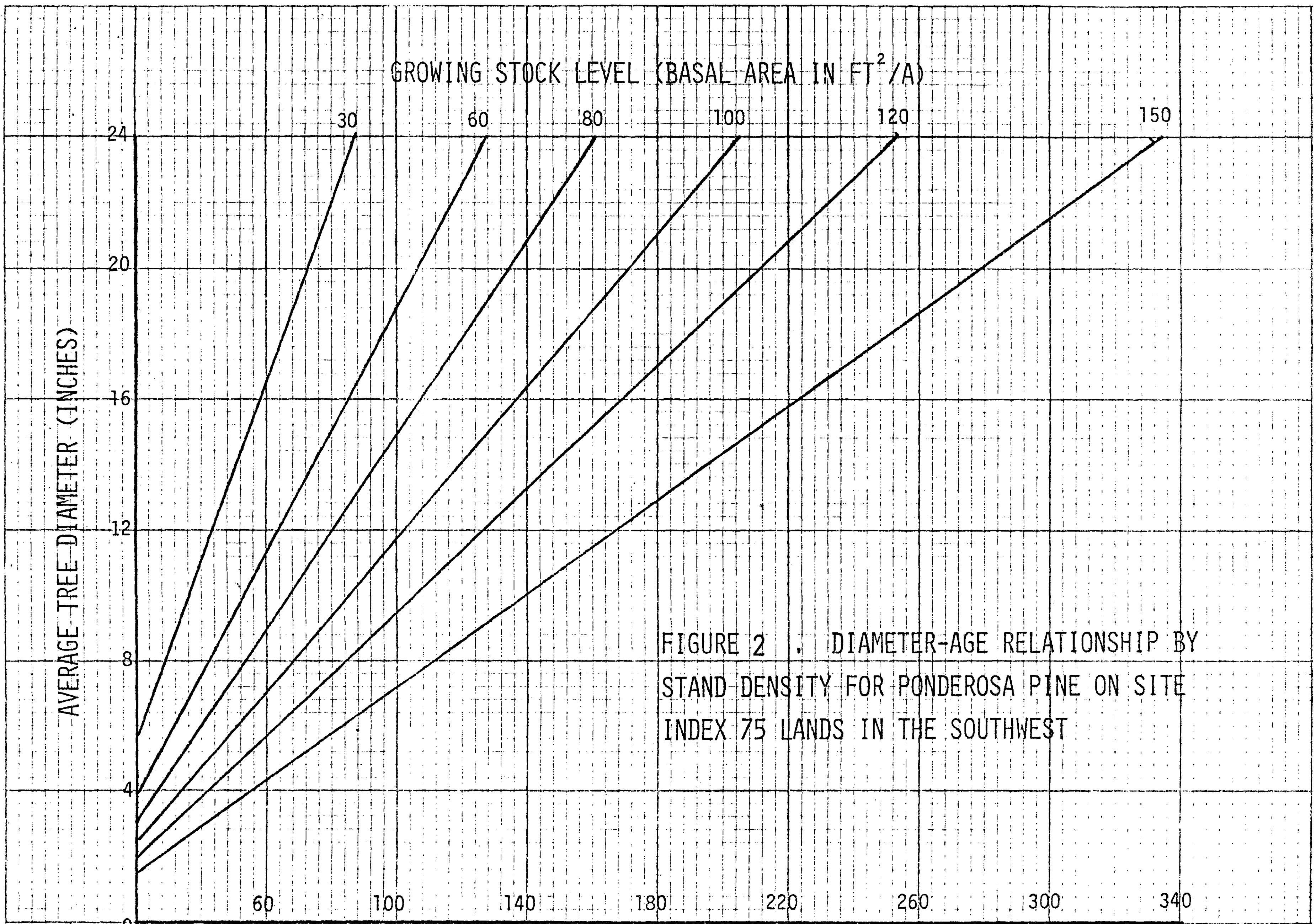

FIGURE 2 . DIAMETER-AGE RELATIONSHIP BY STAND DENSITY FOR PONDEROSA PINE ON SITE INDEX 75 LANDS IN THE SOUTHWEST

and (3) large acreages still occupied by old-growth timber. We can improve yields several fold through more intensive management.

We have used average diameter growth data to demonstrate what could be possible under different growing stock levels on high site timber lands in the Southwest (Table 4). Attainment of these yields would be dependent on several factors: (1) prompt regeneration--either by natural or artifical methods before the final harvest cut is completed, (2) prompt and adequate ingrowth into commercial size classes--through early precommercial thinning, (3) maintenance of rapid growth rates--through maintenance of stand density control by frequent intermediate cuts, and (4) through proper application of the regeneration treatment to start the new rotation.

Table 4 indicates estimated total commercial volumes available for harvest through one rotation. The volumes listed are estimates for several rotation periods. A rotation of 120 years has been tentatively set for ponderosa pine in the Southwest. An examination of these data infers that the largest commercial timber yield for the 120-year rotation may be realized at GSL-60.

These yields are based on an average 20-year growth diameter growth rate, zero mortality, and that each stand is treated at 20 year intervals.

Darrell will present some current operational yield data. This data will not necessarily be the same since the National Forests are not intensively managed at present.

Table 4. Estimated total commercial volume per acre available for harvest and average annual growth rate by growing stock levels and rotation periods for Taylor Woods plot, Fort Valley Experimental Forest Arizona[1/]

GSL[2/]	Rotation period	Estimated average diameter at end of rotation	Estimated total commercial volume available for harvest during rotation[3/]		Estimated average annual volume growth[4/]	
Index	Years	Inches	Cubic Feet	Board Feet	Cubic Feet	Board Feet
30	80	22	3,542	14,970	32	187
	100	28	4,300	20,096	43	201
	120	35	5,090	25,430	42	212
60	100	21	5,750	23,172	58	232
	120	26	7,074	32,097	59	267
80	120	21	6,742	27,879	56	232
	140	25	8,642	36,756	62	263
100	120	19	7,379	28,141	61	234
	140	22	8,690	37,015	62	264
	160	26	10,335	48,111	65	301
120	120	17	6,256	21,416	52	178
	140	21	8,140	33,764	58	241
	160	24	9,362	41,996	59	262
150	120	14	6,481	18,794	54	157
	140	17	8,819	29,574	63	211
	160	20	10,833	42,589	68	266
	180	23	12,744	55,492	71	308
	200	25	13,836	62,824	69	314

1/ Site index of 88 at 100 years.

2/ Numerical designation of the level assigned is the basal area per acre that will remain after cutting when stand diameter is 10 inches or more.

3/ Based on growth rates of 6 rings per inch (RPI) at GSL-30, 8 RPI at GSL-60, 10 RPI at GSL-80, 11 RPI at GSL-100, 12 RPI at GSL-120, and 15 RPI at GSL-150 obtain in the Taylor Woods GSL study for first 10-year period after thinning.

4/ Based on local volumes derived from regression equations in Station Paper RM-2 (Myers 1972) and tree heights from adjacent method of cutting plot.

TREATMENT GUIDES

Growing stock levels are often difficult to comprehend by professional foresters, contractors, and forestry technicians. This difficulty arises in part because the actual basal area stocking, for residual stands that average less than 10 inches d.b.h., is less than that indicated by the GSL index. Cliff Myer's (1967)[3/] has defined the GSL index to be the numerical designation of the level assigned in square feet basal area per acre that will remain after cutting when the stand diameter is 10 inches or more.

Recently Arthur R. Wrobley and James H. Sullivan, Southwestern Environmental Consultants, suggested plotting the data presented in Table 10 of "Silviculture of Southwestern Ponderosa Pine: The Status of Our Knowledge" report (Schubert 1974).[4/] The data are plotted in the same manner as in the Timber Management Handbook for Region 9. The major difference in the plotted graphs is how we use the one for our GSL's.

There are three essential bits of information that can be extracted from our graphs (Figures 3 and 4) which makes them especially useful in the Southwest: (1) knowing the number of

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3/ Myers, Clifford A. 1967. Growing stock levels in even-aged ponderosa pine. U.S. For. Serv. Res. Pap. RM-33, 8 p.

4/ Schubert, Gilbert H. 1974. Silviculture of southwestern ponderosa pine: The status of our knowledge. USDA. For. Serv. Res. Pap. RM-123, 71 p.

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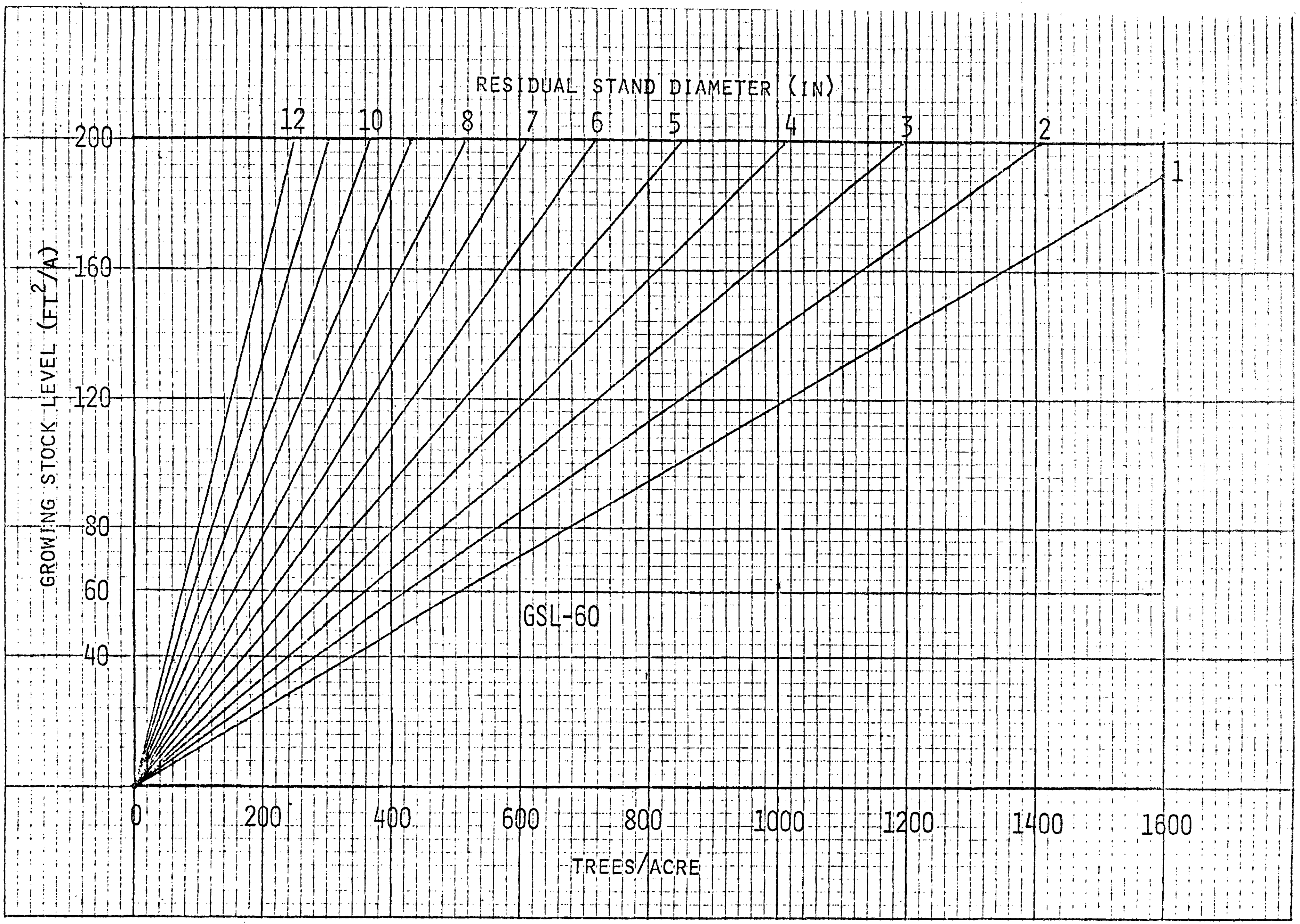


Figure 3.--Relationship of trees per acre and residual stand diameter for growing stock levels from 0 to 200 square feet per acre for stands up to 1,600 stems and diameters from 1 to 12 inches.

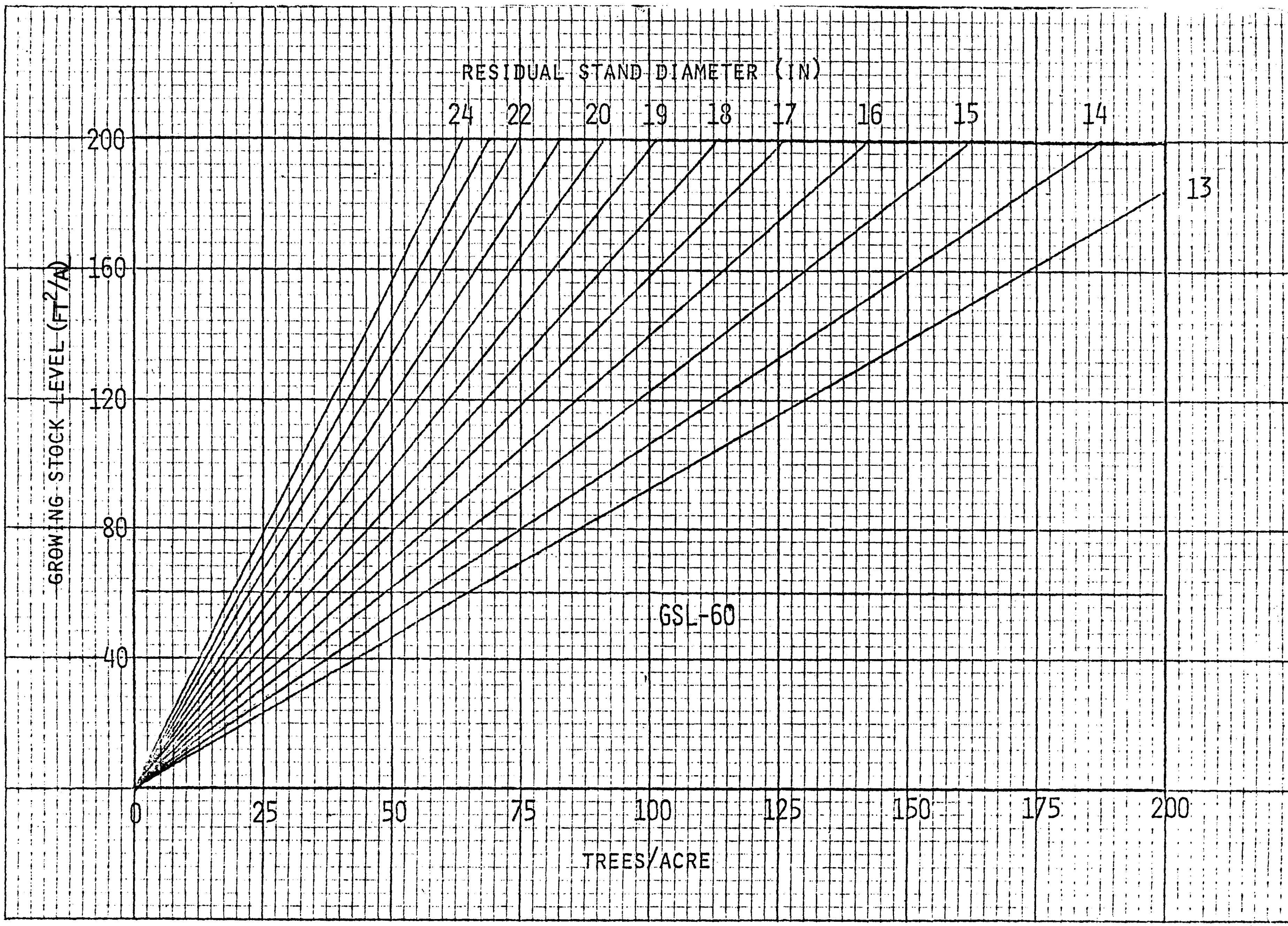


Figure 4.--Relationship of trees per acre and residual stand diameter for growing stock levels from 0 to 200 square feet per acre for stands up to 200 stems and diameters from 13 to 24 inches.

trees in a stand and its average d.b.h., you can determine the Growing Stock Level (GSL), (2) having plotted the coordinates, you can determine how many trees to cut to arrive at a lower GSL, and (3) knowing the estimated growth rate for the lower GSL, you can plot your future stand. There is no longer any need to worry whether the actual basal area is more, less, or the same as the numerical figures in the GSL index. The two graphs (Figures 3 and 4) will provide the basic information for stands up to 1,600 trees and diameters up to 24 inches.

The following illustration of the guide will illustrate its usefulness in stand density control problems. Let us assume that the inventory of our stand showed we had 1,400 trees per acre which averaged 2 inches in diameter. Starting at 1,400 on the x-axis follow the line up the graph to point 2 inches. A glance at the y-axis indicates a GSL of about 200.

Next, if our management plan indicated that we were to manage our stands at a GSL-60, we trace our way down the diagonal line designated 2 until it intersected the GSL-60 horizontal line. The intersection of these two lines indicates that we need to retain 420 2-inch trees for the GSL-60 stocking. In other words, we need to remove 980 trees in a precommercial thinning. This will generally be a thinning from below, so we will remove the smaller trees and defective larger ones. The net result will give us a stand of 420 that average more than 2 inches. If you really wanted to leave only a GSL-60, you would need to cut some more trees.

Now let us assume that it is not critical and we were permitted to leave the 420 trees. Based on our growth records, we have found that the GSL-60 stocking density results in a 5-inch diameter increase in 20 years. In other words, our average stand diameter has increased to 7 inches. Following the earlier procedure, we find that we now have 420 7-inch trees (assuming no mortality) which indicates that our stand has now reached a GSL-136. To reduce this stand back to the GSL-60, we need to cut 240 trees for pulpwood to leave a residual stand of 180 7-inch trees.

This same procedure can be followed to the end of the rotation by continuing on Figure 4. The manager will strengthen his growth rate data with each succeeding 20-year period. At any time during the rotation, he may change the GSL to fit future needs.

SUMMARY

We have attempted to demonstrate how our forests can be made to produce more timber through control of stand density. We have shown that a relatively low growing stock level can produce higher yields over a rotation than higher GSL's. And finally we have presented a simplified method which can be used to obtain desired stocking densities. We used local data, but the techniques are not limited to the Southwest. It is an interesting new approach which you may also wish to try on your forest.

USDA-Forest Service
GPO 942-797

by Darrell W. Crawford

Management Implications of Taylor Woods Growing Stock Levels

The GSL (growing stock level) study at Taylor Woods that Gil Schubert just described has already provided management with much needed information, even though this is only one study area. Even-aged silviculture has been prescribed for management of southwestern ponderosa pine, and management of young even-aged ponderosa pine stands is well-suited to GSL principles.

There are three major areas of stand management with which GSL information has assisted the timber manager in the Southwest: (1) Provides guidelines for TSI (timber stand improvement) work; (2) Provides guidelines for selecting desired rotation period, cutting cycle and average diameter at harvest; and (3) Provides basic data for ADP stand simulation programs that display multiple use management trade-offs.

Examples of these guidelines and programs are displayed by the following exhibits:

Exhibit No. 1 - A table that readily provides the user with number of trees per acre, basal area per acre and spacing guides by various DBH classes and growing stock levels. This is a very useful tool for field personnel.

Exhibit No. 2 - The same information provided in the Exhibit No. 1 table can be provided in graphical form where DBH lines are plotted by GSL and number of trees per acre. This graphical form can be used as a tool to determine desired number of intermediate harvests and approximate yield for each harvest; i.e., if a precommercial thinning is made at the 60 GSL when average stand DBH is 2 inches, the graph indicates 420 trees per acre remain. If the 420 trees per acre are left to grow to an average stand DBH of 6 inches and then cut back to the 60 GSL, there will remain 215 6-inch trees per acre and 205 6-inch trees per acre would have been harvested. The 205 6-inch trees harvested can easily be converted to volume. This procedure can be continued to determine how many intermediate cuts are desired and the volume for each cut.

Exhibit No. 3 - By using the GSL information in SWYLD2 (southwestern yield stand simulation computer program number 2), graphs can be produced showing GSL curves by stand age and DBH. The stand simulation program provides the curve data based on site index and intermediate harvests at each GSL. The graph is useful in determining stand rotation age at various GSL's for any desired average diameter at final harvest. Example - GSL 60, site index 80, at stand age 100 will produce average stand DBH of 19 inches.

Growing stock level data is well-suited to use in computer stand simulation programs. As an example, using such a program (PIPO), a stand simulation was run for ponderosa pine, site index 75, GSL 60, for a period of 60 years where a precommercial thinning was made when average diameter was 2 inches versus waiting until average diameter was 4 inches. The stand thinned at average diameter of 2 inches produced in 60 years a total cordwood harvest of 24.7 cords, while the stand thinned at average diameter of 4 inches only produced 16.7 cords or 32 percent less.

Use of GSL data provides the manager with a simple method of controlling and simulating stand prescriptions. These resultant guides can easily be interpreted and applied by field personnel.

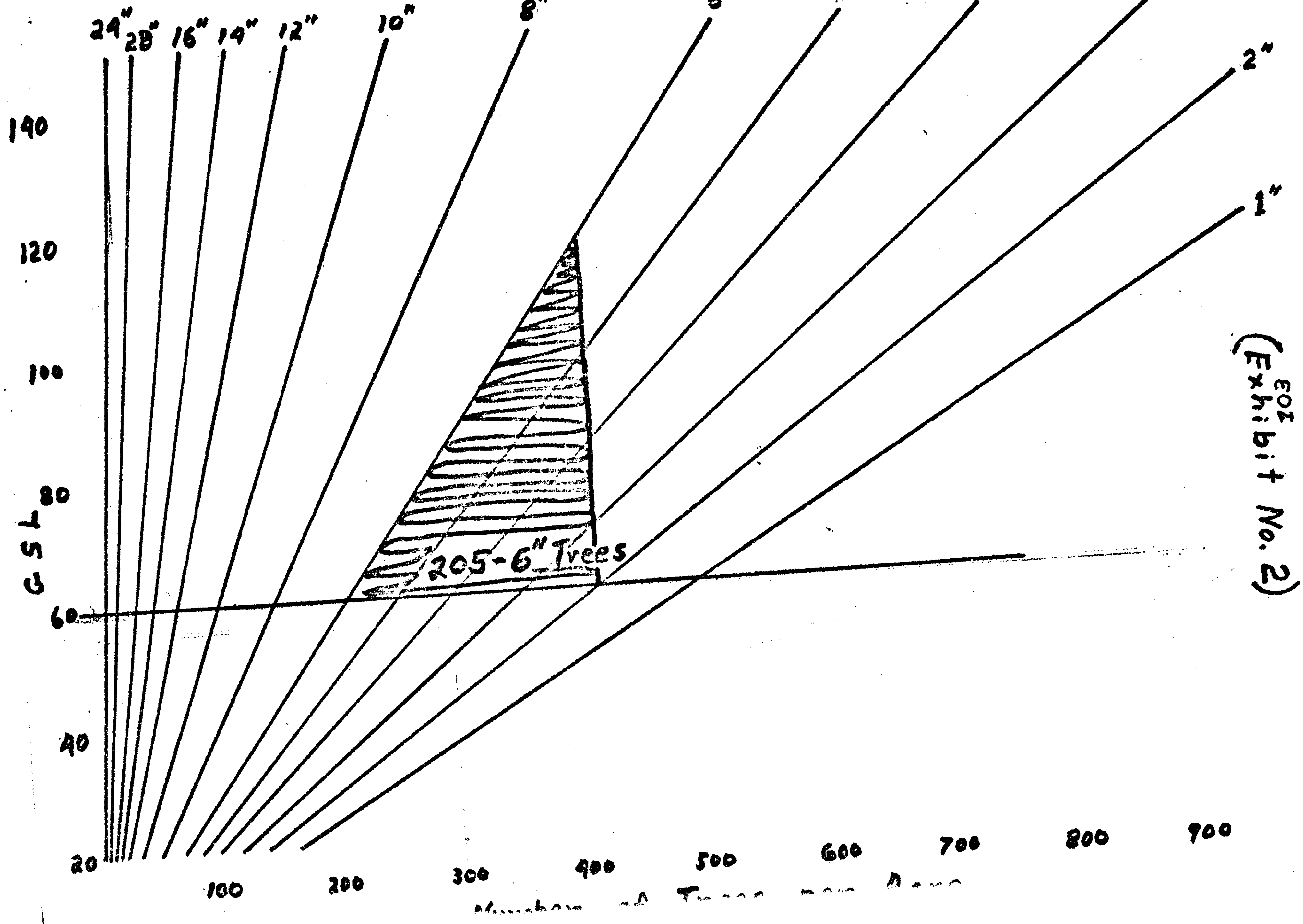
(Exhibit No. 1)

Number of trees per acre, actual basal area in sq. ft./acre and spacing between trees for size classes by growing stock levels.

