A MANAGEMENT DECISION MODEL FOR PINYON-JUNIPER

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Abstract. To aid managers of pinyon-juniper woodlands, a multiresource decision support system (DSS) has been developed. This structurally integrated system combines a multiresource stand simulator, a linear programming optimization package, a geographic information system, and a graphics output display program, all organized around a relational database management system. The system automatically transfers data among components to facilitate total operation as well as gaming and sensitivity analysis. Projected outputs include stand treatment schedules, maps of current and future stand conditions, and multiresource output flows over time. Once fully operational, this DSS should greatly improve management planning for pinyon-juniper woodlands by allowing managers and planners to quickly and efficiently generate and analyze management alternatives.

INTRODUCTION

Pinyon-juniper woodlands occupy over 47 million acres in the western United States, making it one of the largest forest types in the country (Evans 1988). Historically, these woodlands were of low economic value, although they have long provided fuel, building material, and foodstuffs for Native Americans and other inhabitants of the West. Higher levels of human use and awareness of the pinyon-juniper type have led to increased demands for resource flows, both commodity and non-commodity, from these woodlands. Although the demands on the pinyon-juniper type have, and continue to be, multiresource in nature, management has been haphazard, at best, with an emphasis on single resource outputs.

The pinyon-juniper resource in the Southwest has faced increased pressure for commodity outputs over time. Fuelwood consumption in Arizona was estimated at 31,903 cords in 1974 and 73,186 cords in 1978 (Pfolliott and others 1979). Pinyon-juniper fuelwood consumption in the Arizona cities of Phoenix, Flagstaff, Kingman, and Eager-Springerville was estimated at 43,706 cords in 1985 (ITC 1988). The Coconino National Forest of northern Arizona projects fuelwood harvest (pinyon-juniper, oak, and aspen) to increase from 14,800 cords currently to 18,500 cords in 50 years. This increase will only satisfy 72% of projected quantity demanded (USDA 1987). The pinyon pine Christmas trees harvest in the Southwest increased from 3,000 trees in 1948 to 192,000 in 1964 (Rowder 1966), with the current harvest in the Southwest estimated at 500,000 trees annually (ITC 1988).

The management direction specified for the pinyon-juniper type by the Coconino National Forest dramatically illustrates the increased complexity associated with managing this forest type. The Standards and Guidelines for managing pinyon-juniper woodlands on the Coconino National Forest include the following provisions:

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a. Identify and manage stands with "old growth" character, with old growth defined as stands with the following characteristics:

1. At least 3,000 trees per 100 acres 9 inches or greater in diameter at root collar (drc)

2. At least 100 snags per 100 acres 9 inches or greater drc, and at least 10 feet in height

3. At least two logs per acre of down wood material 9 inches or greater in diameter and 10 feet long.

b. Create openings in big game winter range areas within 10 chains of hiding cover;

c. Insure harvested areas are separated by untreated strips at least 8 chains wide;

d. Manage to achieve where possible not more than one-quarter of a stand's perimeter in common with an adjacent stand whose ages vary by less than 30 years (USDA 1987).

The scale of the resource, the increased awareness of its importance for the production of multiple goods and services, and the increasing demands for commodity outputs, such as fuelwood and forage, have resulted in a complex management situation far beyond that previously faced by land managers. Managers face the task of efficiently generating technically and politically feasible management alternatives that respond to these increased demands in a climate of limited budgets, limited time, and knowledge which is often complicated and difficult to incorporate into the decision process. And on most public lands in the West, integrated management to produce a balanced mix of resources is mandated by laws and regulations. As a result, management responses have tended to be reactive, rather than proactive, and conflicts over uses have increased in frequency and severity. The result of all of this has been an increasing cry from within the profession of forestry for a retreat from a quantitative approach of information acquisition and analysis to an anti-intellectual "know-nothingism", the hallmark of which is a reliance on largely uninformed gut-level decision making.