GROWING STOCK LEVELS

DBH (inches)		20	40	60	80	100	120	150
1	No. Trees	168	[redacted] 336	[redacted] 505	[redacted] 665	[redacted] 841	[redacted] 1,009	[redacted] 1,261
	BA	0.9	1.8	2.8	3.7	4.6	5.6	6.9
	Ft. Space	16	11.4	9.3	8.1	7.2	6.6	5.9
2	No.	141	282	423	565	705	846	1,058
	BA	3.1	6.2	9.2	12.3	15.4	18.4	23.1
	SPC	17.6						6.4
3	No.	120	240	360	480	601	721	901
	BA	5.9	11.8	17.7	23.6	29.5	35.4	44.2
	SPC	19.1	13.4	11.0	9.5	8.5	7.8	7.0
4	No.	101	202	302	403	504	605	756
	BA	8.8	17.6	26.4	35.2	44.0	52.8	66.0
	SPC	20.8	14.7	12.0	10.4	9.3	8.5	7.6
5	No.	86	171	257	343	428	514	642
	BA	11.7	23.4	35.0	46.7	58.4	70.0	87.6
	SPC	22.5	15.9	13.0	11.3	10.1	9.2	8.2
6	No.	72	144	216	288	360	433	541
	BA	14.2	28.3	42.4	56.6	70.8	84.9	106.1
	SPC	24.6	17.4	14.2	12.3	11.0	10.0	9.0
8	No.	52	104	156	208	260	312	389
	BA	18.1	36.2	54.4	72.5	90.6	108.8	135.9
	SPC	28.9	20.5	16.7	14.5	13.0	11.8	
10	No.	37	73	110	147	183	220	275
	BA	20	40	60	80	100	120	150
	SPC	34.3	24.4	19.9	17.2	15.4	14.1	10.6
12	No.	25	51	76	102	127	153	191
	BA	20	40	60	80	100	120	150
	SPC	41.7	29.2	23.9	20.7	18.5	16.9	15.1
14	No.	19	37	56	75	94	112	140
	BA	20	40	60	80	100	120	150
	SPC	47.9	34.1	27.9	24.1	21.6	19.7	17.6
16	No.	14	29	43	57	72	86	107
	BA	20	40	60	80	100	120	150
	SPC	55.8	39	31.8	27.6	24.7	25.3	20.2
18	No.	11	23	34	45	57	68	85
	BA	20	40	60	80	100	120	150
	SPC	62.9	43.9	35.8	31	27.7	25.3	22.6

Number of trees per Acre by D.B.H. Classes for GSL's Ponderosa Pine



(Exhibit No. 2)

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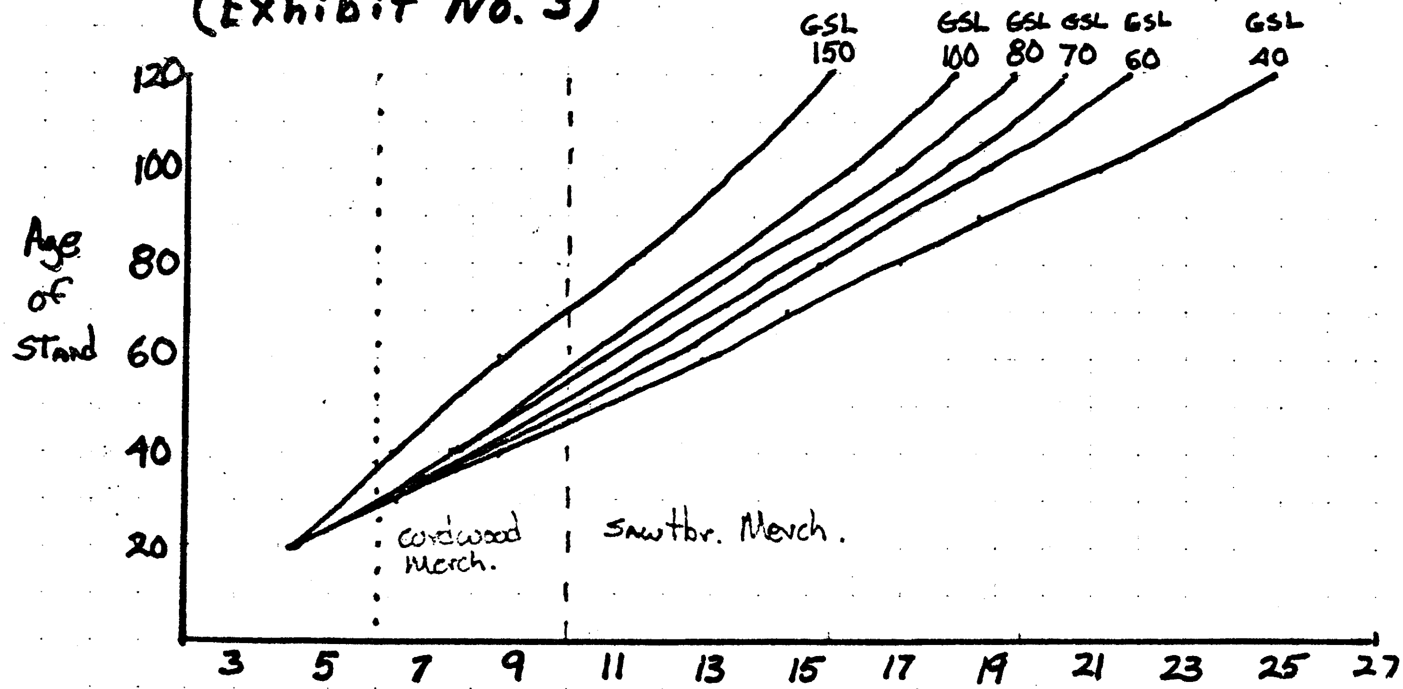
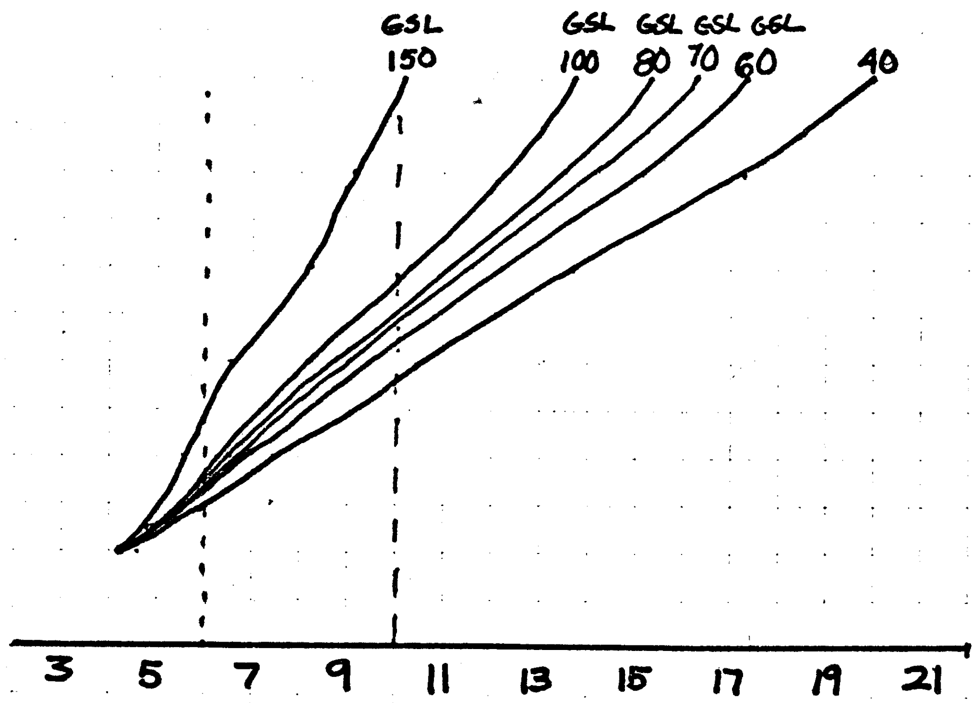
(Exhibit No. 3)



Average Diameter After Intermediate cutting To 120 years At Different G.S.L.

Site Index 80



Site Index 50

SILVICULTURAL PRACTICES FOR INTENSIFIED FOREST MANAGEMENT

By

Gilbert H. Schubert
Principal Silviculturist
Rocky Mountain Forest and Range Experiment Station

Our forests have featured in the development of Arizona and New Mexico since the Gold Rush days of the mid 1800's. These lands have not only produced a wide variety of timber products, but also have produced abundant forage and long have been grazed by livestock. These forests produce much of the region's deer, elk, antelope, turkey, and other wildlife.

Other uses of our forest lands are becoming increasingly important, and timber management activities have an impact on virtually all these uses of our forests. Forage production and habitat for big-game animals may be benefited by opening up timber stands. Water yields are influenced by stand manipulations. Recreational and esthetic values may be improved following the short period required for development of ground vegetation. Current approaches to forest management are being increasingly oriented to enhance these aspects of multiple use.

Forest managers have noticeably shifted their emphasis to more intensive practices, particularly on the more productive lands and lands with special qualities. Managers are now faced, however, with an increasing demand to improve their forestry practices. These demands stem from a need for more timber and other forest-related resources, and a need to produce these goods and services without irreparable environmental damage or visual degradation. To accomplish these things, foresters must use sound silvicultural practices to manage the trees -- the renewable resource.

Silvicultural practices are focused on stand manipulation to: (1) improve growth rates by controlling stand density, (2) accelerate replacement by prompt reforestation and increased rate of ingrowth, (3) reduce mortality by removal of high-risk trees, (4) maximize yields by improvement of stocking and by frequent stand re-entry to maintain growth rates, reduce loss, and improve utilization, and (5) improve quality by removal of inferior trees. To this list, we may also add: (1) fertilization to improve tree survival and growth, (2) tree improvement to increase growth rates and tree quality or resistance to pests, and (3) cultural work to protect the site and to enhance other forest-related resources.

The basic goal of management is to keep forest lands productive. In the past, the forests have been under extensive management. The silvicultural practices were limited generally to sanitation-salvage cuttings. The intensity of management gradually increased as we spent more effort to protect the forest. The annual net growth per acre was often less than 70 board feet. This has increased to about 100 board feet today, largely due to sanitation-salvage cuts. But the productive capacity of these lands ranges from an annual net growth of 150 to 350 board feet. How can we realize the full productive capacity of our forested lands?

We can employ all or part of the silvicultural practices previously listed. The major constraint will be cost as related to benefit. So the upper limit of management intensity is controlled by economic considerations. In the past, with stumpage at less than $5/thousand board feet, the manager could resort only to extensive management. Today when stumpage rates often exceed $50, he can do much more to increase timber production.

Time does not permit going into great detail on each of the silvicultural practices to increase productivity. In my opinion, we can make the greatest gains today by controlling stand density. The other practices are essential to keep the wheels turning, so they cannot be ignored. Our biggest present job is to treat over 3 million acres of overstocked timber land to increase yields. I will cover "the other practices" first, then devote more time to discussing the importance of stand density control.

ACCELERATE REPLACEMENT STANDS

If we intend to practice intensified forestry, it is essential that replacement trees be established promptly. The allowable cut and length of rotation, or time to grow a tree to a specified size, are all dependent on prompt reforestation and the rate of ingrowth into merchantable size classes. Wayne Hite and George Cullom discussed various reforestation methods. In addition to methods, we need to consider some of the consequences when regeneration is slow in coming and left almost entirely to chance.

Many forest management plans require action by man only after nature is given a 10-year period to restock an area. The waiting period has been reduced in more recent plans to 5 years. In the past when stumpage was low, there was very little money for reforestation. This has now changed.

How important is prompt reforestation? Some large forest-land-owning companies claim they cannot afford to gamble on even the first year after cutting, so they plant immediately after cutting. If they get natural regeneration, it is considered a bonus.

How long can we in the Southwest afford to wait? Every year we wait, the difficulties and costs of getting successful regeneration increase. Some areas have remained unstocked for 50 to 100 years. Our stumpage has too little slack to allow a long wait.

I mentioned allowable cut and length of rotation or time to grow a tree to a specific size. The longer we wait, the lower will be the allowable cut. It is not very realistic to plan in terms of a 100- or 120-year rotation when it takes 10 to 30 years to get a new crop started. Our trees can only grow so fast. This "waiting period" dilutes our allowable annual cut.

Getting a new crop started is only part of the replacement problem. These trees must make rapid growth to reach merchantable size within a reasonably short time. If they don't, the allowable cut goes down and the rotation period gets longer.

I am considering growth rate here because it affects the replacement problem. The silvicultural practice we use to combat this problem is precommercial thinning. Under intensified management we come face to face with the time problem. Can we afford to wait 43 years for the average stand diameter to reach 2.6 inches as we did at Taylor Woods on the Fort Valley Experimental Forest? That is over one-third of the 120-year rotation with little to show.

Precommercial thinning is a cost managers must consider. When stumpage is high, it is easy to justify this cost. Can we justify it at our current stumpage prices? I will leave this thought with you; to get into an economic analysis is beyond the scope of this paper.

REDUCE MORTALITY

One of the first tasks a manager tackles on an unmanaged forest is to salvage his mortality. If his forest is large, he may get nothing else done. He will be constantly cutting "recent kill" or "mortality anticipation". The question asked by the logger is "when do we cut the good stuff?"

Under intensive management, the forester does considerably more. How much more depends on the intensity of management. He may start out with a level of intensity higher than just sanitation-salvage. The improvement selection method developed on the Fort Valley Experimental Forest would be one example of a more intensified silvicultural practice. Under this method, the manager would release some of the better trees in addition to cutting the dead and dying trees.

IMPROVE QUALITY

Another objective under the improvement selection method is to improve tree quality by removal of inferior trees. This objective is also listed under all cutting treatments, from precommercial thinning through the seed cut in a shelterwood system, and in all cuts in the selection system. Under extensive management, no special efforts would be made to improve the quality of a residual stand. Under intensive management, stand quality would be improved with each successive treatment.

As management intensity increases, the manager may also prune to improve wood quality. The number of trees pruned per acre may increase with management intensity, but normally pruning would be restricted to the final crop trees. Pruning also has its place in special-use areas where esthetics or safety may be prime considerations.

FERTILIZATION

Fertilization of forest trees in the Southwest is still in the experimental stage. Studies conducted in the Southwest, principally by Dr. Robert Wagle at the University of Arizona, have shown that both tree survival and juvenile growth can be improved.

Soils in the Southwest generally have adequate nutrients for plant growth, although some are deficient in nitrogen and phosphorus for adequate top and root growth. Fertilizers show most potential for improving young natural stands and plantations, and for stimulating cone production. Fertilizer trials with southwestern species are just getting underway. Early results should be available in about 1978. Estimates of increased tree growth range from 5 to 30 percent.

TREE IMPROVEMENT

The tree improvement program is also just getting underway in the Southwest. One of the first accomplishments was the establishment of provisional seed collection zones. Trials will be made to test seed sources for their compatibility with local environmental conditions. Work done to date indicates striking differences in survival, early growth, tree form, and foliage color of different seed sources. Intensified management would expand the tree improvement program to include hybridization.

IMPROVE GROWTH RATES

Growth rates are strongly correlated with site quality and stand density. Our Taylor Woods study of growing stock levels provides some of the best information on the effect of stand density on growth of young ponderosa pines.

DIAMETER GROWTH

Trees with well-developed crowns can grow in diameter at about the same rate over a broad range of age classes, provided they are given adequate growing space. For example, ponderosa pines were found to remain physiologically young and responsive to thinning up to an age of at least 200 years.

Dense stands of slow-growing ponderosa pines have responded well to release. The 43-year-old stands, with an average density of 5,800 stems per acre and an average diameter of 2.6 inches, were thinned in 1962 to test 6 residual growing stock levels (GSL). The growing stock level is defined as the basal area (square feet per acre) that will remain after cutting when stand diameter is 10 inches or more.

Diameter growth was found to drop significantly with increased basal area stocking (fig. 1). Trees in the GSL-30 plots were growing in diameter at over 5 times their prethinning rate. Even at GSL-150, the trees had doubled their growth rates.

An examination of these growth rates gives some insight on length of rotation. For example, if the objective was to grow a 24-inch dbh tree, it would take about 120 years on site index 90 land at GSL-70 (fig. 2). Site index 75 is more representative of southwest forest lands, so a 140-year rotation is more realistic. Trees should grow to the 24-inch size on intensively managed areas. By intensively managed, I mean the stands would need to be thinned to GSL-70 and then retreated at frequent intervals to maintain the growth rate. The growth rates shown in figure 1 are conservative, so the re-entries may be at 20-year intervals.

BASAL AREA GROWTH

In contrast with diameter growth, net basal area increment was greater at higher residual stocking levels throughout the range of GSL-30 to 150 (fig. 3). At low stocking levels, trees were too few to use the site's full potential for basal area growth. Above GSL-80, increased stocking made less difference. The periodic annual increment averaged about 4.4 square feet per acre.

HEIGHT GROWTH

Height growth increases with site quality, but is not affected by stand densities from GSL-30 to 150. Height growth of southwestern ponderosa pine is slow even on the best sites, and decreases with age. Growth on trees at age 20 is two to three times that at age 140 (fig. 4). Very little height growth is made after age 160 years. Therefore, total height of dominant trees over age 160 years could be used as an estimate of site quality.

MAXIMIZE YIELDS

One of the prime objectives of timber management is to maximize timber production. Timber yields have been low, due in part to unstocked and poorly stocked lands, overstocked stands, and large acreages still occupied by old-growth timber. These yields can be increased through more intensive management.

The average gross annual increment on large sample plots on the Fort Valley Experimental Forest has ranged from 70 to 116 fbm per acre. Mortality has reduced these annual yields to a range of 25 to 93 net fbm per acre. Small, well-stocked plots that have received intermediate cuts show net yield of 103 to 232 fbm per acre. Trees in these stands range up to 300 years in age and over 40 inches in diameter.

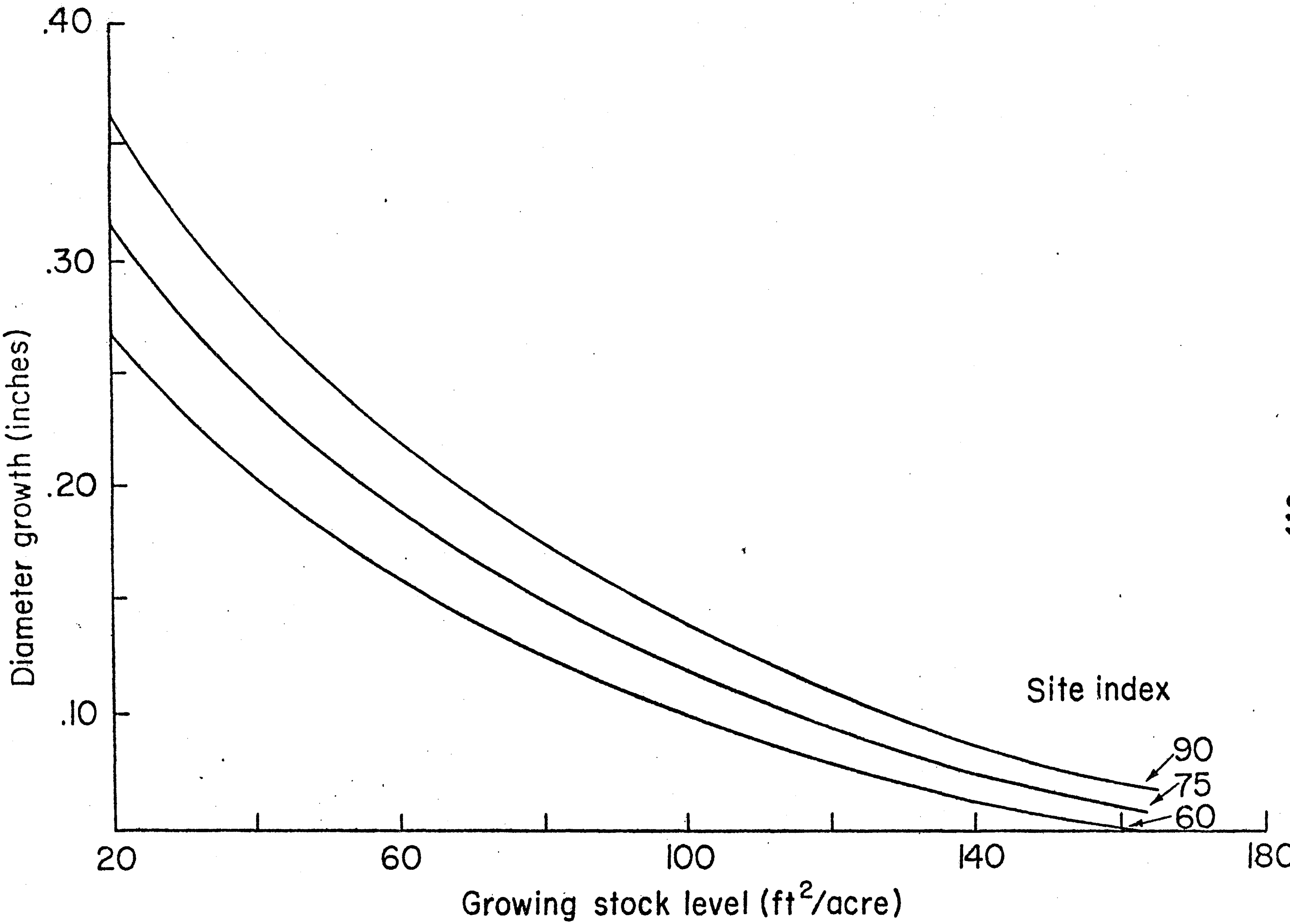


Figure 1.--Relation of diameter growth to growing stock levels for young-growth southwestern ponderosa pines.

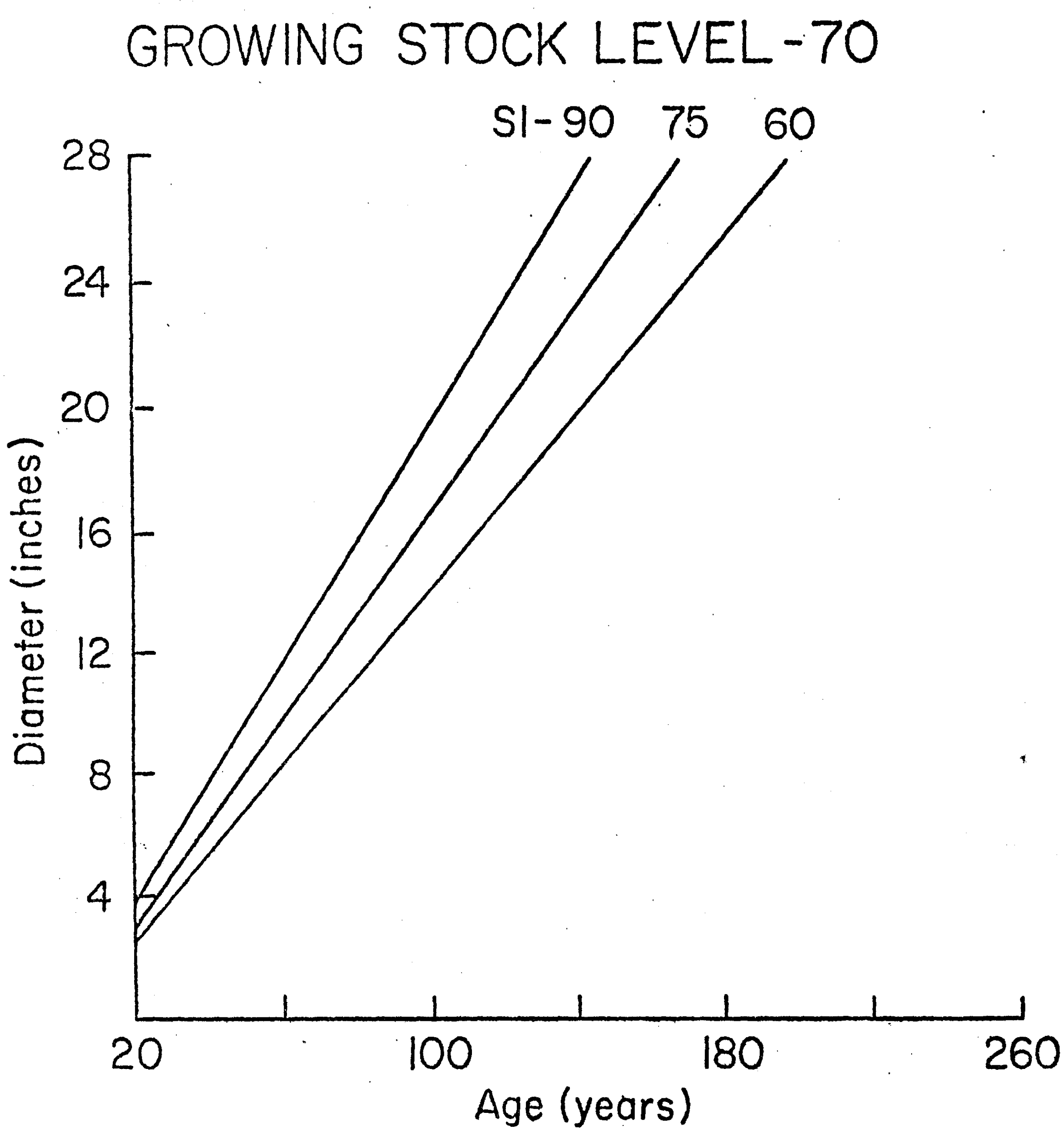


Figure 2.--Years required to grow a ponderosa pine to different diameter size classes at the GSL-70 growth rate on different site quality lands.

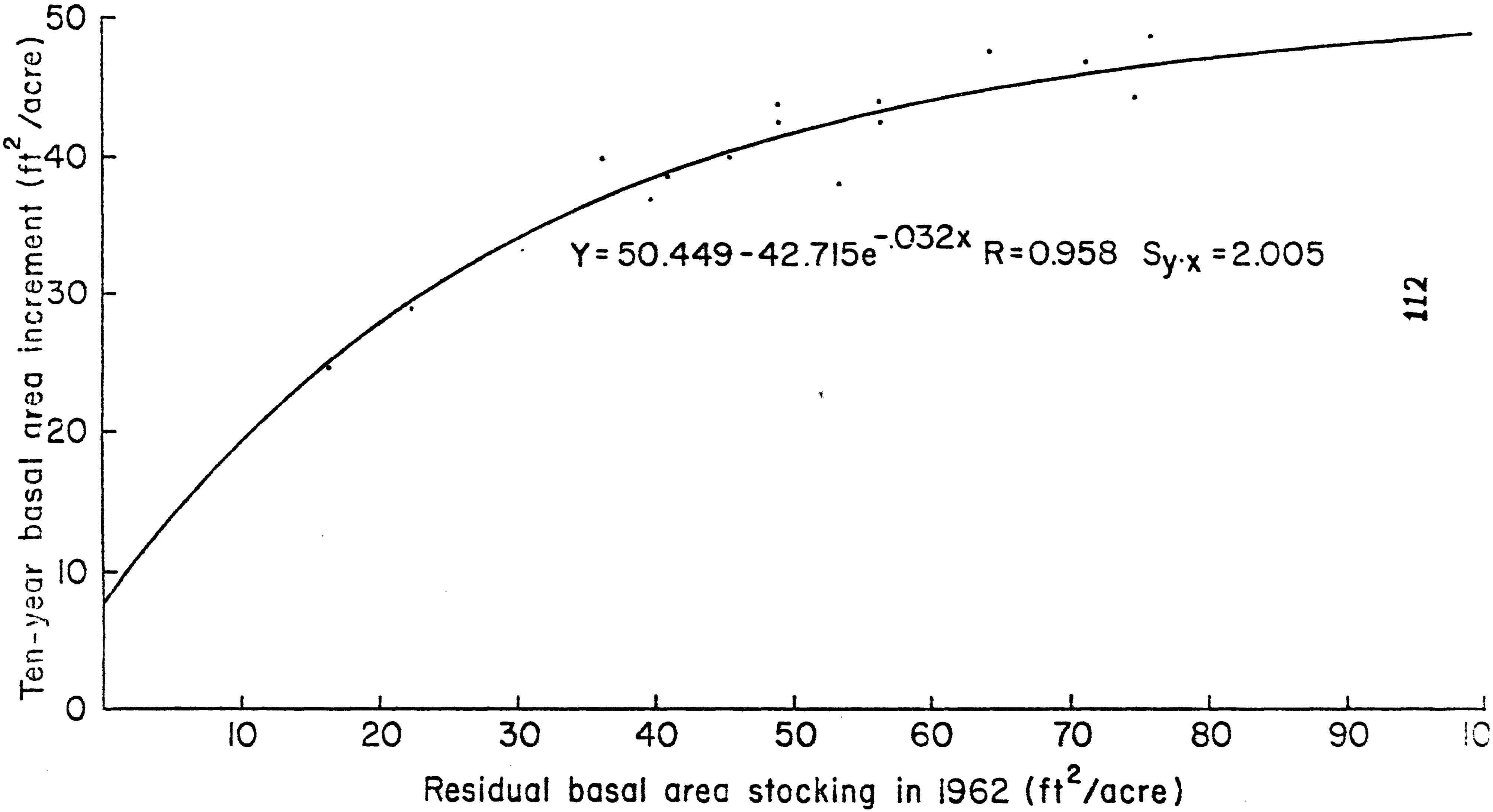


Figure 3.--Relation of periodic basal area growth to basal area stocking.

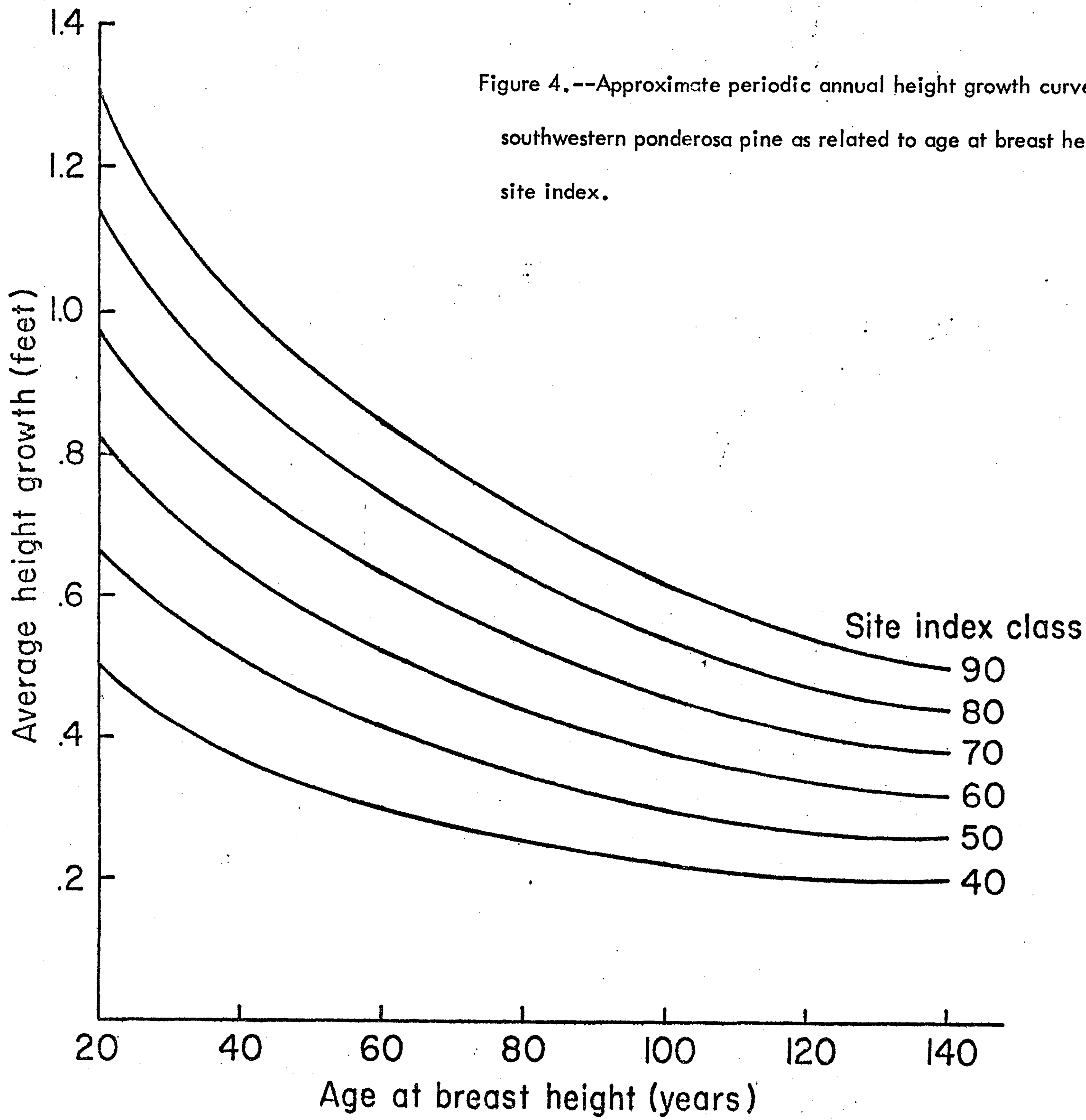


Figure 4.--Approximate periodic annual height growth curves for southwestern ponderosa pine as related to age at breast height and site index.

What kind of yields may we expect under intensive management where the objective is to maximize sawtimber volume in trees with at least a 24-inch dbh? Using the diameter growth rates shown in figure 1, and a 120-year rotation, we find that the greatest volume production of 36,000 fbm per acre occurs at a GSL-70 on site index 90 lands (fig. 5). Production at GSL-60 and 80 are also quite high. GSL-70 also produced the maximum volume on site index 75 and 60 lands under the longer rotations.

Tables 1, 2, and 3 indicate the estimated mean annual sawtimber increment (MAI) per acre for site index 90, 75, and 60 lands for growing stock levels 30 to 180. These tables illustrate several useful bits of information for decision making. First, they show the estimated highest MAI by growing stock level and site index. Second, they show a rather broad top band of MAI's with little difference in increment within each GSL. Third, a comparison across GSL levels within each site index class shows the amount of growth given up by changing levels of stocking. Fourth, they show the rotation ages where estimated MAI's decrease with a further extension of the rotation. Fifth, a plotted curve across any rotation age indicates the "best" GSL for the particular rotation age. And sixth, a comparison of the three tables shows the relative yields by site index. These plotted values (fig. 6) illustrate that a manager could very well select the same GSL and vary his rotation by site quality. Similar procedures could be explored to develop other options.

Most of the data discussed today were related to even-aged stands. This may be somewhat out of line for forests that are composed primarily of uneven-aged stands. Many of our uneven-aged ponderosa pine stands could be converted to an even-aged structure, however. The reverse is also true. According to my estimates, the manager may obtain about the same timber yields from even-aged and uneven-aged management (fig. 7).

The forests we inherited have undergone considerable change during the past century. Our virgin forests were described as open-parklike. There were many large trees and relatively few small ones. A comparison of their frequency distribution with a reference frequency for a managed selection forest would show the problem we face in management for sustained yield (fig. 8). The problem is not so much the large number of big trees as it is the shortage of little ones. We must budget our cut over time. If we have no little ones to grow into big ones, we could in a hundred years or so be out of trees.

If we compared our present forest with the GSL-70 reference, as in figure 8, we note the change due to past management. Our stocking of large trees has been reduced. We have a lesser deficiency in medium-sized trees as noted by the smaller difference between the two curves. And we picked up an excess of small

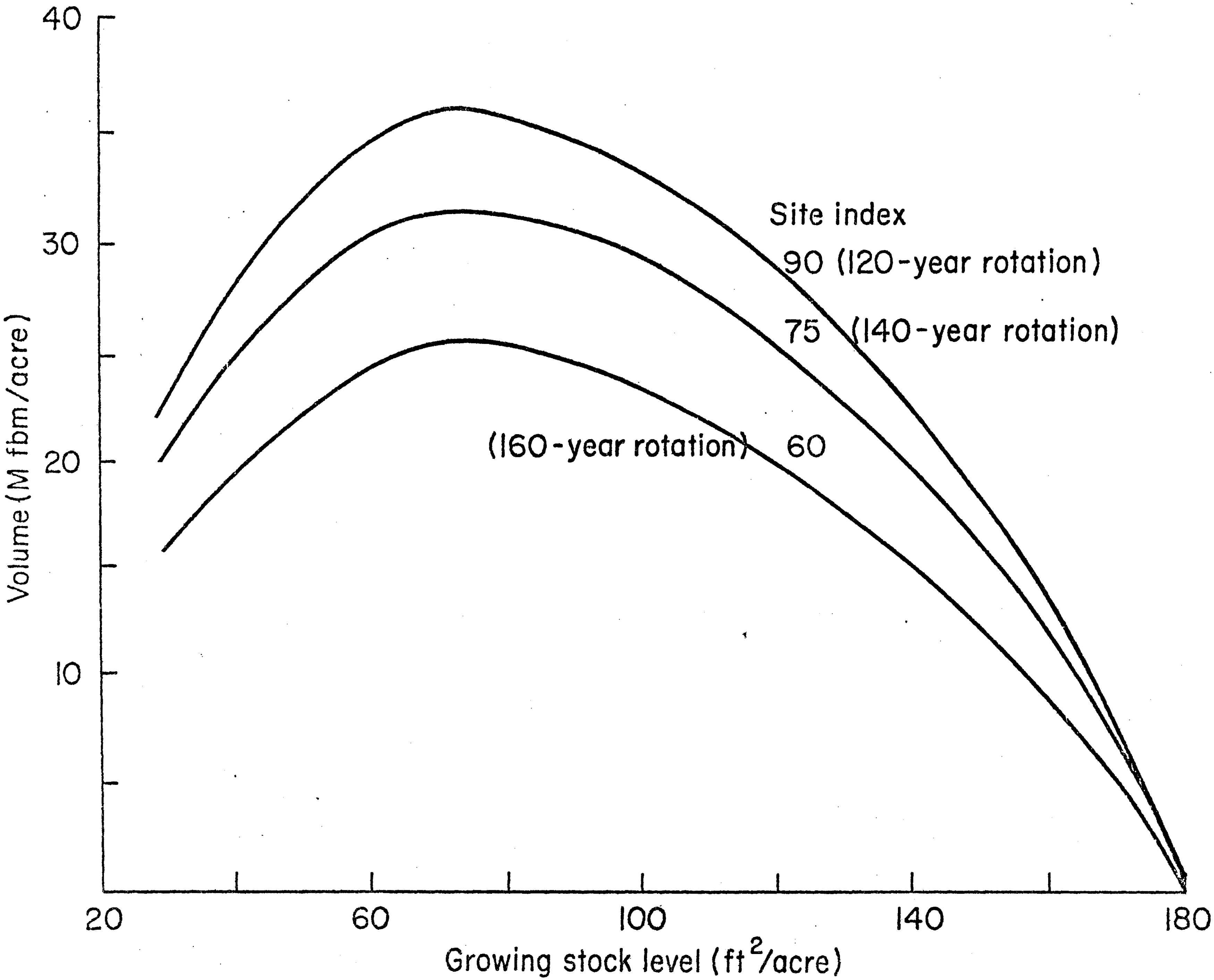


Figure 5.--Estimated sawtimber yield of southwestern ponderosa pine by site quality and growing stock level for different rotation periods under intensive management.

Table 1.-- Estimated mean annual sawtimber increment per acre of southwestern ponderosa pine on site index 90 lands by rotation age for various growing stock levels

Rotation age[2/] (Years)	Growing stock level[1/]											
	30	40	50	60	70	80	90	100	110	120	150	180
	Fbm											
40	13	0	0	0	0	0	0	0	0	0	0	0
60	102	120	120	111	91	0	0	0	0	0	0	0
80	151	176	183	189	193	163	137	130	0	0	0	0
100	176	210	235	259	258	231	222	225	186	171	0	0
120	186	223	262	284	301	292	284	283	246	245	173	0
140	188	234	274	304	328	330	334	341	314	302	250	0
160	186	232	278	311	339	349	358	373	355	352	296	218
180		229	277	311	341	357	369	388	380	385	344	267
200			271	306	339	358	375	394	392	400	377	296
220						351	370	393	393	404	391	333
240										402	399	352
260											403	367
280											403	374
300											401	378
320												382
340												381
360												380
380												379

1/ Basal area (square feet per acre) that will remain after cutting when stand diameter is 10 inches or more.

2/ MAI carried to point of decline or general leveling off or average stand diameter is equal to or exceeds 24.0 inches.

Table 2.--Estimated mean annual sawtimber increment per acre of southwestern ponderosa pine on site index 75 lands by rotation age for various growing stock levels

Rotation age 2/ (Years)	Growing stock level 1/											
	30	40	50	60	70	80	90	100	110	120	150	180
	Fbm											
60	68	70	59	42	0	0	0	0	0	0	0	0
80	99	112	128	120	104	94	71	0	0	0	0	0
100	124	144	164	155	153	142	144	118	101	0	0	0
120	140	160	187	194	193	181	185	173	166	132	0	0
140	145	170	203	216	225	222	224	206	202	185	139	0
160	144	171	197	225	239	243	251	242	236	208	181	0
180		172	198	228	245	251	263	260	258	241	206	148
200		168	196	227	246	256	271	269	274	259	225	175
220				224	244	254	271	273	278	270	243	196
240									281	273	257	206
260										275	264	215
280										273	268	230
300											272	238
320											272	245
340											272	249
360											270	252
380												253
400												253
420												257
440												250

1/ Basal area (square feet per acre) that will remain after cutting when stand diameter is 10 inches or more.

2/ MAI carried to point of decline or general leveling off or average stand diameter is equal to or exceeds 24.0 inches.

Table 3.--Estimated mean annual sawtimber increment per acre of southwestern ponderosa pine on site index 60 lands by rotation age for various growing stock levels

Rotation age 2/ (Years)	Growing stock level 1/											
	30	40	50	60	70	80	90	100	110	120	150	180
	Fbm											
60	33	25	10	0	0	0	0	0	0	0	0	0
80	62	66	64	56	45	0	0	0	0	0	0	0
100	78	84	92	94	94	76	65	52	0	0	0	0
120	90	103	112	112	117	110	105	98	77	0	0	0
140	96	113	128	135	139	129	129	128	115	92	0	0
160	99	119	137	148	157	151	146	146	138	123	86	0
180	99	122	140	155	165	166	166	162	151	140	116	0
200		122	142	157	170	173	176	177	167	151	134	93
220			142	157	172	177	182	185	179	166	146	115
240					170	177	183	188	184	174	152	129
260								189	186	180	156	136
280									188	182	166	143
300										184	171	147
320										184	175	150
340											177	157
360											180	163
380											180	165
400											180	168
420											180	170
440												171
460												171
480												172
500												172

1/ Basal area (square feet per acre) that will remain after cutting when stand diameter is 10 inches or more.

2/ MAI carried to point of decline or general leveling off or average stand diameter is equal to or exceeds 24.0 inches.