As an alternative to such a retreat, the School of Forestry is developing a computer-based decision support system (DSS) that combines a stand-based multiresource forest simulation model with various economic algorithms, a geographic information system, a relational data base, a linear programming optimization model, and a graphics output display package. With user-defined objectives and constraints, the decision support system can generate an optimal treatment schedule, maps of present and future stand conditions, and projections of corresponding multiresource outputs, given management goals and associated budget, management, and resource limitations.
DECISION SUPPORT SYSTEMS

For this discussion, we use the following definition of a DSS:

...flexible integrated software for accessing, retrieving, and generating reports (both tabular and graphic) on geographic data base information, plus simulation and other decision models for conducting further analyses, including sensitivity analysis, automated goal seeking and gaming (Fox and others In Press).

Major Uses of DSS

We feel that such systems have the following six major uses as aids in forest management planning:

1. DSS can help managers define management objectives in clear and precise terms;

2. Such systems can help managers generate alternative strategies to achieve defined objectives;

3. They can quickly analyze generated alternatives in terms of specified objectives;

4. DSS can help managers explicitly recognize resource trade-offs and opportunity costs associated with different management strategies;

5. DSS enable managers to use sensitivity analysis to test input assumptions and to help identify required levels of precision and accuracy in input data;

6. DSS enable researchers to test the sensitivity of model results to changes in functions and assumptions within the model (Fox and others In Press).

Important Characteristics

From a management perspective, DSS should have the following characteristics with respect to inputs, operation, and outputs. Regarding inputs, DSS should be based on easily obtainable input data, in terms of time and funds. A system that requires obscure or expensive data will not have high acceptance levels. Second, once obtained, input data should be easy to enter into the system, so that output results can be obtained in a timely and efficient fashion.

Operationally, DSS should require relatively little user training. Systems that require highly sophisticated computer programmers to operate will not be used by operating managers, or even, most probably, by their immediate staff personnel. Second, DSS should have integrated information flows. Data should transfer automatically between and among system components. An integrated decision support system should eliminate the need for manual transfer of routine data among components. Managers and management support staff have more important and productive ways of spending their time. Third, as should be the case with all well-designed computer programs, DSS
should include self-checking mechanisms which flag inputs and intermediate results that fall outside of user-established permissible ranges. Such a characteristic would help prevent systems from generating erroneous, yet plausible, results based on major data errors. Fourth, program components within a DSS should be easily updatable as new information, models, or software become available. Therefore, DSS components should be modular in construction to facilitate revision and replacement. Fifth, a DSS should operate quickly and efficiently, requiring relatively little time—both computer and user time—to generate results. Decision makers are seldom willing to wait long periods of time for results. More commonly, managers hear "Get me the answers and get them to me yesterday!" Not only will quick turn around times aid a manager in responding to an immediate decision request, but system responsiveness will encourage managers to test alternatives and examine assumptions through sensitivity analysis.

Outputs from a DSS should be in terms of important decision-making variables. For example, one output of a forest management DSS might typically be a cutting budget identifying acres harvested over time. But for project planning, a listing of acres harvested is by itself insufficient. Volumes per acre, total volumes, volumes by species and size or quality classes, harvest locations, and the temporal distribution of the harvests, are all necessary for a forest manager to plan harvesting methods, and determine costs, mill support levels, and outside wood needs. Unless such outputs are included in system design, the decision support system is not serving the needs of the forest manager.

DSS outputs should also be in easily understandable formats. Although numbers may be extremely useful for exact calculations, often graphs or maps more effectively present the results of an analysis. Returning to the cutting budget example, a graph showing harvests over time would quickly and effectively demonstrate changes in volume flows. A map depicting year of harvest for the different stands in a project area would be a more informative display of the temporal and geographic distribution of harvests than a mere listing of stand numbers and harvest years. The importance of display format increases when comparing two or more alternatives. Charts and graphs that allow for the simultaneous display of outputs for multiple alternatives greatly increase the ability of managers to compare and contrast alternatives in terms of achieving management objectives (Fox and others In Press).