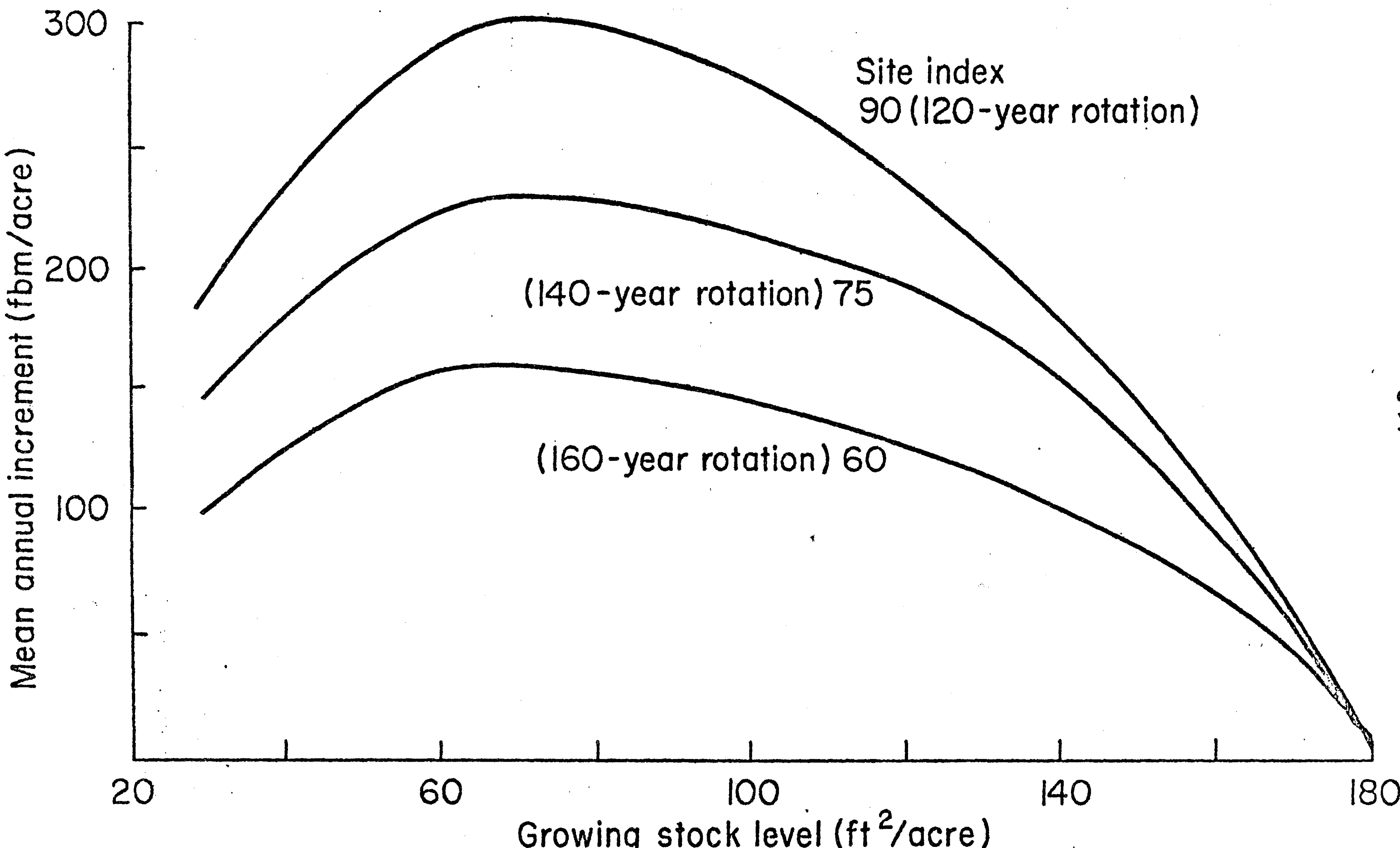


Figure 6.--Estimated mean annual sawtimber increment by growing stock levels for even-aged southwestern ponderosa pine forests on different site quality lands for selected rotation periods under intensive management.

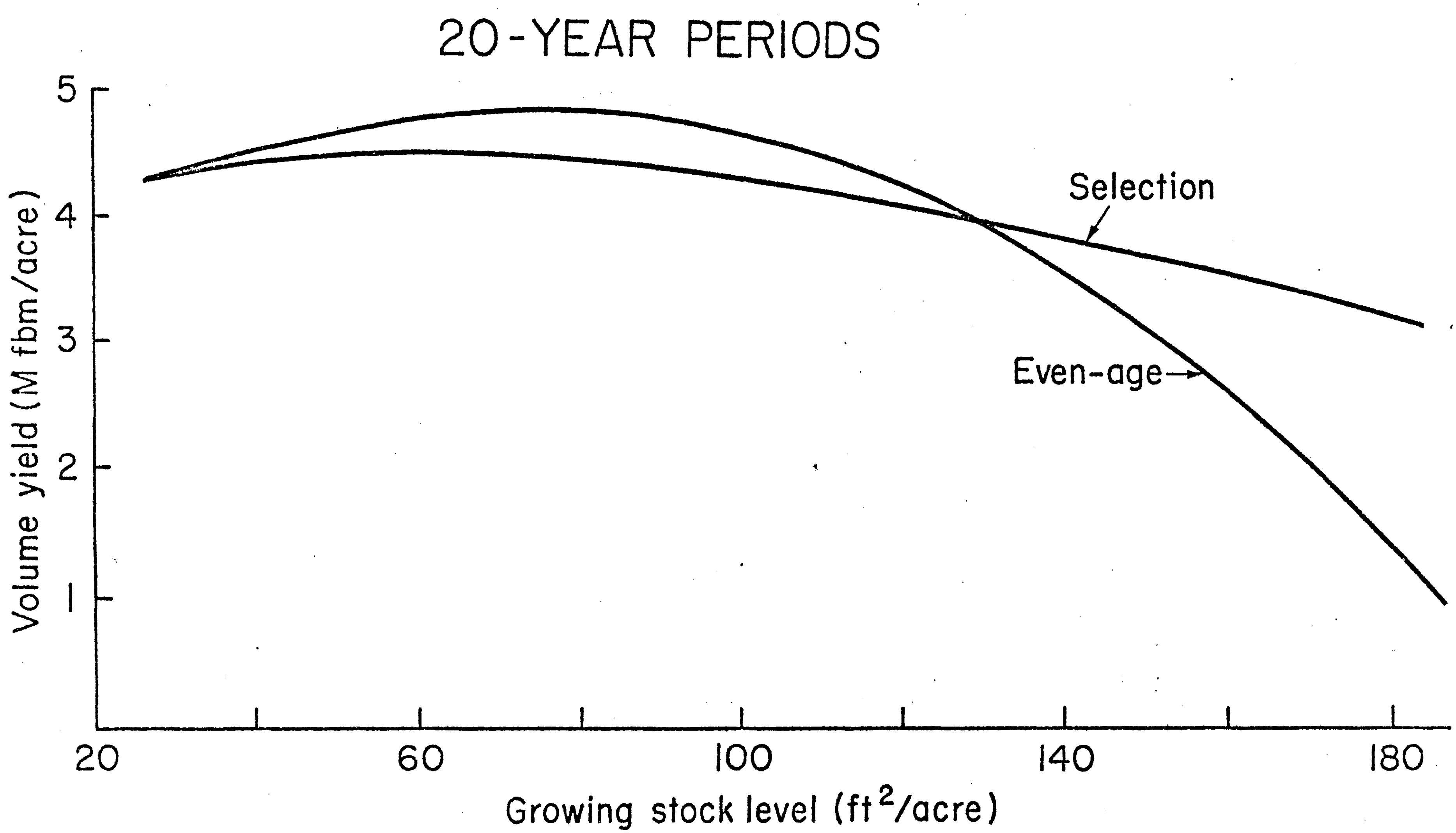


Figure 7.--Comparison of estimated 20-year volume cuts by growing stock levels for selection and even-aged southwestern ponderosa pine forests on site quality 1 lands under intensive management.

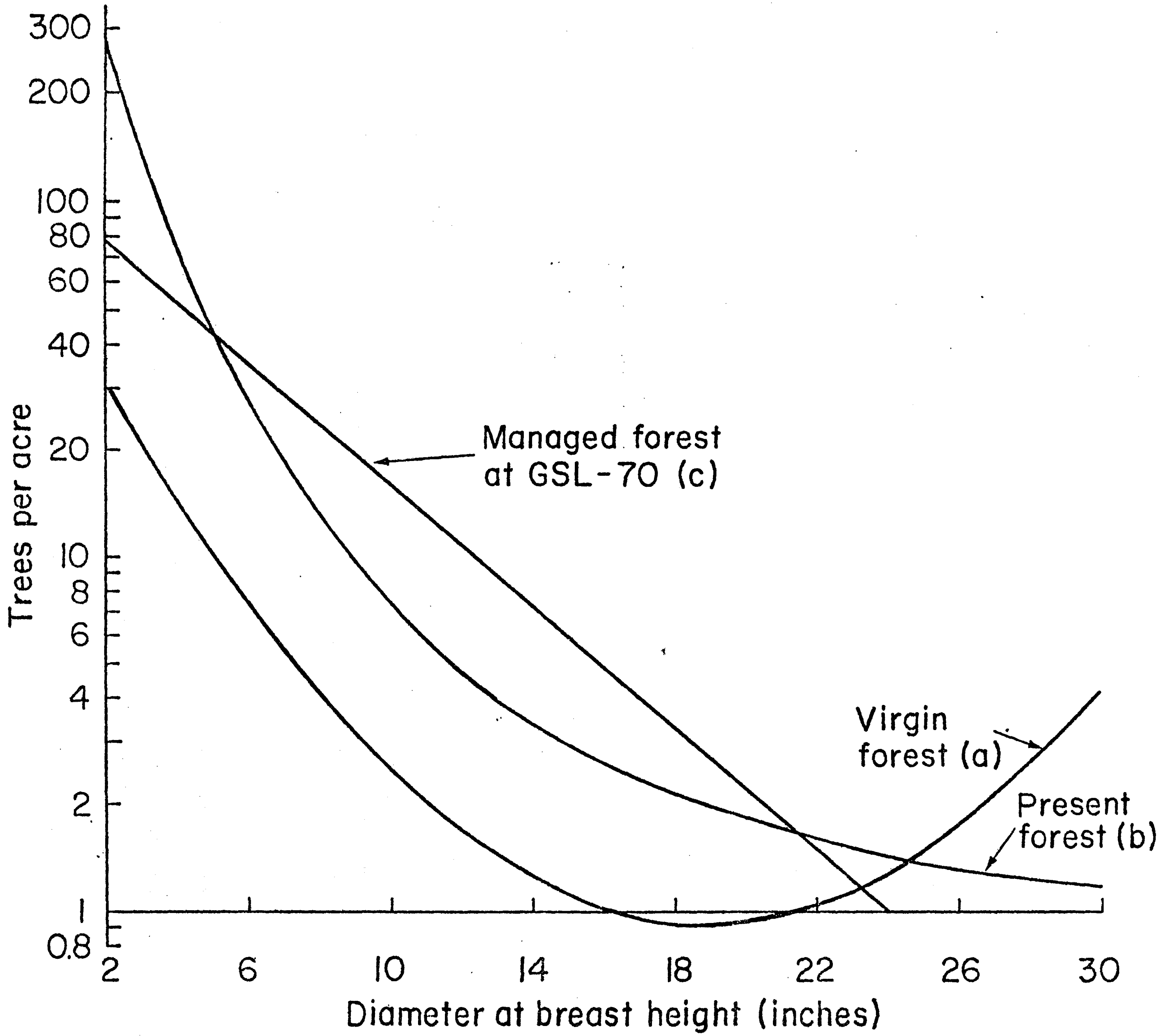


Figure 8.--Change in tree frequency distribution pattern for virgin to managed condition for a southwestern ponderosa pine selection forest at a GSL of 70.

trees. All this has been achieved through extensive management. If we continue the extensive management long into the future, our "new present" frequency may well pivot to show a severe shortage in all sawtimber sizes and a slightly greater excess of small trees.

To achieve the "managed-forest" in figure 8 will require intensification of our silvicultural practices. If we are to harvest on an even sustained-yield basis at the site potential, we will need to have our forest close to the normal stocked acre. This normal stocked acre does not necessarily need to be the GSL-70. A further evaluation of growth response in 1983 should sharpen up the results of the Taylor Woods study. An expansion of the GSL study into large size-class stands and on lands of different site quality will hasten the information-gathering process.

In conclusion, I would like to point out the things we must do to maximize our yields. We will need to intensify our management efforts along three main lines: (1) Reduce the time lost in reforesting logged and burned areas by taking prompt and effective action to get replacement stands started, (2) shorten the time required to get the replacement trees to commercial sizes by early precommercial thinning, and (3) maintain the desired growth rate throughout the tree's life by properly scheduled intermediate cuts.

STOCKING LEVELS --

GUIDES AND FIT TO MANAGEMENT PLAN

by

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STOCKING LEVELS --

GUIDES AND FIT TO MANAGEMENT PLAN

I was asked to discuss three things:

(1) Guides to evaluate present stocking and to determine appropriate residual stocking in second growth stands.

(2) How to get the proper stocking established in the woods.

(3) How to get the control of stocking tied in with the management plan.

I am going to change the order around and talk about the management aspects first.

I have changed the order of presentation because control of stand density is a silvicultural operation, and each silvicultural operation is specific to a particular stand at a particular time.

The dominant objective of our management is to achieve even-flow sustained yield from our forest. Because a silvicultural operation is specific to a specific stand, silviculture, per se, has nothing to do with sustained yield exeept by implication. We can't just set out to practice "good" silviculture and expect that sustained yield will automatically result.

That's where the management plan comes in. In the management plan we set up a schedule of cutting such that the forest will sooner or later attain a regulated structure and provide regular yields. The volume attainable under this schedule, during the management plan period, is the allowable cut.

Before I go on to show how the control of stand density fits into the management plan, I want to discuss briefly the determination of the allowable or the potential cut. It may seem that I am straying from my assigned topic, but bear with me and see where I go wrong.

It is generally accepted that we get sustained yield by cutting only the growth from a forest--assuming that we're somewhere close to a regulated structure. If the structure is too far from the regulated condition, we adjust the rate of cutting to achieve a regulated condition, then cut the growth.

Traditionally, we make periodic inventories, usually based on permanent sample plots, to determine volumes and acreages by types and species on the different sites. We have the same kind of information from previous inventories. We can add up or estimate what was cut or died in the meantime, and then calculate what the periodic growth has been. We project the appropriate rate of growth for the next period, and calculate an allowable cut on that basis.

In an oversimplified way this is how our annual cuts have traditionally been determined, at least in our second growth eastern hardwood forests. On a national basis, Forest Survey figures have been used in somewhat similar fashion to estimate volumes available to meet national needs for various future periods.

Am I still on relatively safe ground? OK, then I will proceed to get into trouble.

This traditional method doesn't work. In fact it can be very dangerous as markets improve to where actual cuts approach the full potential or allowable yield. The reason it does not work is because it can only monitor, but cannot predict, and certainly cannot control, changes in forest structure. These are the changes in age-class or size-class distribution that result from growth, mortality, and cutting.

I am not saying that periodic inventories based on permanent sample plots are not worthwhile. In fact they are very useful. They tell us with good accuracy what is actually in our forest today, and how the situation has changed since the last time. Such inventories are particularly valuable for keeping a handle on unusual mortality caused by fires, windstorms, epidemics, and natural or man-made catastrophes of one kind and another. And they provide at least some check on volume, cut, and growth projections determined by other methods.

My charge is that such inventories, and growth models based on them, are very dangerous as a basis for future volume, growth, and allowable cut projections.

I realize that this is a serious charge and people might worry about it except that I am so obviously crazy. But let me give you a quick example.

I spent some years in Ohio and became fairly well acquainted with its hardwood forests. In these forests it takes about 100 years to produce sawtimber yields on natural rotations, but you could do it in 60 or 70 years with periodic thinnings or improvement cuttings, if these are properly applied.

Regardless of the type of management or the rotation length, to achieve a sustained yield of sawtimber-size products, you would need to keep 20 to 25 percent of the forest area in seedlings and saplings, 35 to 40 percent in poletimber, and 35 to 45 percent in sawtimber.

In 1952, the Forest Survey in Ohio showed the following distribution of forest area by size-classes:

Ohio Forest Area, 1952 - - M acres (percent)

Sawtimber	Poletimber	Seedl. and Sapl.
2679 (50%)	1978 (36%)	739 (14%)

In trying to compare these figures with the next Forest Survey in 1967, we run into a problem caused by changes in classification standards between inventories. I was able to determine that on the basis of 1967 standards there would have been 607,000 fewer sawtimber acres in 1952, but I don't know how these would have been split between pole stands and sapling stands. I suspect that they would have been classified as seedling and sapling stands representing the results of heavy high-grading cuts that left sparse overstories of low-grade sawlogs over young stands of reproduction. If I throw those 607 M acres into the sapling stand class, in 1952 Ohio would have had an ideal distribution of acreage for sustained yield. To be conservative, let's split the acreage between saplings and poletimber.

Ohio Forest Area, 1952 adjusted --- M acres (percent)

Sawtimber	Poletimber	Seedl. and Sapl.
2072 (38+%)	2282 (42+%)	1042 (19+%)

This is not quite ideal, but close. If it were feasible for an entire state to go on sustained yield, in 1952 Ohio was in excellent shape to achieve it.

By 1967, Ohio had an increase of 933,000 acres of forest land. These were acres of old fields reverting to forest, and they had to be classified as seedling and sapling stands. I subtracted this amount from the 1967 s. and s. acreage to put the figures on the same basis as would have been used for planning in 1952. The results are:

Ohio Forest Area, 1967 adjusted -- M acres (percent)

Sawtimber	Poletimber	Seedl. and Sapl.
1948 (36%)	690 (13%)	2758 (51%)

Because of the scarcity of pole stands, by 1967 there was no way that Ohio could go directly on even-flow sustained yield without going through a lengthy period of reduced yields. This is because there is simply no way to get saplings to sawtimber size without going through a lengthy poletimber stage.

In the meantime, according to the Outlook for Timber in the United States (1973. USDA Forest Serv. Forest Res. Rept. 20, 367p.), sawtimber volume increased by 3 billion board feet.

If, in 1967, the sawtimber growth rate were used to project an allowable cut, the situation would rapidly get worse.

Another example of this phenomenon occurred in the early 1960's, in the oak forests in the southern part of old Region 9. They were just starting on the third round of improvement cuts on those forests and discovered that, in many stands, although the total volume was there, there weren't enough big trees to provide an operable cut.

I have other examples of this phenomenon, some based on personal experience, that I won't take your time on. But it may be instructive to examine why this phenomenon occurs.

It occurs because, in our management planning, we assume that a board foot is a board foot is a board foot, and therefore 8 or 10 small trees equal 1 big one.

For example, let's consider an oak stand that is growing 250 board feet per acre per year, based on periodic inventories of permanent sample plots. The sawtimber growth rate is determined by the rate of increase in size of all trees 11 inches and larger plus ingrowth into the 11 inch class. The 11 inch diameter represents our minimum merchantability specification for sawtimber.

Unfortunately, the market wants 18 to 24 inch trees, will readily accept 14 to 16 inch trees, but will take only a limited number smaller than that, and then only when forced. Therefore, to get an operable sale, we've got to have relatively more cut volume in big trees than in small ones. Now, we can cut all of that 250 board feet per acre by cutting 1 big tree. The stand grows that amount back again next year, but it spreads that growth in little chunks over a lot of small trees. And there are a great many more small trees than there are big ones. So as this process continues eventually we end up with all our sawtimber volume clustered in a narrow range of diameters just above the threshold of merchantability.

If I may coin a principle here, it is this: If there is a differential between the threshold diameter for merchantability and the minimum diameter the market will freely accept, both human nature and economics force us to cut proportionately heavier among the large diameters than we should. In doing so we change the structure of the forest, and therefore we change the distribution of growth among size classes.

Or, stated in more positive fashion, if we plan to grow products of a certain minimum size on an even-flow sustained yield basis, the periodic growth must be cut from each diameter class, down to and including the smallest diameter that we wish to regulate, in direct proportion to the amount that occurs there.

This is another way of saying that to achieve even-flow sustained yield, we must cut in such a way as to establish the desired forest structure, and thereafter cut in such a way as to maintain that structure. Which means that we must control the cutting not by the apparent forest growth rate in product classes, but according to the distribution of size classes that we want to regulate. This statement holds, of course, whether you plan to use even-aged or uneven-aged management.

As a tool for management planning, the traditional method of basing growth projections and allowable cuts on periodic inventories of permanent sample plots falls down in several respects. First, it doesn't tip you off as to what is happening to forest structure until after it has happened, by which time it may be too late. Second, it doesn't tell the manager what stands need to be treated, in what fashion, nor where the volume is located that is available for cutting.

These two objections might have been overcome when we were using uneven-aged management--if we had used it correctly, or could have used it correctly, to maintain the same regulated reverse J-shaped diameter distribution in each and every stand. But I see no way in the world of using it to control the rate of cutting in forests of even-aged stands in which the structures not only vary widely among stands but must also change constantly as the stands get older.

The only alternative I see is to go to individual stand data obtained from permanent and periodically updated stand records. During the next management plan period, a certain acreage of older stands will be regenerated, and will yield so much volume. A certain acreage of immature stands will be thinned. These will yield certain volumes depending on their stocking, their structure, and their composition. The management plan must set the amount of acreage to be treated in the various categories and indicate the appropriate treatment for each category. This is so that each stand will fit into its proper place in the hierarchy. I foresee that the stand records will be maintained by computer, programmed to update them periodically as needed. The updates will be corrected by fresh data gathered during stand examinations either prior to or just after treatment.

And now I've come full circle on the management planning. It is not just a case of fitting stand density control in with the management plan. Rather, the management plan is the instrument that must control stand density. But there's more to it than just the control of stand density; we must also control stand structure, and in many types, composition. And then we must get the control applied on the ground.

Since these operations must be performed on an individual stand basis, let's leave the subject of management planning for a while, and go to the first topic I was assigned: Guides for stocking levels. Because of my broad ignorance of most types, I will merely cover what we consider necessary in one specific type: the Allegheny hardwoods.

The forest type that we fefer to as the Allegheny hardwoods is, for a natural type, somewhat unnatural. It developed following the heavy cuttings that removed the beech-hemlock forest between about 1880 and 1930.

The Allegheny hardwoods consists of sugar maple, beech, and some remnant hemlock with varying admixtures of black cherry, red maple, yellow and sweet birch, white ash, yellow-poplar, cucumbertree, and half a dozen others.

The yellow-poplar is very intolerant and very fast growing. It is either dominant or absent. The black cherry is also intolerant and also fast growing, but not quite as much as yellow-poplar in either category. White ash is moderately intolerant and grows well, though not quite as fast as the cherry. The birches may be a little more tolerant than the ash, but still are usually classed as moderately intolerant. They grow slower than most of the other species and unless released are overwhelmed by about the middle of the rotation.

Red maple and cucumbertree are intermediate in tolerance, but both grow nearly as fast as the black cherry. Red maple responds well to release, at least in the intermediate and higher crown classes.

Sugar maple, beech, and hemlock are all very tolerant--sugar maple a little less so than the other two. All three grow very slowly when crowded or when under a canopy, but will survive for decades in the understory. All respond well to release at any age, and will grow very well until they again become crowded.

The intolerant species do not respond well to release, so they must be managed as dominants and codominants. When these intolerants are mature, which means a maximum age of 90 to 100 years (80 years is safer), the stand must be regenerated, or else we must be satisfied to manage the next stand as only sugar maple or beech, or a combination of the two, with a consequent loss of value, yield, and variety.

Thinnings must be heavy enough to get enough growth response from the sugar maple and beech for these species even to make merchantable pulpwood by the end of the rotation. This means also that thinnings must begin no later than a stand age of 55 to 60 years, preferably much earlier. But we dare not thin too heavily or we lose production and reduce the value of the final yield of the highly valuable intolerants.

We also have problems getting natural reproduction due largely to the termendous populations of whitetail deer, which range from 60 to 100 animals per square mile--pre-fawning. Unless we fence them out, which is both difficult (Did you ever try to chase all the deer out of a 25-acre area?) and very expensive, about the only way we can beat them is to overwhelm them with tree reproduction. When a stand is to be regenerated we must have enough advance reproduction, of a size and vigor to grow fast enough, over a large enough area, that the deer can't possibly eat it all within the time it takes for some of it to grow out of reach.

Since new germinants can't compete in the new stand with vigorous advance reproduction, this means that advance reproduction of all species desired in the new stand must be present when the regeneration cut is made. And in turn this requires that representatives of all species desired in the new stand be retained in the old stand right up to the time of the final harvest.

Even having advance reproduction isn't adequate to ensure that beech and sugar maple will have a place in the new stand. These species lag so far behind the new crop of intolerants that they must have a head start--as large saplings or small poles--if we want them to reach sawtimber size in the next stand. But we mustn't leave too many maple and beech saplings and poles or they seriously reduce the percentage of intolerants in the next stand and may retard the development of the ones that do make it.

So the Allegheny hardwood type poses some interesting silvicultural and management problems. But the purpose of the foregoing is not to impress you with our problems,--everybody has problems. What I want to get across is that, with us, the control of stand density is not just another moot academic exercise that would be nice to do if we had the time and money. For us, the need to control not only stand density but also stand structure and species composition is an unavoidable fact of life. Either we do it or we lose the type.

The control of stand density requires that there be some stocking standards to serve as the basis for adjustment. I set out to determine if our stands would reach some average maximum level of stocking, and if so, if it could be described mathematically.

I collected data on 106 natural undisturbed stands. Stand ages ranged from 18 to about 100 years; basal area from 75 to 175 square feet per acre. Altogether I had diameter tape measurements on about 125,000 trees. I used these data in multiple regression analysis to derive a tree-area ratio equation (Chisman, H. H. and Schumacher, F.S., 1940. On the tree-area ratio equation and certain of its applications. J. Forest 38: 311-317).

The best regression that I found is one based on six species groups. It is highly significant with a coefficient of multiple determination (R^2) of 99 1/2 percent, and a standard error of about 5 percent of the mean value of the plots.

The good precision of the tree-area ratio equation lends a pleasing amount of confidence that Allegheny hardwood stands do indeed achieve a maximum degree of crowding--or stocking--and that it can be described mathematically. The next problem was to find a way to display the relationship graphically based on stand parameters for which data could be easily obtained in the woods. I hoped that I could develop a chart similar to the one Gingrich developed for the oaks (Gingrich, Samuel F., 1967. Measuring and evaluating stocking and stand density in upland hardwood forests in the Central States. Forest Sci. 13: 38-53).

When I tried a regression using the same variables Gingrich did (basal area per acre plotted over number of trees per acre). My R^2 dropped to 34 percent, and the standard error increased to 16 percent.

Species composition was the major point of difference between my tree-area ratio equation and the stocking equation. The former was broken down into six species groups while the latter had all species lumped together. It seemed obvious that I had to find a way to account for composition.

To shorten a long story somewhat, I found that the percentage of stand basal area contributed by various species worked very well. And I could determine the percentages of basal area by species groups simply by tallying the groups separately during the wedge prism cruise.

However, I couldn't figure out any practical way to show more then two species groups on a two-dimensional stocking chart. The combination that gave the best accuracy (R^2 of 70%, standard error of 10%) was one group comprising cherry, ash, and yellow-poplar, which I shall hereafter designate as CAPs, and the other group containing all other species. Then I was able to prepare the stocking chart (figure 1). We have been field testing this guide for about three years, and so far it seems to be working very well.

The A-lines on the chart show the average maximum basal areas that will be attained by stands of given average diameters when certain percentages of the total basal area are contained in the CAP group. For example, a stand with an average diameter of 8 inches that contains no cherry, ash, or yellow-poplar will normally have about 114 square feet of basal area per acre. But if an 8-inch diameter stand has 80 percent of its basal area in CAPs, the basal area will be about 170 square feet per acre.

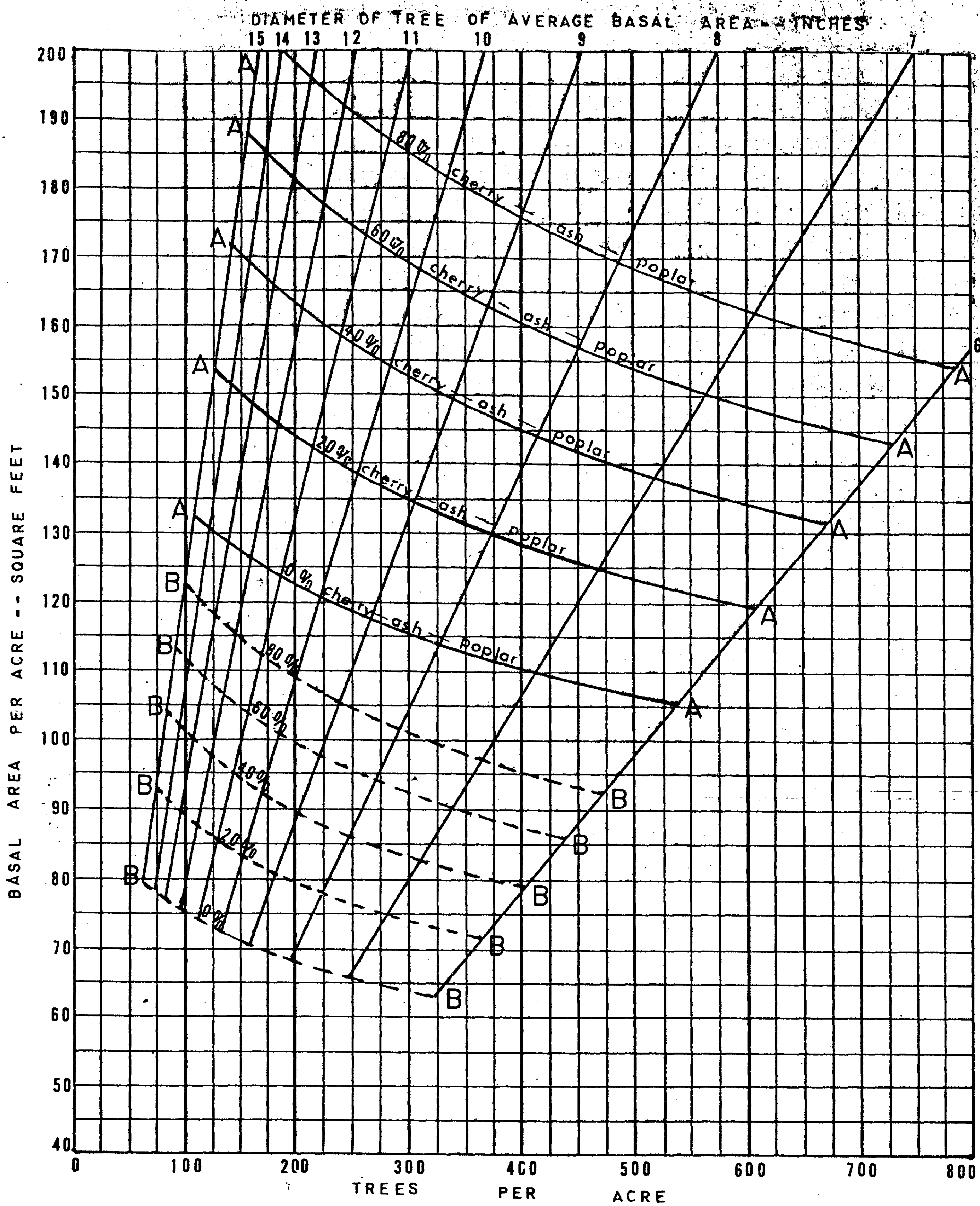


Figure 1. STOCKING GUIDE FOR ALLEGHENY HARDWOODS

The B-lines on the chart indicate our best guess at the minimum stocking necessary to use all the growing space, for stands of a given average diameter and percent CAPs. For the two stands mentioned above, the first should be thinned to leave at least 68 square feet per acre; the second to leave at least 102 square feet--if the average diameter and percent CAPs remains the same.

Using the stocking chart requires three pieces of data: the stand basal area, the percentage of the stand basal area contained on the CAP group, and the stand average diameter. These data are obtained during stand examination, using point samples for the basal area tally and 1/20-acre plots for the tree count (Figure 2).

The basal area tally is broken down by the two species groups and by four size classes based on ocular estimates of the diameters of the sample trees. Tallying by the two species groups reveals the percent CAPs; tallying by the four size classes gives a good quick picture of stand structure and is most helpful in revealing the size classes that must be favored to provide the final crop and, by elimination, the size classes that should be marked heavily to increase the stand diameter and push the stand along toward maturity.

Kane Exp. For.	Cherry-Maple	4/17/75
UNIT	TYPE OF SPECIES	DATE
Bl. II, Plot I, 10ac.	54	BSR
STAND, AREA	AGE	

BASAL AREA AND TREE TALLY

Sample Point Number	LARGE SAWT. 17+ CAPs	LARGE SAWT. 17+ Other	SMALL SAWT. 11–16 CAPs	SMALL SAWT. 11–16 Other	POLES 6–10 CAPs	POLES 6–10 Other	SAPLINGS 1–5 CAPs	SAPLINGS 1–5 Other	TREE COUNT 1/20 acre CAPs	TREE COUNT 1/20 acre Other
1			4		4	3	1	1	6	34
2	1		2	1	1	5		5	3	39
3			5		2	4		1	5	43
4			6		3	1		1	7	36
5			3	2	3	3			4	49
6			3		2	4		4	4	39
7			2		2	3	1	4	4	35
8	1		1	3	2	2		5	3	45
9			3	1	3	3			5	41
10			4	1	3	3		1	6	41
11										
12										
13										
14										
15										
TOTAL									47	402
TOTAL per acre	2		33	8	25	31	2	22	94	804
TOTAL per acre	2		41		56		24		898	

DISTRIBUTION OF THE CUT

	LARGE SAWT. CAPs	LARGE SAWT. Other	SMALL SAWT. CAPs	SMALL SAWT. Other	POLES CAPs	POLES Other	SAPLINGS CAPs	SAPLINGS Other
Cut Basal Area			6		11	6	2	13

STAND CALCULATIONS

	Trees per acre	Basal Area per acre TOTAL	Basal Area per acre CAPs	Basal Area per acre Other	Percent CAPs	Average Stand Diameter	Basal Area for 100 % Stocking	Stand Stocking Percent
ORIGINAL Stand	900	123	62	61	50	5.0	129	95
RESIDUAL Stand	390	85	43	42	50	6.4		60
CUT Stand	510	38	19	19				35

Figure 2. Stand tally sheet showing determination of basal area to cut by species groups.

When the basal area and tree tally are completed, the nature of the original stand can be calculated. The percent CAPs is determined by dividing the basal area in CAPs by the total basal area. The stand average diameter is determined from the stocking chart by using the total basal area per acre and the number of trees per acre. Using the stand average diameter and the percent CAPs, the chart is entered to find the A-level basal area that would be expected in a normally stocked stand. Dividing this basal area into the actual stand basal area shows the percent stocking in the original stand--that is, how well the present stand is stocked compared to the average maximum found in nature for a stand of the same average diameter and composition.

Next, the chart is used to determine the minimum residual stand to leave. The prescriber must decide three things: the percent stocking desired in the residual stand, the percent composition that he wants in the residual stand, and the probable average diameter of the residual stand. From our thinning and cutting method studies, we have developed guides to show the extent to which composition can be changed, and the direction and amount by which the average diameter will change for a particular kind of cutting. Then using the residual stand diameter and the residual percent CAPs, the prescriber can enter the stocking chart, using the B-level curves, to determine the minimum residual basal areas to leave. Subtracting the residual stand from the original shows the basal areas that may be cut by species groups. Then the prescriber distributes these basal areas by size classes to conform to his intended treatment. This distribution of the cut then becomes the marking prescription. The marking crew can compare the amount to be cut in each size class and species group with what the basal area and tree tally show to be present, and they can tell what proportions to mark in each class.

This is a very brief excursion through the procedure. A manuscript now in the publication process explains it thoroughly, and we fully expect it to be printed long before the turn of the century. So I will not go into more detail here except to note several significant points.

You will notice that there is more involved than simply the control of stand density. The procedure provides also for some regulation of both species composition and stand structure. Second, because emphasis is placed on determining the desired residual stand, the stand prescribers can operate on a higher professional level. They can exert some deliberate control in guiding the stand some known distance toward maturity, rather than let the stand push them around so to speak. Third, rather than just going out looking for merchantable trees to cut, the marking crew has definite guidelines as to the proportions of various size classes to look for. And finally, the good documentation permits checking the process at any level, in the field or in the office. It provides substantiation for decisions made or gives an objective basis for questioning them.

Initially the procedure may seem complex, but it has not proved to be so in practice. We have conducted 8 training sessions so far, and a two-day session has been adequate to get a good job done in the field. Ironically, most of the difficulty comes, and most of the training time has to be spent on, getting reliable stand data. Every forester automatically assumes he knows how to conduct a good stand cruise, but it seems that only about 60% do a consistently good job. And if you don't get adequate stand data, you're just kidding yourself.

Last spring we had a training session for District TMA's and stand examiners on the Allegheny National Forest. Then the Forest gave it a three month trial on each district, and have since adopted it for forest-wide use.

The next question we faced was whether the marking crews could mark according to the prescriptions.

In September we held a training session for the Allegheny's timber marking crews, using 100 percent inventoried plots to check stand tallies and residual stands after marking. Seven out of eight crews came within 5 percent of the desired residual stocking on the first try. The removals by species groups and size classes were very close to the prescriptions--within 1 or 2 square feet--except for the poletimber category in the "other" species group, where they tended to undermark by 3 to 6 square feet. At least part of this was probably due to the fact that our inventories included in the pole class some trees smaller than the merchantability standards for pulpwood. So probably they didn't find all the poles that we said were there.

All crews agreed, without any pressure or leading questions, that the prescriptions caused very little change in their normal procedure, and also that the prescriptions were very helpful in focusing their attention on the size classes that were to be marked heavily or that were to be favored and retained.

The jury is still out, of course, as to how well the marking will work on an operational basis, but the initial trial was promising.

So far I've discussed in general how the management plan should control the silviculture. Then I discussed stocking levels for Allegheny hardwood stands. Then I told you how we are going about the problem of getting physical control of stocking on the ground. Now I'd like to revert back to the first topic and explain more specifically how the whole business is dovetailed together.

Usually when we talk about even-aged management, we talk in terms of using it to control age-class distribution. This is convenient because it makes the concept easier to understand. Also, of course, if we regenerate a certain portion of the acreage each period--and get prompt reproduction--it goes a long way toward ensuring that we have a reasonable distribution of age-classes to work with.

But actually, we don't need to care about stand age, at least on the Allegheny Plateau. What we're really interested in is tree-size. We want to grow some standard volume of products of a certain size and species, in the shortest time feasible, with no loss of production in the meantime. When a stand has that volume in those products, the stand is mature regardless of its physical age. And the average stand diameter is a most useful guide to setting that point of maturity, or for estimating how far a given stand is from it.

Table 1 shows, for unmanaged stands, the increase of average stand diameter with age, and also the increase in average diameter of each species group with age. You will note that the average diameter of stands of average composition increases at the rate of about 1 1/8 inches every 10 years.

Dave Marquis and a graduate student have developed equations that do a good job of predicting stand volumes for a given average diameter, percent composition, and percent stocking. From this we should be able, with some economic analyses, to select an average stand diameter that represents maturity for any given intensity of management.

Now there are several ways to increase the average stand diameter faster than the norm of 1 1/8" per 10 years, or decrease it if desired. From our cutting experiments we can estimate reasonably well how much the average diameter will shift upward or downward as a result of cutting from above, cutting from below, or cutting in the middle. From our thinning studies, we can predict, a little tenuously yet I admit, how rapidly a stand will increase in average diameter and stocking after thinning to any particular level.

Table 1. Diameter of tree of average basal area (quadratic mean diameter) in fully stocked, even-aged, and previously unmanaged stands of Allegheny hardwoods.

Stand Age (years)	Yellow-poplar	Black Cherry	Pin Cherry	White Ash	Red Maple	Yellow and Sweet Birch	Sugar Maple	Beech	Entire Stand
	(Average diameter in inches)								
10									1.04
20	2.9	3.3	2.9		2.4	2.5	1.2	1.1	2.16
30	5.3	5.5	4.1	3.5	3.7	3.7	1.9	1.6	3.30
40	8.1	7.7	5.2	4.8	5.0	4.8	2.4	2.0	4.46
50	11.4	10.1	6.5	6.5	6.4	5.9	3.0	2.4	5.64
60	14.9	12.6		8.6	7.8	7.0	3.6	2.7	6.83
70		15.2		11.1	9.2	8.0	4.1	3.1	8.04
80		17.8		13.9	10.6	9.0	4.7	3.4	9.25
90		20.6		17.2	12.0	10.0	5.3	3.8	10.46
100		23.4		20.8	13.5	11.0	5.8	4.1	11.69
Number of stands	16	97	28	23	84	79	101	63	101
R^2	93%	79%	54%	92%	73%	77%	59%	52%	80%

(All regressions were highly significant. R^2 is the coefficient of determination--the percentage of the variation in mean diameter associated with stand age. Lowest ages and crosslines show limits of data).

For example a 50-year-old stand that is 100 percent stocked, with a composition of 40 percent CAPs, will have an average diameter of about 5.6 inches, and it will contain a certain volume. If this stand is left alone, in 10 years it will still be 100 percent stocked, with an average diameter of about 6.8 inches, a composition of 41 or 42 percent CAPs, and it will contain a certain amount more volume.

However, if that 50-year-old stand is thinned back to 60 percent stocking, and the marking removes about 2/3 of the cut basal area from below the mean diameter in each species group, the average diameter will increase to about 6.4 inches as a result of cutting, and during the next 10 years it will increase an additional 1.4 to 1.5 inches, instead of 1 1/8 inches, as a result of faster growth on individual trees after the thinning. In 10 years that stand will be between 72 and 75 percent stocked with an average diameter of 7.8 or 7.9 inches, and its volume will be a certain amount. In effect this stand will be very close to the characteristics of a 70-year-old stand even though it is only 60 years old, and it can be considered as a 70-year-old stand if the management plan is based on age-class distribution.

However it should be much more convenient to base the management plan on size classes. The stand average diameter is readily available from stand examination data, and the use of average diameter eliminates the practical difficulties of determining stand age in the field or trying to decide the proper stand age for stands containing more than one age class.

Within 10 years this kind of information should be available for most of the stands on the Allegheny National Forest. The data will be in the computer on a stand by stand basis, together with the programs for updating them up to 20 years or so at a stretch. And the next time the Allegheny TM staff prepares a management plan, they should be able to project a pretty realistic potential cut, by products, and know what specific stands the cut will come from. And they should be able to specify the silvicultural treatments needed for any particular stand, or for a proportionate area of any particular class of stands, to adjust their forest structure toward the desired fully-regulated goal.

There are some other fringe benefits on the horizon. The stocking chart that I showed you hasn't been published yet, but already I feel it is obsolescent. Rather than fool with the chart in the woods, the Allegheny is providing their stand examiners and prescribers with programmable pocket calculators--the kind that save the program even when the calculator is turned off. The calculators are pre-programmed with an equation that, once the appropriate stand data are plugged into it, gives the average stand diameter, percent CAPs and percent stocking, for the present stand and for any desired residual stand. This permits the prescriber to explore the effect of various cutting prescriptions, and the resulting distribution of cut basal areas, right in the field if he wishes.

These calculators are most convenient because we are no longer limited by the two-dimensional chart to only two species groups. The calculator will be able to handle as many species groups as can be readily tallied in the field. This will permit us to measure and control stocking levels more accurately and to develop better volume estimates. Further we plan to explore the possibility of equations that will tell the prescriber what volumes per acre he should obtain with any particular type of cut. This should help ensure operable sales, or conversely help prevent stands from being cut where overcutting would be necessary to provide an operable volume. And, of course, it should provide a much better basis for sales and project planning than now exists.

Now, having painted that rosy picture, I need to back down some ~~and~~ enter a disclaimer.

What I have described is not all available yet. The stocking guide seems to be working well and is being used. But we cannot yet predict with confidence what the 10 year growth will be in either stocking percent or average diameter, let alone volume. Our density studies are only four years old, and I have a great distrust of early growth data. Our data have been pleasingly consistent over the past three growing seasons though, and I'm getting increasingly optimistic. Dave Marquis's volume tables and equations have agreed remarkably well with determinations made by conventional means in several stands. But they need much more checking, and of course we have had no opportunity yet to check growth projections against actual stand growth.

So, we're not as far along as I may have implied. But I feel pretty confident that we're well on the way.

In summary, during this session I have tried to explain my ideas on why and how silvicultural prescriptions must be tied to management plans. I have explained why I distrust current methods of projecting growth and allowable cuts, and I have tried to explain how I think it must be done--namely, by building projections up from individual stand data. I have described our stocking guides: how they are used to evaluate stocking in present stands; how they are used as a tool to manipulatee not only stand stocking, but also stand structure and composition, along a deliberate course toward maturity; and how this control is applied on the ground. And I have looked into the crystal ball to show how, as our growth data accumulate, more accurate or detailed stocking guides might be used as a tool, together with other stand data, to estimate present stand volumes, potential cut volumes, and growth projections following treatment.

APPENDIX I

USE OF STOCKING GUIDE FOR ALLEGHENY HARDWOODS

(Determining initial stocking)

1. Decide on stand boundaries, and plan cruise route.

2. Make stand inventory:

   a. Wedge prism cruise (10 plots minimum) for basal area, tallying sample cruise by two species groups and four size classes (estimate size class by eye).

   b. Tree count of all trees 1.0 inch dbh + on 1/20 acre plots (26 1/3 ft. radius) using same plot centers as used for wedge prism cruise.

3. Summarize columns on tally form to determine:

   a. BA/acre in CAPs and "Others" for each size class.

   b. BA/acre in CAPs and "Others" (totals by species groups)

   c. Total BA-acre

   d. Number of trees per acre.

4. Determine percent CAPs: $\frac{\text{BA in CAPs}}{\text{Total BA}}$

5. Determine average stand diameter from chart. (Use total BA/acre and trees per acre).

6. Determine BA for 100% stocking. (Use average stand diameter and percent CAPs--A curves).

7. Determine percent stocking in stand: $\frac{\text{Stand BA}}{\text{A-level BA}}$

8. Determine size class (or classes) for future management. (What size class or classes contain bulk of basal area? Generally favor larger size classes.)

APPENDIX II

USE OF STOCKING GUIDE FOR ALLEGHENY HARDWOODS

(Determining desired residual basal area)

1. Decide on percent stocking desired in residual stand.

2. Decide on percent CAPs desired in residual stand.

3. Estimate average diameter of residual stand.

4. Determine BA/Acre needed in residual stand (from chart).
    a. If 60% stocking: use estimated residual average diameter and residual % CAPs, get basal area from B curves.
    b. If other than 60% stocking: use estimated residual average diameter and % CAPs; determine A-level basal area; multiply A-level basal area by stocking percent desired.

5. Determine number of trees per acre in residual stand. (Use residual basal area and average diameter of residual stand.)

6. Determine BA in CAPs in residual stand. (Multiply residual BA/Acre by % CAPs desired.)

7. Determine "Other" BA/Acre. (Subtract CAP BA/Ac. from Total BA.)

8. Determine "cut" stand. (Subtract residual stand from original stand

9. Distribute cut BA in CAPs among CAP size classes. (Assign 2/3 of cut basal area to the two smaller size classes.)

10. Distribute cut BA in "Others" among "Other" size classes. (Assign 2/3 of cut basal area to the two smaller size classes.)

11. For each species-size class, compare cut BA with original BA to determine proportion of trees to mark.

F-J-X

NATIONAL SILVICULTURE WORKSHOP
EUGENE, OREGON
OCTOBER 13-15, 1976

PRECOMMERCIAL THINNING - THE WORTH

BY: WALTER FOX R-8
EDWARD A. SMITH R-8
RICHARD E. LOWREY SOFES

A major question being asked in Region 8 by our Rangers concerns the costs and benefits of precommerical thinning. Much has been written and published on the subject but there is a real dearth of information for actual costs and benefits in dollars. Since beginning the development of this material which I'll be discussing, I've read much of the precommercial thinning literature concerning the southeast and I think one statement I found summarizes all the literature. That is, minimal gains in volume production justify a moderate precommerical thinning investment, particulary if the thinning is done at an early age. But, this means very little to the Ranger who is trying to set priorities for his management dollars. Nor does it help him make decisions between broadcast direct seeding and planting alternatives. And, he needs a simplified methodology he can use - he does not have access to or the knowledge to use the sophisticated computer programs such as Multiploy.

Where does this lead us? When the announcement was made concerning this Silviculture Workshop, I volunteered Bill Mann and I to present a paper on the costs and benefits of precommerical thinning. Of course, this was after consultation with Bill. So, since Bill was physically crippled with a leg injury and I am mentally crippled (just ask Bill Tuttle) I journeyed to Alexandria with high hopes the two cripples could get it all together. At the end of a week, I arrived at a conclusion that supports my statement of "mentally crippled" - I should have never volunteered and I suspect Bill Mann agreed. However, Bill Mann is the greatest - he suffered with my ignorance for a week. From this week with the Southern Station folks, I got acquainted with Dick Lohrey and the precommercial thinning studies he has underway in Louisiana. FS-SO-1102-3.07 (Problem 3) is, "Pre-commercial Thinning In a Direct-Seeded Loblolly Pine Stand" in Louisiana. The purpose of the study is to determine the effects of various methods and intensities of precommercial thinning in a dense direct-seeded loblolly pine (Pinus taeda L.) stand. Nine treatments under test include four intensities of selective thinning, three strip thinnings, a combination strip plus selective thinning, and an unthinned check. Thinning treatments were installed at age 3 years. Data on this study is published through age 11 (SO Rsearch Note 139). Data through age 16, although not yet published, is complete and is used as a base for this discussion, thanks to Dick.

For the purposes of this discussion, we selected only two of the thinning treatments installed by Dick and rounded site index to 90--

--Treatment 3 - trees were removed on strips 7.5 feet wide leaving a swath of trees 3.5 feet wide. At age 16, there were 1,347 trees per acre. This thinning closely resembles the brushcutter (Hydro Ax, Kershaw Klearway, Bombardier Muskeg) thinning we've applied to thousands of acres in Region 8. These brushcutters cut a swath 8 feet wide and we try to leave strips 1 - 3 feet wide, resulting in a residual stocking of 700 - 1500 stems per acre.

--Treatment 5 - trees thinned to 750 of tallest best-formed, well-spaced trees per acre. At age 16 these were 690 trees left. We often arrive at this stocking level as just mentioned by use of the brushcutters. Occasionally we hand thin the brushcutter leave strips of 1500 per acre down to similar densities. Then too, 690 trees per acre often resembles final stocking from planting.

The check which of course was not thinned had slightly in excess of 5,000 stems/acre at age 3 years and 2,340 stems at age 16. In essence then, I'm comparing 3 stocking levels - 690 trees (treatment 5), 1,347 trees (Treatment 3) and 2,340 trees in the check, at age 16.

Our first step was to determine yields from these 3 stands and the ages at which these yields could be obtained. My compatriot, Ed Smith developed the yield data we used so any questions concerning those should be directed to him.

Since the Study is in Louisiana, we used stumpage prices and thinning costs applicable on the Kisatchie National Forest. The cost of brushcutter precommerical thinning in a 3-year old loblolly stand in Louisiana can be in the range of $8 per acre. Thus, this is the figure we used for the thinning in treatment 3. For treatment 5, we assumed a cost of $40 per acre, figuring that brushcutter thinning would be done, followed by hand thinning in the leave strips. This is not the thinning method used by Lohrey but it is a practical method for arriving at much the same result and can be done for $30 - $40 per acre.

Stumpage prices used ranged from $4 - $8 per cord for pulpwood and from $100 - $125 per MBF for sawtimber. These price ranges reflect differences in size of material. Attachment 1 shows the yields at the time of each commercial thinning. The first thinning was prescribed for the earliest age at which it was practical to thin and this is a function of size of material (5" DBH class minimum) and density (volume cut per acre). Attachment 2 illustrates total projected yield through the rotation in both total value and total volume for the check and the 2 treatments.

Using the costs and prices just mentioned, we determine net present worth (NPW) of the yields at each stand entry age by simply using Present Worth interest table factors for 6½% and 10% and a calculator.

Why do it this way when computer programs are available? Because the Ranger doesn't have a computer terminal and the time involved with this method was about 1 hour. We compared both treatment 3 and 5 to the untreated check at both interest rates. Results are shown on Attachment 3. When we found out we had a positive NPW for both treatments at 6½% we calculated yield volumes which would result from the same treatments on site 80 and 70 and found a positive NPW for both sites. Then, we applied a 10% discount rate to site 90 treatments including the check and again found a positive NPW. Treatment 3 on sites 80 and 70 also provides a positive NPW. However, while treatment 5 on site 90 resulted in a positive NPW, sites 80 and 70 did not. Results are shown in attachment 3. From this data it is simple to rank the alternatives. In essence, the Ranger can utilize this method if, yeild data is available.

Of course, a more sophisticated approach is available through INVEST III. We used the fast version of this to confirm the manual data we developed at the 10% rate for site 90. As most of you know, INVEST III can furnish other comparision data in addition to NPW. It provides benefit-cost ratios, annual equivalent value of NPW, internal rate of return and ranks the projects by internal rate of return. In the examples used here we found that treatment 5 provided an internal rate of return of 11.99% while the IRR for treatment 3 is 15.91%.

You real experts are probably laughing at the over simplification of what we've done. Sure, there are a great many other inputs needed and we can move ahead from this point - the only way to go is up. We in Region 8 now have a method for quantifying wildlife benefits (in dollars) resulting from silvicultural treatments and I have a copy of an illustration of this if anyone would like to discuss it later. Time did not permit the use of this method for this discussion. We're convinced that these wildlife benefits will put many of our otherwise mariginal projects in the plus column of the ledger.

In closing, I apologize to Bill Mann and Dick Lohrey for not giving them a chance to review this paper. Perhaps, they'll forgive me when they learn that my boss, Bill Tuttle didn't get to see it either.

Thanks for listening and if you have any comments, fire away.

ATTACHMENT 1

Yield Volumes at Age of Entry

Check

Age	25	6.2 cords	Commercial Thinning
	35	11.3 cords	Commercial Thinning
	45	3.5 MBF	Commercial Thinning
	55	25.4 MBF	Clearcut

Treatment 3

Age	20	4.4 cords	Commercial Thinning
	25	6.5 cords	Commercial Thinning
	35	3.3 MBF	Commercial Thinning
	45	4.1 MBF	Commercial Thinning
	55	25.2 MBF	Clearcut

Treatment 5

Age	16	7.3 cords	Commercial Thinning
	25	12.0 cords	Commercial Thinning
	35	4.3 MBF	Commercial Thinning
	45	4.7 MBF	Commercial Thinning
	55	27.5 MBF	Clearcut

Ave. D.B.H. of trees at age 55

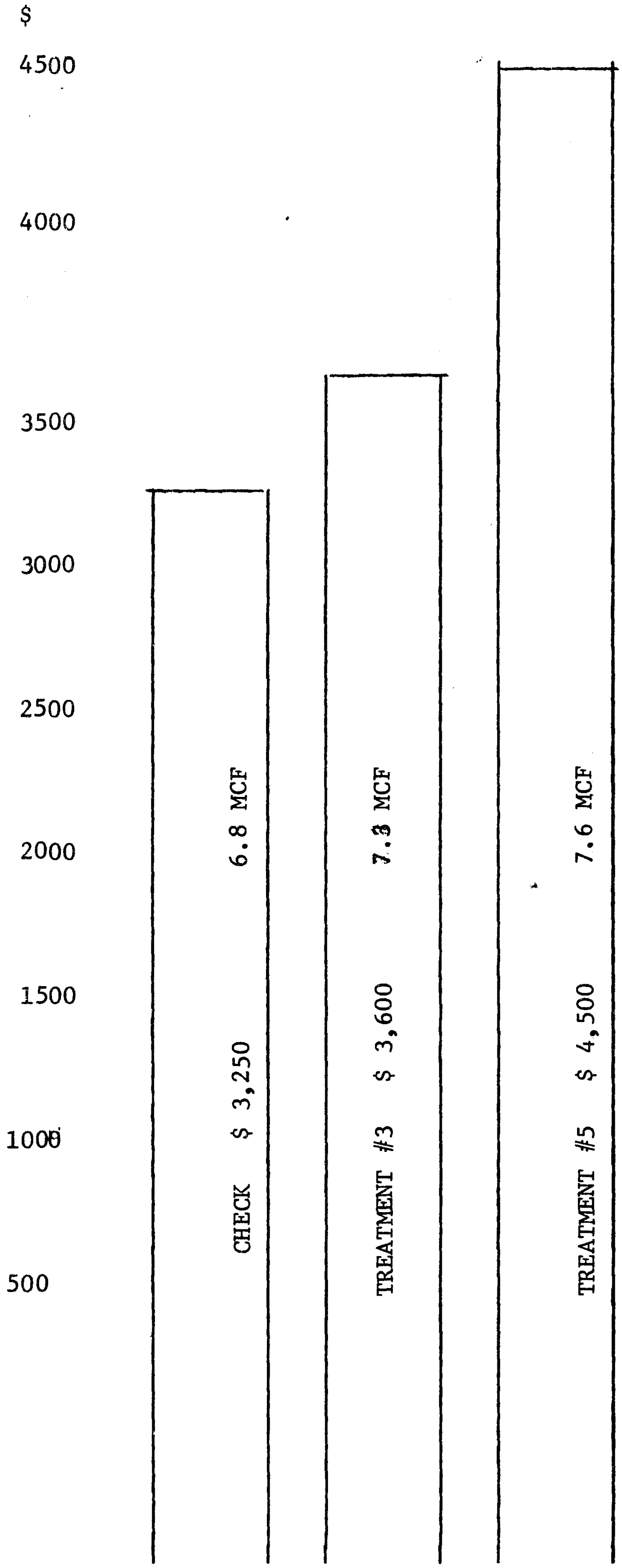
Check 14.2 inches

Treat 3 14.8"

Treat 5 21.0"

Loblolly pine - site index 90

ATTACHMENT 2



Bars reflect total value of harvested products at age 55 (60 year rotation)

Loblolly pine - site index 90

ATTACHMENT 3

6½% Rate
Net Present Worth by sites

	90	80	70
Check	$122	$100	$ 82
Treatment 3	155	126	102
Treatment 5	182	143	111

10% Rate (OMB)
Net Present Worth by sites

	90	80	70
Check	$24	$20	$16
Treatment 3	32	25	20
Treatment 5	25	15*	7*

* NPW LESS THAN CHECK

Douglas-fir - What One Specific Thinning Requires

There are a number of items that we should be aware of before prescribing any silvicultural activity in a Douglas-fir stand. First of all the prescriber should know the general and specific land management objectives for the area. This information comes from both land use and resource management plans.

It was not too long ago that we were unconcerned with the grazing potential in most of the Douglas-fir subregion but recently sheep and other livestock are being used to reduce vegetative competition by utilizing, at a profit the grass, forbes, and brush during the regeneration phase of stand management. Our present emphasis on early precommercial thinning may prolong this grazing opportunity.

The requirement for forage, thermal cover, and visual cover for wildlife influences stand density at various ages on areas that have been identified as critical wildlife game range, especially winter game range.

The proximity of a stand to class one thru four streams may also modify treatment.

A major influence on our prescriptions is the combination of visual resource management inventory and the management decisions that are being made upon how to manage those lands that have been inventoried under the different categories. We will be talking to you more about that subject on Friday morning.

The influences imposed by other than timber management plans are generally less restricti~~on~~ve on thinning opportunities than on regeneration harvests but must be considered in planning an entry into any stand.

The soils inventory as it indicates potential for mass failure, surface erosion, compactability, productivity, moisture holding capacity, etc., limits or influences our flexibility in type of equipment, potential for access, and sometimes the frequency or timing of entries.

The timber management plan establishes broad acreage targets for different silvicultural opportunity categories. Jack Usher discussed the establishment of these targets in some detail this morning. Timber management planning is both a short and long range process. Estimates of utilization standards and marketability of products are <u>important</u> to long range decisions and are <u>critical</u> to project planning. I mention this because along with targets set in Timber Management Plans is the need to establish priorities. In order to maximize the gains in wood fiber production, commercial thinning entries in fully stocked stands should be programed at the earliest age that excess trees are marketable; a combination of access, logging costs, and product value. The setting of priorities implies the availability of information in sufficient detail to evaluate one stand against another within a silvicultural opportunity class.

No entry into a timber stand should be anticipated without an adequate silvicultural prescription. A prescription should place major emphasis on the residual stand that is anticipated subsequent to the activity, especially for a thinning entry, either precommercial or commercial.

The prescription should include objectives for the anticipated stand treatment, an adequate description of the stand's history, the stand characteristics and condition, biologically acceptable alternative treatments and sufficient detail about the recommended treatment to accurately describe crop trees to be retained and the excess trees to be harvested. Finally what do you expect the stand to be at the next entry.

We have a timber stand examination process in this Region which I will display and discuss with slides. It is probably quite similar to the technique used by several other Regions.


VALLEY-
THRU ROUTE
FOR SILV
CONF BUS PLOT
TOUR #10
Plate #4-10
represent area
seen on tour
stop.

OT MUCH OVERSTOCKED

USDA - Forest Service

Typed DME 78-03

STAND EXAMINATION COVER CARD

TRI SYSTEM IDENTIFICATION	CARD TYPE I DATA (1)
1. Compartment Name Gobel	15. Forest No. (2-3) 18
2. Compt. No. 8305	16. Ranger Dist. No. (4-5) 05
3. Cell Nos. 6583, 8583	17. Exam No. (6-8) 127
4. X-Ref Compt. Names	18. Site Tree Data: Species / Age / Ht.: 205 / 63 / 153; 205 / 73 / 120; 205 / 53 / 115
5. X-Ref Nos.	19. Yield Table Species (9-11) 205
	20. Site Index (12-13) 140
6. X-Ref Cell Nos.	21. Stocking Level Curve Species (14-16) 202; Site Class (17) 2
7. Posting Record: Period Examined; Accomp. Rptd.; Posted; Microfilmed	22. BAF Factor (18-19) 40
	23. Fixed Area Plot (20-22) 1/ 000 Ac.
	24. No. of points (23-25) 010
	25. Maturity Age Group (26-27) 10
8. Area Location Lapwood Springs	26. Date exam (28-29) Mo. 07; (30-31) Yr. 77

AREA CONDITION DATA	
9. Percent slope 25	27. Remarks: Recommend that this stand be left to grow - (OVER)
10. Exposure S	
11. Site condition Good - Loam - Excellent drainage	
12. Stem distrib.	
13. Ground Veg. Oregon grape, Vine maple - Salmonberry	
14. Fuel Type 6	28. Examiner Hunter, McAtee

Form R6-2410-312 (1/71)

Vegetation - Alder
Ocean spray
Salal
Pacific Madrone
Bigleaf Maple
Hazel Brush
Rhododendron

Wildlife - Many Elk game trails - This is a winter range area with a minor salt lick - with the present fresh Elk sign, this may be a calving area.

The trees in plot #5 were short

Near plot #8 there is one large old growth

STAND ANALYSIS TABLES
SX SYSTEM VERSION 3

COMPARTMENT NAME. SOBEL MT — COMP. NO. 8306 — CELL NOS. 6583,8833

X-REP COMP. NOS. — X-REP CELL NOS.

WILLAMETTE NATIONAL FOREST — RANGER DISTRICT 8 — EXAM NO. 127 — RUN DATE 09/08/73

TABLE A. STAND EXAMINATION SUMMARY

** STAND CONSTANTS **

CROP AGE	95
SITE INDEX	160
STOCKING LEVEL CURVE	
SPECIES	205
SITE CLASS	2
BASAL AREA FACTOR	40
FIXED PLOT AREA	NONE TAKEN
NUMBER OF POINTS	10

** STAND CHARACTERISTICS **

FOREST TYPE (CROP TREES)	205
STAND AGE (CROP TREES)	65
PERCENT STOCKING	
CROP TREES	92.01
EXCESS TREES	14.59
MATURE TREES	0
CULL TREES	4.74
ALL LIVE TREES	111.34

** DATES **

EXAM DATE	7/73
TAPE SCRATCH DATE	

** POPULATION PARAMETER ESTIMATES **

	GROSS VOLUME/ACRE		BASAL AREA/ACRE(5.0+) VARIABLE PLOTS			TREES PER ACRE VARIABLE PLOTS			TREES PER ACRE FIXED PLOT		
	BF	CF	SQ.FT.	CV PCT.	SE PCT.	NO.	CV PCT.	SE PCT.	NO.	CV PCT.	SE PCT.
MATURE	0	0	0	0	0	0	0	0	0	0	0
IMMATURE	31791	7722.3	196.0	22	7.1	123.87	86	27.2	0	0	0
(CROP)	29353	6976.5	173.7			89.99			0		
(EXCESS)	2438	745.8	22.3			33.88			0		
LIVE SOUND	31791	7722.3	196.0	22	7.1	123.87	86	27.2	0	0	0

* * SAMPLE ESTIMATE QUALIFICATION * *

1. SIMPLE RANDOM SAMPLE ( )
2. SYSTEMATIC SAMPLE ( )
3. SUBJECTIVE SAMPLE (✓)

TREATMENT(S) PRESCRIBED FOR THIS STAND- NTM

NH1: NOT MUCH OVERSTOCKED

ALT: NTM: YOUNG AGE

DATE- 12/73 BY- [signature]
NEXT EXAM SHOULD BE GIVEN-

* * * * TRI SYSTEM TREE DATA * * * *

	TA CL	NA SP	MI SP	AVD BH	TPA	DIST	BA/TA	MBF/A	YEAR D	NIST	DAHAG
M											
C	DF		19	90			173	29	1910		
E	DF		16	34			22	3	1910		
X											
D											

124 196 32

COMPARTMENT NAME. GOBEL MT   COMP. NO. 8306   CELL NOS. 6583,8823

X-REF COMP. NOS.   X-REF CELL NOS.

WILLAMETTE NATIONAL FOREST   RANGER DISTRICT 6   EXAM NO. 127   RUN DATE 09/08/73

TABLE B. ESTIMATED NUMBER OF TREES PER ACRE ON EACH POINT BY TREE CLASS

POINT NO	CROP TPA	EXCESS TPA	MATURE TPA	LIVE SOUND TPA	CULL TPA	ALL LIVE TPA	SALVABLE DEAD TPA	UNMERCH DEAD TPA
1	5.41	3.18	0	8.59	0	8.59	0	0
2	5.41	.92	0	6.33	0	6.33	0	0
3	8.03	0	0	8.03	0	8.03	0	0
4	10.04	.29	0	10.33	0	10.33	0	0
5	4.31	0	0	4.31	11.07	15.38	0	0
6	7.43	0	0	7.43	0	7.43	0	0
7	4.23	1.72	0	5.95	0	5.95	0	0
8	18.60	21.82	0	40.42	0	40.42	0	0
9	11.10	5.95	0	17.05	0	17.05	0	0
10	15.43	0	0	15.43	0	15.43	0	0
SUMS	89.99	33.88	0	123.87	11.07	134.94	0	0

TABLE C. PERCENT STOCKING ON EACH POINT BY TREE CLASS

POINT NO	* CROP *1*	PERCENT *2*	CATAGORIES *3*	TOTAL *	EXCESS PERCENT	MATURE PERCENT	CULL PERCENT	ALL LIVE PERCENT
1	0	10.00	0	10.00	3.29	0	0	13.29
2	0	10.00	0	10.00	1.30	0	0	11.30
3	0	8.43	0	8.43	0	0	0	8.43
4	2.00	8.00	0	10.00	.20	0	0	10.20
5	6.69	0	0	6.69	0	0	4.74	11.43
6	4.44	3.98	0	8.42	0	0	0	8.42
7	1.88	8.12	0	10.00	1.51	0	0	11.51
8	0	10.00	0	10.00	5.52	0	0	15.52
9	0	10.00	0	10.00	2.77	0	0	12.77
10	2.00	6.47	0	8.47	0	0	0	8.47
SUMS	17.01	75.00	0	92.01	14.59	0	4.74	111.34

FULL CROP TREE STOCKING PER POINT (100.0 / NO.PTS.) = 10.00

COMPARTMENT NAME. GOBEL MT COMP. NO. 8306 CELL NOS. 6583, 8883

WILLAMETTE NATIONAL FOREST RANGER DISTRICT 8 EXAM NO. 127 RUN DATE 09/08/73 X-REF COMP. NOS. X-REF CELL NOS.

TABLE D. NUMBER OF TREES AND GROSS VOLUME PER ACRE BY CLASS AND TREE CLASS

DBH	CROP TREES			EXCESS TREES			MATURE TREES			LIVE SOUND TREES			CULL	LIVE	SALV DEAD		UDE
CLASS	TREES	BD FT	CU FT	TREES	BD FT	CU FT	TREES	BD FT	CU FT	TREES	BD FT	CU FT	TREES	TREES	TREES	BD FT	TR
S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
6	0	0	0	20.37	0	65.2	0	0	0	20.37	0	65.2	0	20.37	0	0	
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
10	0	0	0	0	0	0	0	0	0	0	0	0	7.33	7.33	0	0	
12	8.73	506	214.8	6.54	379	160.8	0	0	0	15.27	885	375.6	0	15.27	0	0	
14	25.32	2660	931.5	.86	91	31.7	0	0	0	26.18	2751	963.2	3.74	29.92	0	0	
16	16.37	2902	867.3	.29	50	14.7	0	0	0	17.16	2952	882.0	0	17.16	0	0	
18	9.58	2472	655.6	3.98	1026	272.0	0	0	0	13.56	3498	927.6	0	13.56	0	0	
20	5.49	1792	483.0	0	0	0	0	0	0	5.49	1992	483.0	0	5.49	0	0	
22	7.28	3548	801.8	1.84	892	201.4	0	0	0	9.12	4440	1003.2	0	9.12	0	0	
24	5.08	3200	683.6	0	0	0	0	0	0	5.08	3200	683.6	0	5.08	0	0	
26	4.32	3420	698.0	0	0	0	0	0	0	4.32	3420	698.0	0	4.32	0	0	
28	2.82	2745	538.5	0	0	0	0	0	0	2.82	2745	538.5	0	2.82	0	0	
30	1.62	1900	361.2	0	0	0	0	0	0	1.62	1900	361.2	0	1.62	0	0	
32	2.88	4008	741.2	0	0	0	0	0	0	2.88	4008	741.2	0	2.88	0	0	
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
78+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
SUMS																	
TREES	89.99			33.88			0			123.87			11.07	134.94	0		
BD FT		29353			2438			0			31791					0	
CU FT			6976.5			745.8			0			7722.3					
BASAL AREA			173.7			22.3			0			196.0	8.0	204.0			

VARIABLE PLOT

COMPARTMENT NAME. GOBEL NT COMP. NO. 0306 CELL NOS. 6503, 8803
X-REF COMP. NOS. X-REF CELL NOS.
WILLAMETTE NATIONAL FOREST RANGER DISTRICT 2 EXAM NO. 127 RUN DATE 09/08/73

TABLE E. NUMBER OF TREES AND GROSS VOLUME PER ACRE BY SPECIES, TREE CLASS AND TREE SIZE CLASS

SIZE CLASS	SPECIES	CROP TREES			EXCESS TREES			MATURE TREES			LIVE SOUND TREES			CULL	SALV DEAD
		TREES	BD FT	CU FT	TREES	BD FT	CU FT	TREES	BD FT	CU FT	TREES	BD FT	CU FT	TREES	BD FT
5.0 - 8.9	205	0	0	0	20.37	0	65.2	0	0	0	20.37	0	65.2	0	0
9.0 - 10.9	361	0	0	0	0	0	0	0	0	0	0	0	0	7.33	0
11. - 20.9	205	65.99	10532	3152.2	11.67	1546	479.2	0	0	0	77.66	12078	3631.4	0	0
	312	0	0	0	0	0	0	0	0	0	0	0	0	3.74	0
21. +	205	24.00	18821	3824.3	1.84	892	201.4	0	0	0	25.84	19713	4025.7	0	0
SUMS - TREES		89.99			33.88			0			123.87			11.07	
SUMS - BD FT			29353			2438			0			31791			0
SUMS - CU FT				6976.5			745.8			0			7722.3		

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COMPARTMENT NAME. GOBEL MT   COMP. NO. 8006   CELL NOS. 6583, 8783

WILLAMETTE NATIONAL FOREST   RANGER DISTRICT 8   EXAM NO. 127   RUN DATE 09/08/73   X-REF COMP. NOS.   X-REF CELL NOS.

TABLE 7. AVERAGE DBH (INCHES) BY TREE CLASS FOR TOTAL STAND AND SELECTED STAND PARTS

	TOTAL STAND	TREES 6 INCHES AND LARGER	TREES 8 INCHES AND LARGER	TREES 10 INCHES AND LARGER	TREES 12 INCHES AND LARGER	TREES 14 INCHES AND LARGER	TREES 16 INCHES AND LARGER
CROP TREES	18.8	18.8	18.8	18.8	18.8	19.4	21.4
EXCESS TREES	11.0	11.0	15.8	15.8	15.8	16.6	19.2
MATURE TREES	0	0	0	0	0	0	0
LIVE SOUND TREES	17.0	17.0	18.4	18.4	18.4	19.3	21.2

	TREES 6 INCHES AND SMALLER	TREES 8 INCHES AND SMALLER	TREES 10 INCHES AND SMALLER	TREES 12 INCHES AND SMALLER	TREES 14 INCHES AND SMALLER	TREES 16 INCHES AND SMALLER
CROP TREES	0	0	0	12.0	13.5	14.4
EXCESS TREES	6.0	6.0	6.0	7.9	8.1	8.3
MATURE TREES	0	0	0	0	0	0
LIVE SOUND TREES	6.0	6.0	6.0	9.1	11.4	12.6

NUMBER OF SEEDLINGS NOT IN ABOVE MEANS = 0

COMPARTMENT NAME. GOBEL MT COMP. NO. 8306 CELL NOS. 8583, 8883

WILLAMETTE NATIONAL FOREST RANGER DISTRICT 8 EXAM NO. 127 RUN DATE 09/08/73 X-REF COMP. NOS. X-REF CELL NOS.

TABLE 6. INDIVIDUAL TREE RECORD

**** FIELD CODED VARIABLES ****												*	***** COMPUTED VARIABLES *****							
POINT	MIST	SPEC	DBH	DEFCT	CRAT	CCLS	DCLS	AGE	MISLE	PTDCC	GROTH	*	TR CL	TPA	BD FT	CU FT	S PCT	BF PA	CF PA
1	1	205	28	0	2	2	0	7	0	1	0		C-2	.94	973	191.0	2.20	915	179.5
1	1	205	26	0	3	3	0	7	0	2	0		C-2	1.08	792	161.6	2.41	855	174.5
1	1	205	24	0	2	3	0	7	0	3	0		C-2	1.27	630	134.6	2.37	800	170.9
1	1	205	22	0	2	3	0	7	0	4	0		C-2	1.52	487	110.0	2.16	740	167.2
1	1	205	22	0	2	3	0	7	0	5	0		S-2	1.52	487	110.0	2.16	740	167.2
1	1	205	18	0	1	3	0	7	0	6	0		E-2	2.26	258	68.4	1.99	583	154.6
2	1	205	28	0	3	3	0	7	0	1	14		C-2	.94	973	191.0	2.20	915	179.5
2	1	205	26	0	3	2	0	7	0	2	15		C-2	1.08	792	161.6	2.41	855	174.5
2	1	205	24	0	3	3	0	7	0	3	0		C-2	1.27	630	134.6	2.37	800	170.9
2	1	205	22	1	3	3	73	7	0	4	0		C-2	1.52	487	110.0	2.16	740	167.2
2	1	205	22	0	2	3	0	7	0	5	0		S-2	1.52	487	110.0	2.16	740	167.2
3	1	205	26	0	3	2	0	7	0	1	0		C-2	1.08	792	161.6	2.41	855	174.5
3	1	205	20	0	3	3	0	7	0	2	0		C-2	1.83	363	88.0	2.03	664	161.0
3	1	205	18	0	2	3	0	7	0	3	0		C-2	2.26	258	68.4	1.99	583	154.6
3	1	205	16	0	2	4	0	7	0	4	0		C-2	2.86	172	51.4	2.00	492	147.0
4	1	205	30	0	4	2	0	7	0	1	0		C-1	.81	1173	223.0	2.00	950	180.6
4	1	205	28	0	3	3	0	7	0	2	0		C-2	.94	973	191.0	2.20	915	179.5
4	1	205	16	1	3	4	73	7	0	3	0		C-2	2.86	172	51.4	2.00	492	147.0
4	1	205	16	0	2	3	0	7	0	4	0		C-2	2.86	172	51.4	2.00	492	147.0
4	1	205	16	0	2	3	0	7	0	5	0		S-2	2.86	172	51.4	2.00	492	147.0
5	1	205	24	2	4	2	53	5	0	1	0		C-1	1.27	630	134.6	2.37	800	170.9
5	1	205	22	0	4	3	0	5	0	2	0		C-1	1.52	487	110.0	2.16	740	167.2
5	1	205	22	0	4	3	0	5	0	3	0		C-1	1.52	487	110.0	2.16	740	167.2
5	4	312	14	0	0	0	0	0	0	4	0		X	3.74	50	32.8	2.09	187	122.7
5	4	361	10	0	0	0	0	0	0	5	0		X	7.33	0	15.0	2.65	0	110.0
6	1	205	26	1	4	2	53	5	0	1	34		C-1	1.08	792	161.6	2.41	855	174.5
6	1	205	20	0	4	3	0	5	0	2	44		C-1	1.83	363	88.0	2.03	664	161.0
6	1	205	18	0	3	3	0	5	0	3	0		C-2	2.26	258	68.4	1.99	583	154.6
6	1	205	18	0	3	3	0	5	0	4	0		C-2	2.26	258	68.4	1.99	583	154.6
7	1	205	32	0	3	2	0	7	0	1	0		C-2	.72	1392	257.4	1.88	1002	185.3
7	1	205	32	0	4	2	0	7	0	2	0		C-1	.72	1392	257.4	1.88	1002	185.3
7	1	205	32	1	3	2	53	7	0	3	0		C-2	.72	1392	257.4	1.88	1002	185.3
7	1	205	32	0	3	2	0	7	0	4	0		C-2	.72	1392	257.4	1.88	1002	185.3
7	1	205	30	0	3	2	0	7	0	5	0		C-2	.81	1173	223.0	2.00	950	180.6
7	1	205	18	0	3	3	0	5	0	6	0		S-2	2.26	258	68.4	1.99	583	154.6
8	1	205	14	0	2	3	0	5	0	1	0		C-2	3.74	105	36.8	2.09	393	137.6

8	1	205	14	0	2	3	0	5	0	2	0	C-2	3.74	105	36.8	2.09	393	137.6
8	1	205	14	0	2	3	0	5	0	3	0	C-2	3.74	105	34.8	2.09	393	137.6
8	1	205	14	0	3	3	0	5	0	4	0	C-2	3.74	105	36.8	2.09	393	137.6

COMPARTMENT NAME. GOBEL MT COMP. NO. 0306 CELL NOS. 6580, 88D

WILLAMETTE NATIONAL FOREST RANGER DISTRICT 8 EXAM NO. 127 RUN DATE 09/08/73 X-REF COMP. NOS. X-REF CELL NOS.

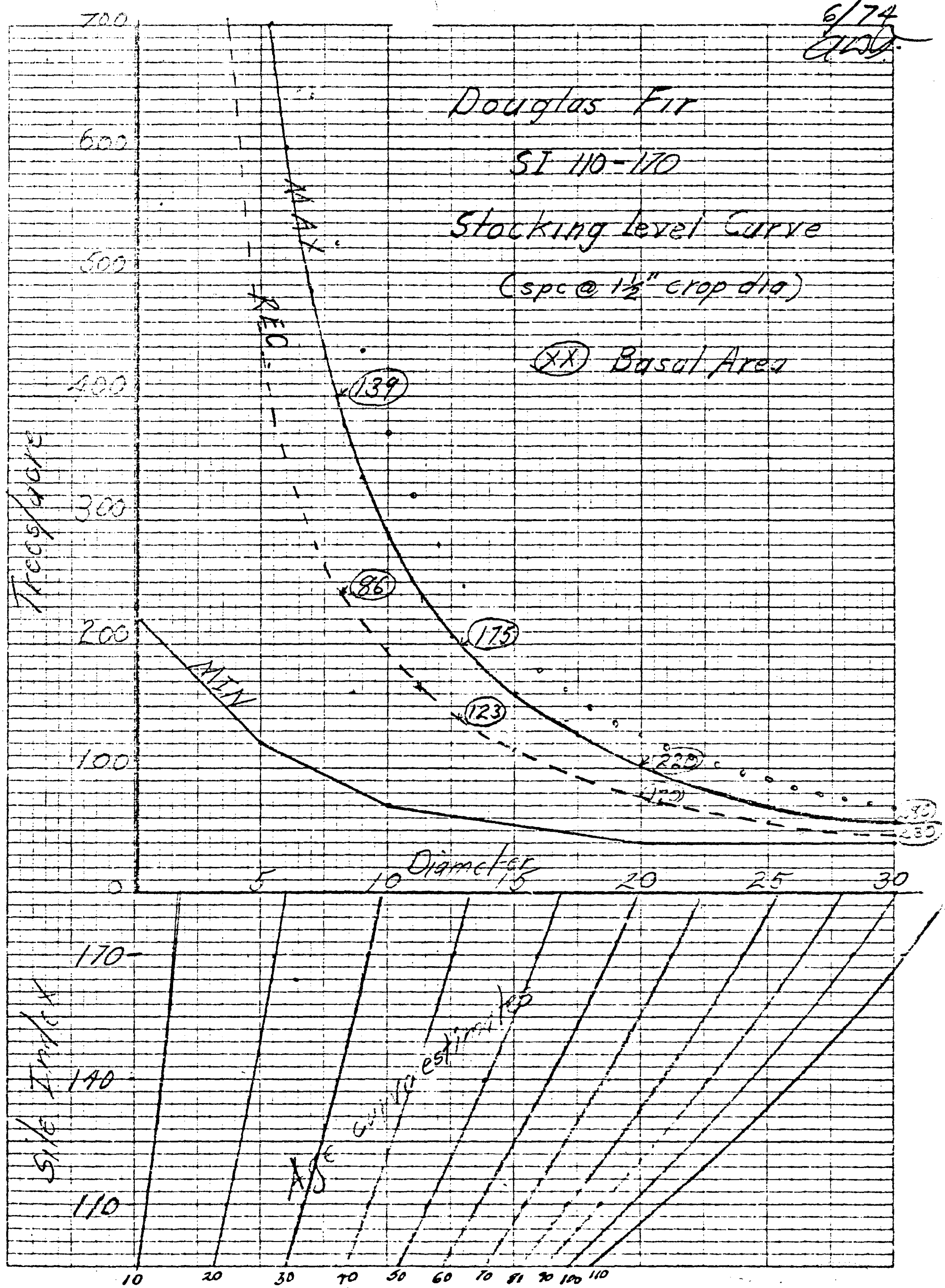
**** FIELD CODED VARIABLES ****												***** COMPUTED VARIABLES *****						
POINT	NIST	SPEC	DBH	DEPCT	CRAT	CCLS	DCLS	AGE	MISLE	PTOCC	GROTH	TRCL	TPA	BDFT	CUFT	SPCT	BFPA	CFPA
8	1	205	12	0	3	4	0	5	0	5	0	S-2	5.09	58	24.6	2.29	295	125.2
8	1	205	6	0	1	5	0	5	0	6	0	E-2	20.37	0	3.2	4.87	0	65.2
9	1	205	24	0	3	2	0	6	0	1	26	C-2	1.27	630	134.6	2.37	800	170.9
9	1	205	20	0	3	3	0	5	0	2	0	C-2	1.83	363	88.0	2.03	664	161.0
9	1	205	18	0	2	3	0	5	0	3	22	C-2	2.26	258	68.4	1.99	583	154.6
9	1	205	16	0	3	3	0	5	0	4	0	C-2	2.86	172	51.4	2.00	492	147.0
9	1	205	14	0	2	3	0	5	0	5	0	S-2	3.74	105	36.8	2.09	393	137.6
9	1	205	12	0	1	4	0	5	0	6	0	E-2	5.09	58	24.6	2.29	295	125.2
10	1	205	16	0	4	2	0	5	0	1	0	C-1	2.86	172	51.4	2.00	492	147.0
10	1	205	14	0	3	3	0	5	0	2	0	C-2	3.74	105	36.8	2.09	393	137.6
10	1	205	14	0	3	4	0	5	0	3	0	C-2	3.74	105	36.8	2.09	393	137.6
10	1	205	12	0	3	3	0	5	0	4	0	C-2	5.09	58	24.6	2.29	295	125.2

There are a couple of cover cards which I have not shown that record some information on stand location, elevation, topography, ecoclass, age, existing fuel type, who examined, when, etc., that contributes basic information. Some of this information is not recorded on the stand analysis table but the cards are photographed and recorded in TRI.

Some of the stand characteristics displayed in the TSE printout that help the prescriber to arrive at acceptable alternatives are:

> Site index, species, density and variability of density within the stand, age, indication of tree vigor, mistletoe, other defect or damage, an array of average stand diameters, total range of tree diameters, and growth rates of measured trees.

All thinning enteries need a target density for the residual stand. This density target is controlled by resource management objectives, site productivity and the period of time that will elapse before the next scheduled entry. We have stocking level curves that serve as general guides to be modified by the prescriber.


6/74
Douglas Fir
SI 110-170
Stocking level Curve
(spc @ 1½" crop dia)
(XX) Basal Area
MAX
REQ
MIN
139
86
175
123
Trees/acre
Diameter
S/E Index
170
140
110
0
5
10
15
20
25
30
100
200
300
400
500
600
700
10
20
30
40
50
60
70
80
90
100
110

This set of curves is for the midrange of Douglas-fir sites. The maximum curve is similar to a curve recommended to us by Bruce and Reukema of the PNW and approximately represents the average number of trees that will reach the indicated diameter in a fully stocked stand. The recommended curve has been selected by management as the target density to which a stand should generally be reduced. The site should not be seriously understocked at this density.

The minimum curve is a priority curve. When stocking is below the minimum curve the stand should be harvested and replaced with a new stand at the recommended level.

If the existing stand exceeds the density of the guide and crop trees are growing faster than predicted, the planned density can be adjusted upward or schedule revised. If snowbreak potential requires a more open stand, both density and schedule should be adjusted. When harvesting costs require greater volume to be harvested, fewer entries on a longer schedule are required. The other resources such as recreation and wildlife may call for specific criteria such fall individual tree crowns for wildlife cover or to frame a viewpoint to enhance the view. There is an opportunity to meet these other resource need and produce a high level of wood by adjusting density and entry periods. Our guide is very subjected to adjustment and frequently should be.

The prescriber should be able to predict with some degree of consistency the relative differences in production that may result from his prescriptions. We have developed a computer program that does the arithmetic for a yield prediction or yield table. It is <u>not a simulator</u>.

The program does not grow a stand or a tree and has no control on growth rates as related to density. The program simply displays an array of individual stands that are held together by a time schedule.

The gross volume for each stand is computed plus accumulated thinning from previous enteries to summarize the production in both cubic feet and board foot scales.

FIELD DATA

AGE	HT	FC	TOP	DBH ALL	DBH CUT	DBH LV	TPA ALL	TPA CUT	TPA LV	MORT	GROWTH
12	16	0	0	1.5	1.0	2.1	999.0	610.0	389.0	32.0	6.9
34	75	69	4	9.0	9.4	8.8	357.0	125.0	232.0	4.0	3.7
44	93	73	4	12.5	12.5	12.5	228.0	80.0	148.0	2.0	3.1
54	106	73	4	15.6	15.5	15.6	146.0	43.0	103.0	1.0	2.4
64	117	75	4	18.0	18.0	18.0	102.0	20.0	82.0	.0	2.5
74	127	75	4	20.5	20.5	20.5	82.0	10.0	72.0	.0	1.8
84	135	75	4	22.3	22.3	22.3	72.0	8.0	64.0	.0	1.7
94	141	74	4	24.0	.0	24.0	64.0	.0	64.0	.0	1.5
104	147	74	4	25.5	.0	25.5	64.0	.0	64.0	.0	1.2
114	152	74	4	26.7	.0	26.7	64.0	.0	64.0	1.0	.9
124	156	74	4	27.6	.0	27.6	63.0	.0	63.0	.0	.8
134	159	74	4	28.4	.0	28.4	63.0	.0	63.0	1.0	.8
144	161	73	4	29.2	.0	29.2	62.0	.0	62.0	.0	.5
154	163	73	4	29.7	.0	29.7	62.0	.0	62.0	.0	.0

BASAL AREA

AGE	------- ALL -------		------- CUT -------		LEAVE
	PER TREE	PER AC.	PER TREE	PER AC.	PER AC.
12	.0123	12.3	.0055	3.3	8.9
34	.4418	157.7	.4819	60.2	97.5
44	.8522	194.3	.8522	68.2	126.1
54	1.3273	193.8	1.3103	56.3	137.4
64	1.7671	180.2	1.7671	35.3	144.9
74	2.2920	187.9	2.2920	22.9	165.0
84	2.7122	195.3	2.7122	21.7	173.6
94	3.1415	201.1	.0000	.0	201.1
104	3.5465	227.0	.0000	.0	227.0
114	3.8881	248.8	.0000	.0	248.8
124	4.1546	261.7	.0000	.0	261.7
134	4.3990	277.1	.0000	.0	277.1
144	4.6503	288.3	.0000	.0	288.1
154	4.8109	298.3	.0000	.0	298.3

5PC

TOTAL STEM VOLUME - CUBIC FT.

	ALL		CUT			TOTAL
AGE	PER TREE	PER AC.	PER TREE	PER AC.	ACCUM.	PROD.
12	.0	.0	.0	.0	.0	.0
34	12.5	4445.2	13.6	1697.9	1697.9	4445.2
44	29.5	6735.4	29.5	2363.3	4061.2	8433.2
54	49.8	7272.2	49.2	2114.4	6175.6	11333.4
64	74.2	7566.1	74.2	1483.5	7659.1	13741.7
74	101.8	8344.6	101.8	1017.6	8676.8	16003.8
84	125.7	9051.8	125.7	1005.8	9682.5	17728.6 - 18,398
94	146.7	9386.1	.0	.0	9682.5	19068.7
104	170.7	10922.8	.0	.0	9682.5	20605.3
114	191.8	12274.4	.0	.0	9682.5	21956.9
124	208.9	13163.3	.0	.0	9682.5	22845.8
134	224.4	14138.1	.0	.0	9682.5	23820.7
14	233.6	14485.8	.0	.0	9682.5	24168.3
154	244.0	15126.5	.0	.0	9682.5	24809.0

VOLUME - CUBIC FT.

	ALL		CUT			TOTAL
AGE	PER TREE	PER AC.	PER TREE	PER AC.	ACCUM.	PROD.
12	.0	.0	.0	.0	.0	.0
34	11.7	4182.0	12.9	1611.6	1611.6	4182.0
44	28.9	6599.0	28.9	2315.4	3927.0	8210.5
54	49.3	7193.5	48.6	2091.1	6018.1	11120.5
64	73.7	7515.3	73.7	1473.6	7491.6	13533.3
74	101.3	8305.8	101.3	1012.9	8504.6	15797.5
84	125.3	9018.5	125.3	1002.1	9506.6	17523.1
94	146.2	9357.0	.0	.0	9506.6	18863.6
104	170.2	10894.2	.0	.0	9506.6	20400.8
114	191.3	12246.1	.0	.0	9506.6	21752.8
124	208.5	13135.7	.0	.0	9506.6	22642.3
134	224.0	14110.8	.0	.0	9506.6	23617.4
144	233.2	14458.9	.0	.0	9506.6	23965.5
154	243.5	15099.8	.0	.0	9506.6	24606.4

VOLUME - BOARD FT.

	ALL		CUT			TOTAL
AGE	PER TREE	PER AC.	PER TREE	PER AC.	ACCUM.	PROD.
12	.0	.0	.0	.0	.0	.0
34	28.9	10315.9	33.4	4172.2	4172.2	10315.9
44	104.8	23904.3	104.8	8387.5	12559.7	28076.5
54	210.6	30751.8	207.2	8911.7	21471.4	43311.5
64	344.3	35120.0	344.3	6886.3	28357.6	56591.4
74	513.0	42066.4	513.0	5130.0	33487.7	70424.0
84	660.2	47502.0	660.2	5281.3	38769.0	81019.6
94	785.0	50243.0	.0	.0	38769.0	89012.0
104	933.6	59748.5	.0	.0	38769.0	98517.5
114	1073.2	68687.1	.0	.0	38769.0	107456.1
124	1187.7	74823.6	.0	.0	38769.0	113592.6
134	1290.5	81303.7	.0	.0	38769.0	120072.7
144	1348.4	83602.6	.0	.0	38769.0	122371.6
154	1417.1	87860.2	.0	.0	38769.0	126629.2

M.A.I.

AGE	CU. FT.	BD. FT.			
12	.00	.00	17.	.00	.00
34	123.00	303.41	39.	107.23	264.51
44	186.60	638.10	49.	167.56	572.99
54	205.93	802.06	59.	188.40	734.09
64	211.46	884.24	69.	196.14	820.16
74	213.48	951.68	79.	199.97	891.44
84	208.61	964.52	89.	196.89	910.33
94	200.68	946.94	99.	190.54	899.11
104	196.16	947.28	109.	187.16	903.83
114	190.81	942.60	119.	182.80	902.99
124	182.60	916.07	129.	175.52	880.56
134	176.25	896.07	139.	169.91	863.83
144	166.43	849.80	149.	160.84	821.29
154	159.78	822.27	159.	154.76	796.41

This is a table built for the average high site here on the Willamette National Forest and is being used in Timber Management planning. The field data of age, height, form class, top utilization diameter, average stand diameter before an entry, the cut diameter, the initial number of trees before the first entry, number of cut trees at each entry, and the anticipated mortality between each entry are entered by anyone using the program. All of the remainder of the data displayed is a product of machine calculation. The real merit of this program is its speed and consistency of calculation. Its limitation with regard to accuracy is the knowledge and the skill of the user.

A logical following step after predicting the response one expects to get from any operational silvicultural activity is to establish a monitoring system to discover the accuracy of your predictions. The results of a monitoring system, unless it is quite expensive in time and money, will not have as much dependability as we would like but accurately taken data, carefully analyzed should tell us if our predictions are very high, low, or pretty close.

We are just getting started on the monitoring process. We are using the stand examination program to evaluate the actual leave stand as compared to the target density. Growth response is another problem that is more difficult to measure.

During the past six months we have had an Ad Hoc group including private industry, State, research, and National Forest members working on a technique. Their first was aimed at monitoring growth response from operational application of area fertilizer. We hope to use essentially the same process to monitor other silvicultural practices that are aimed at adjusting growth rates.

Some of the key elements of the monitoring system are:

1. No activities within area during the past 5-years.
2. Select 3 to 4 plots of 50 trees each, both inside and outside the treatment area.
3. Specify how to measure tree heights, (as tree heights increase this becomes more difficult).
4. Observe plots during operation to be sure those outside are untreated and those inside are treated.
5. Square or rectangular plots are more easily defined.
6. Number and tag all trees.
7. Measure and record d.b.h. on all numbered trees.
8. Prepare for remeasurement at a specified time.

A plotted trajectory of subsequent development of both the treated and untreated stands will be evaluated with the intent that difference will be attributed to the treatment. The past history as read by increment cores of both treated and nontreated should confirm the similarity of control to treatment for evaluation purposes. A detailed description of the monitoring plan will be included in the proceedings.

Now I will try to answer any questions about anything I have said.

OPERATIONAL FERTILIZATION RESPONSE
MONITORING PLAN

I. Introduction

Response monitoring is needed on operationally fertilized areas for the manager to make decisions on future investments.

II. Purposes of Monitoring

A. To measure the growth response of a particular operationally-treated area. Information may be used to calculate cost/benefit.

B. To compare growth response results to results from trial plots.

C. To claculate increased yield of wood products resulting from fertilization activity which can be used in the management planning process to predict increased allowable harvest effect.

D. To predict probable response of future treatments based on a range of experienced responses which have occurred on similar areas.

III. Procedure Explanation:

A. Prior to Treatment

A low intensity sample is needed in each treatment area to indicate a potential level of response to the fertilizer application.1/

The following items should be kept in mind when considering plot locations:

1. Make an initial reconnaissance of the project area, early in your planning, to select potential plot locations.

2. Locate stands of similar age and initial stocking inside and outside treatment area. Selection of areas for potential plot location should be done with as little bias as possible. Aerial photos are suggested as the basis to locate areas for comparability and then select at random several potential plots within these locations. Be aware of where plot boundaries will fall when finally located to avoid areas which will not be treated.

1/ Bob Curtis, PNW, suggests a minimum of three to four plots of 50 trees each at end of measurement period both inside and outside treatment area.

3. Temporarily mark and select enough locations to be able to retain a sufficient number of comparable plots after treatment.

4. Make certain that no activities have occurred five years prior to planned treatment. This would invalidate later measurement results and affect monitoring results.

5. Determine how to measure tree heights for the size of trees to be measured on the plots.

B. During Treatment

1. Plots Outside Treatment Area

Observe potential plot areas during treatment to make certain no application was made on these areas that will invalidate later measurements.

2. Plots Inside Treatment Area

Observe potential plot area during treatment to insure fertilizer was received on the entire plot area. There is no best solution method to determine the level of treatment at this point but several things may be considered to quantify treatment. Several methods have been proposed to measure or observe treatments; such as:

a. Use of a hoop to be thrown onto ground to obtain a pellet count.

b. Catch basins or bags on elevated poles to intercept material.

c. Greased targets.

Some of these may not be feasible, depending on weather and stand conditions in the treatment area. The objective should be to best state how many pounds of fertilizer landed on the plot and if it was evenly distributed. Any means to measure the amount and distribution of fertilizer and to calculate pounds per acre should be utilized. As a minimum, you should be able to classify the treatment as (1) "average"equal the approximate planned per acre dosage, (2) "less than average", or (3) "more than average." Document your estimate or calculation so that results measured at a later time may be fairly evaluated.

IV. Initial Plot Installation and Measurement

A. Plot Size

Plots should be as large as possible to avoid stocking variability between clumps of trees and opening. Larger plots tend to even out stocking variability. Plots should contain 50 residual trees as a minimum after final measurement. Mortality must be considered which may occur from time of installation to final measurement (final measurement may be made just prior to next harvest entry in stand or at least 10 years after treatment). One-tenth (1/10) acre plots should be the normal minimum size and no smaller than one-twentieth (1/20) acre plots in heavily stocked, young sapling stands.

B. Plot Shape and Marking

Square or rectangular plots are preferred since corners may be well defined and fewer questions will exist about trees being inside or outside plot. Corners should be marked permanently for easy recovery for remeasurement. Paint or mark plot boundaries to aid in measuring plot trees.

C. Trees Numbering and Measurement

1. Number all trees 1.5" d.b.h. and larger with prenumbered aluminum tags. Attach tags with aluminum nails at breast height point of measure in thick-barked trees; however, to avoid callousing in thin-barked trees, make a paint mark at breast height point of measure and place the numbered tag about one foot lower on the tree.

2. Measure and record d.b.h. of all numbered trees to nearest 1/10-inch (0.1).

3. Record tree condition class using stand examination condition class code.

4. Heights of some trees need to be measured. Select ten trees per plot and not less than 30 trees per treatment for height measurement. 2/

   Weight sample to larger trees, e.g., 2/3 of measured trees should exceed the mean diameter. The trees selected should be distributed over the range of diameter as well as possible. Height measurement may be difficult but every effort should be made to obtain heights as accurately as possible. Shorter trees may be measured using height poles but taller trees will will need to be measured using the best instruments available for the stand condition. Height measurements should be taken to the nearest 1/2-foot on all trees measured.

2/ Bob Curtis, PNW, notes that if fertilizer dosage varies widely among plots, we may need to compare individual trees separately.

V. Procedure for Monitoring

Future monitoring of the plots will be based on what seems most desirable at time of remeasurement. Stands may be remeasured on the same basis as originally established and then continued in case of retreatment, or trees may be felled and dissected which will terminate some options for continued sampling.

Plots will be remeasured at end of five years. All previously numbered trees on plot will be remeasured to compute gross growth increment in both treated and nontreated control plots. Tag and measure in-growth trees if monitoring will be continued.

The measurements required for the growth response projections are:

DOB_1 = DBH at occasion I for all trees
DOB_2 = DBH at occasion II for all trees
H_1 = Ht at occasion II
DINC = Diameter Increment (record in 1/10-inch)

This is to be obtained on 20 percent of all trees at the first occasion measurement. Weight the 20 percent sample to larger trees, e.g., two-thirds of trees should exceed mean diameter. Trees should be distributed across diameter wherever possible. This diameter increment is for a period five years prior to treatment. These boring measurements must be obtained on both control and treated plots.

This information is to be recorded on the following form. From this form the first occasion data will be punched on IBM cards and stored on tape at FCCC. At the second occasion, this form will be taken back to the field for recording the second occasion data. The entire set of data will then be punched on IBM cards and stored at FCCC for analysis.

Plot No. ______
XXX

Plot Description

Date ________________

Site Index or Site Class ______________________

Occasion I						Occasion II		
Tree No.	Specie	DBH I	Ht. 1	DBH Incr. for previous 5-Yr. period	Damage Class	DBH 2	Ht. 2	Damage Class
XXX	XXX	XXXX	XXXX	XXX	XX	XXXX	XXXX	XX

A. DBH Projections

1. Basic data: treated plots and control plots,

let: DOB_1 = individual tree measured dbhob at date of treatment, obtained for all trees.

DOB_2 = measured dbhob at future remeasurement

$\Delta DOB = DOB_2 - DOB_1$

dinc = diameter increment inside bark in a specified number of years immediately prior to treatment, as determined from increment borings (available for a sample rather than all trees) made at time of plot remeasurement.

2. Relationships to be calculated from the data.

Treated plots:

$\Delta DOB = f_1$ (dinc) (eq. I-F)

dinc $= f_3$ (DOB_1) (eq. II-F)

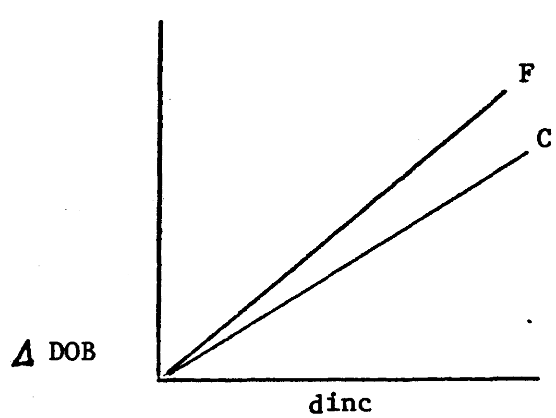
Control plots:

$\Delta DOB = f_2$ (dinc) (eq. I-C)

% mortality $= f_4$ (DOB_1) (eq. III-C)

3. Analysis (several minor variations possible)

a. Compare equations I-F and I-C graphically. If response was obtained, it should be evident.



b. Apply relationship III-C to initial stand table for fertilized plots and remove mortality expected in the absence of fertilization.

c. For each tree remaining (fertilized) after (b), use equation II-F to estimate "dinc" for those trees on which this was not actually measured.

d. Substitute actual or estimated values of "dinc" (as available) in the right side of equation I-C. When applied tree by tree to the "survivors" remaining after (b). this gives estimates of the DOB expected if the trees had not been fertilized. (Hence, the expected future stand table if no fertilizer had been applied.)

e. (1) Initial stand table + initial height-d.b.h. curve gives initial plot volume ($=V_1$).

(2) Actual remeasured stand table + actual H-D curve gives actual remeasured volume with fertilization, ($=V_{2F}$).

Actual growth with fertilizer = $V_{2F} - V_1$.

(3) Estimated growth of same plot without fertilizer = $V_{2C} - V_1$, where estimated final volume (V_{2C}) is calculated from the estimated stand in (d) and the estimated final H-D curve obtained by one of the procedures in section B below.

B. Height Projection

This will be bothersome and inaccurate at best, but should be attempted. Two options:

1. Tree dissection. (Much the most reliable method, but costly and destroys the plot.) Draw a sample of trees across the d.b.h. range, fell them, and measure:

a. Present total height (H_2).
b. Initial total height (H_1).
c. Final DOB_2.
d. Initial DOB_1 (available from plot record).

Use these values to construct initial and final H = f(D) curves for each plot (fertilized and control).

Obtain estimated H = f(D) if fertilizer had not been applied as $H_{1F} + \Delta H_C$, by d.b.h. classes, where H_{1F} is the initial curve for the fertilized plot and H_c is the observed increment for that d.b.h. class on the control plot.

2. Differences between $H = f(D)$ based on standing tree measurements.

   a. On both control and fertilized plots, at time of establishment, measure heights on a sample of trees.

   b. Repeat this at time of final measurement.

   c. Obtain estimate of $H_2 = f(D)$ if plot had not been fertilized as $H_{1F} + \Delta H_c$, as before.

This procedure will be less precise and requires a strong sample and careful measurement to get any useful result. However, it does not destroy the plot and may turn out to be the only feasible procedure. Therefore, one should get a good set of height measurements at time of plot establishment.

A simple comparison of growth on fertilized plots with growth on the unfertilized plots will be worthless, because of the impossibility of getting exactly comparable initial conditions on the two sets of plots. They would differ in growth even if no fertilizer were applied.

Therefore, we compare growth after fertilization with estimated growth of the same plot if it had not been fertilized, using prior (pre-fertilization) growth rate ("dinc") as the basis for the estimate. To do this:

> One could project the initial stand simply by assuming the same growth rate for each tree during the current growth rate as its measured growth rate in the previous period, prior to fertilization. However, this is likely to be affected by variation in growth rate due to year-to-year weather differences, and by change in age and density.
>
> Therefore, we use the ΔD-dinc relationship from the control plots (which should measure any such weather influence) as the basis for estimating growth rate of trees on the fertilized plots, if they had not been fertilized.

RESEARCH IMPLEMENTATION BY S&PF

By

Richard F. Watt

, I appreciate this opportunity to meet with you from NFA and Research. I am firmly convinced that each of the three branches of the Forest Service has something to offer to the other two that will help them in accomplishing their goals and those of the Forest Service. We tend to go our own ways and not have the interchange of ideas that is so helpful in understanding the problems and activities of the other two branches.

I've been asked to spend a few minutes talking about research implementation activities of State and private forestry. I'd like to confine myself to the activities of the Northeastern Area. If Ham Williston wishes to add something from his work with the Southeastern Area, I would welcome his contribution. Perhaps the Southeastern Areas operates a little differently.

What I would like to do is first define Research Implementation, tell why I think it is important, especially as an S&PF activity, and tell how we accomplish research implementation.

Research implementation encompasses all those activites that present applied research results to potential users in a form that teaches and encourages them to use these results to solve a problem or to conduct an ongoing operation more efficiently. It implies screening research results and selecting those that have a practical on-the-ground operational usage and then presenting these results in a how-to-do-it, step-by-step form so that the potential user will be able to use the research in his work. Research implementation also includes reasons why the new methods are better than those presently being used - we all tend to continue along a known path and really need strong motivation to try out a new method. Why bother to change if you're getting along passably well?

You may wonder why S&PF is so concerned with research implementation. Isn't this really a job for research? Dosen't research know best what their results mean and how they can be applied? Why do they need any help in getting their research out to the user? Don't they publish their results and distribute them to the potential user? Why bring in a middle man to get between the user and the researcher, muddying up the clear pure research results?

There are a number of answers to these questions. Perhaps the simplest is that research wants us to help them with research implementation. Many researchers believe their function is to do research - their job finishes when they publish the results of a study in Forest Science, Ecology or a Station publication. Their reward system puts little weight in promoting research - they don't get brownie points for application of research results.

Another very good reason for S&PF work in Research Implementation is that we are told to do it. Supplements to FSM 1032, Basic Policy syas that "S&PF is charged with assisting in the application of research results."

If we go a little farther back in time, or perhaps upward in policy making levels, we can look at the 1950 CFM Act. This act instructs that the Secretary of Agriculture provide technical assistance to landowners and primary wood processors, through cooperation of the appropriate State agencies. S&PF is, of course, the branch of the Department with this primary responsibility for technical assistance. Much of this technical assistance to the State forestry organization consists of keeping state-employed foresters up to date on new research results as well as reviewing older work to see that it is applied properly. But we also provide technical assistance to consultants and to NF personnel.

You may also ask why research implementation is necessary. Recall the old saying about building a better mousetrap and the world will beat a path to your door. In other words, if research really has produced an excellent product, it will be eagerly sought out by potential users who will immediately apply it in their day-to-day operations.

The only problem with this adage is that human nature does not operate this way. Except for a few innovators, the human animal likes to move in familiar paths - it's easier, it's safer, it's more comfortable. Why change if you're getting along - why rock the boat?

Another reason why the mousetrap theory doesn't work too well is that people must know a better mousetrap has been built before they can beat out the path to the researcher's door. I used to think - when I was in research - that we had a good publications distribution system, that all potential users of research were on our mailing lists. I learned years ago that those who receive research publications often don't read them, but that at least they do get them.

Since I've been in S&PF, I've learned that there are State Foresters who actually discourage their professionals from placing their names on the mailing list of the Experiment Stations. So another reason for research implementation is that many people don't receive research reports and those that do often don't read them for various reasons. Those that do read research reports often complaim that they are difficult to read and understand - they don't care too much about regression equations, analysis of variance, and Chi square, and statistical significance. What they want to know is - can this research result help me with my day-to day activities?

Now these reasons for research implementation are not unknown to research administrators - they have made strong attempts to get their research applied through show-me trips to experimental forests, through training sessions of various types, and by their presence here on the program this week. I don't want to give the impression that research hasn't tried, with some success, in the past in getting their results out on the ground.

But OMB and Congress are putting increased pressure on the FS to justify our programs in all areas and research is not excepted. They no longer are satisfied with a listing of publications issued - stations used to use a numbers game and divided annual appropriations by number of publications with the prize going to those whose cost per publications was the least. Now the need is to point at on-the-ground usage of results. An indication of this pressure is a packaging guide for research results issued recently by the Research Group in the W.O.

So much for the why of research implementation. Now how does S&PF implement research? What tools or methods do we use?

I don't have any breakthoughs to report in implementation. If we in S&PF have any great secret, it is that we devote considerable time and effort to the process since it is one of our primary functions. We know that many states don'thave have the manpower, incentive, money, or leadership to screen results of research and encourage their men to use it.

Our most effective means of research implementation is the training session where we spend several days with a group of foresters - usually partly indoors and partly in the woods - telling them of a new technique, and then going out and using it on several typical areas that they are working in. We show the prospective user how he can actually do something differently right in the woods in which he is working. We attempt to show him that the new technique is useful to him - that he will do a better job, that he will do the same job more quickly and cheaply, that here is a technique that will give him greater job satisfaction.

We also turn out publications - usually these are short how-to-do it type. Again the emphasis is to stress that here is something that you can use immediately in your work. Here are the instruments you need; here are the measurements you collect; here is the form you record your data on; here are the computations that you make; here is what you do with the results. We try to present a complete package to the potential user - remove all reasons for not using a new technique, anticipating his objections.

We also conduct symposia and workshops in conjunction with research - meetings in which all phases of a problem are presented. You may have heard of the Black Walnut Symposia and seen the proceedings - several other eastern hardwood have had the spotlight thrown on them this way.

We have also produced some slide tapes - again nothing unique but a rather time-consuming process that research often doesn't wish to use because of the expense and time involved in making good slide-tape program.

One rather unusual ability we have in S&PF that other branches don't have in the field of research implementation is the use of money. We have funds available that can be used to help pay for part of the cost of adopting a research finding. For example, research has studied seed sources and found that some sources, if planted north of their collection zone, grow more rapidly than the local source. We have helped finance a large purchase of short-leaf pine for use in Missouri. Without this seed money, this carrot, Missouri might have been very reluctant to spend money outside its boundaries to get a seed that would be better than its native seed. Similar help has been given in movement of white pine seed. We probably will be engaged in similar work when promising sweet - high-yield sugar maples are ready for distribution. We are currently funding a pilot project in walnut multicropping - bringing together what research has developed in walnut culture for sawlogs and nut production and combining with grass production for cattle feeding.

Another program that many of you may be unfamiliar with is our Research Needs System involving North Central and Northeastern Stations, Forest Products Lab, R-9, and S&PF in Upper Darby. We distribute to the States and regions a Research Needs form on which anyone - State, R-9, consultant - may submit a question that he believes requires research to supply the answer. This form systemizes the process by asking for a statement of the problem as a question - what is the importance of the problem - area involve, values, etc. - what benefits might result if research develops an answer - dollars and manhours saved, higher planting survival, more timber produced, etc. - and training - how soon is a solution needed and what happens if we don't get research to work the answer.

These forms are screened by S&PF and then sent to the project(s) most likely to be familiar with the problem. In many instances, research is able to provide an answer, either from existing publications or sometimes from ongoing but unpublished research. In some cases, the answer is not available and research considers the need in their periodic reviews of their programs.

Since we get a copy of the research reply to the request, we are able to get an idea of what information is available but for some reason hasn't moved from the research publication into the store of knowledge that the forester in the field is using in his operations. Thus, both we and research gain a better idea of what areas should be emphasized in our research implementation and training activities.

And of course, the originator of the request gets a written reply which often gives in considerable detail the answer to his needs plus publications and bibliographies.

I'd also like to call your attention to the fact that people in S&PF are the primary tool in research implementation. What kind of people do we have? I'm in the Resource Management Group concerned with silviculture, mensuration, management, wildlife, urban forestry and grazing. In our group we have three who came up through the Eastern National Forests, two who had many years in research - again mainly in the East, a wildlife biologist with a background in Department of Interior and R-7, a former State CFM supervisor, and a geneticist with recent training in this country and Europe. Five of us are housed in the same building with the NE Station, two in the field at research laboratories, and one about 10 miles from a research laboratory. So our physical setting does encourage frequent contact with researchers.

TO SUMMARIZE:

I've defined research implementation as all those activities that presents research results to potential users in a form that teaches and stimulates them to use these results to solve a problem and to conduct their work more efficiently.

S&PF is engaged in research implementation because research has requested our assistance and because Congress and FS policy states that we will do this. We also do this because many of our states just don't have the manpower, money, and some the desire, to upgrade and to help their service foresters keep abreast of new applied research results.

We don't have any magic approach to the job - we use in-the field workshops, how-to-do-it type publications, and slide-tapes. We work very closely with research - without their assistance we would be much less effective. We also believe we in turn make research more effective, relieving them of research implementation activities so that more of their time goes toward research.