TEAMS: AN OPERATIONAL DECISION SUPPORT SYSTEM

TEAMS (Terrestrial Ecosystem Analysis and Modeling System) was developed at the School of Forestry, Northern Arizona University, as a decision support system to aid land managers in conducting project-level analyses of multiresource information to ensure consistency with forest-level plans (Covington and others 1988).

TEAMS combines a multiresource stand simulator, a linear programming optimization package, a geographic information system, and a graphics output display program into an integrated information and decision support system, all organized around a relational data base management system.
TEAMS allows for the relatively rapid analysis of numerous alternative management strategies and provides tabular, graphical, and map displays of results. Currently, TEAMS is fully operational only for the southwestern ponderosa pine forest type. The School of Forestry is developing a version of TEAMS for use in the southwestern pinyon-juniper forest type, the status of which is described below, and is investigating the possibility of adapting TEAMS for use in other forest types.

Outputs from the ponderosa pine version of TEAMS include timber volume harvested, water yields, wildlife forage and cover acres, total forage production, scenic beauty, sedimentation levels, costs, and present net value. Several variations of the ponderosa pine TEAMS exist that project resource yields for different periods of time in different intervals. These variations reflect the need for different levels of precision in project planning.

A PINYON-JUNIPER DECISION SUPPORT SYSTEM

Description

In response to the needs of land managers, the current TEAMS model is being modified for use in the pinyon-juniper woodland type. A key element in this modification has been the identification of an appropriate multiresource simulation module. Unfortunately, due to the historic low values associated with pinyon-juniper woodlands, relatively little knowledge about this type exists. The previously described desirable input characteristics of a DSS were considered while evaluating available models in terms of the ease and cost of acquiring necessary input data. This was especially important with respect to pinyon-juniper since its assumed low value discourages expensive data collection.

After an intensive review of the literature describing existing response functions for pinyon-juniper, two multiresource simulation modules were developed. Due to a lack of information on most of the resources produced by pinyon-juniper woodlands, only two outputs are projected in each module: wood and herbage production.

The first module uses the following equations to predict wood volume over time (Chojnacky 1988):

\[
V_t = 100[-0.077 + 0.398X_t + 0.011(X_t^2)]
\]

for \(X_t \leq X_0\)

OR

\[
100[4.664 + 0.398X_t - 37.926/X_t]
\]

for \(X_t > X_0\)

where:

\(X_t = BA_t \times "SITE INDEX" \div 100\)
\[ X_0 = 12 \]

t= time in decades

BA= basal area at root collar of all trees having at least one stem 3 inches in diameter at root collar (drc) or larger (square feet per acre)

V= volume of wood and bark from stems and branches larger than 1.5 inches in diameter (cubic feet per acre)

SITE INDEX= mean height of all trees 6 inches drc and larger with undamaged tops (feet)

BASAL AREA: \[ BA_t = \left[ n/k + Ce^{(m-1)kt}\right]^{1/(1-m)} \]

where:

\[ n = 3.5497(STEMS/1000)^{0.2591} \]

\[ e = \text{natural log} \]

\[ m = 0.2591 \]

\[ k = -0.0446(STEMS/1000) \]

\[ C = BA_0(1-m) - n/k \]

\[ t= \text{time in decades} \]

\[ BA_0 = \text{initial stand basal area (square feet per acre)} \]

\[ STEMS = \text{total basal tree stems, 1.5 inches and larger, for all trees having at least one basal stem 3 inches drc or larger (number per acre)} \]

These equations were developed for the Forest Survey Project of the Intermountain Forest and Range Experiment Station for the 1985 survey of Arizona and are based on data from 91 survey points in northern Arizona. They are felt by their developer to be appropriate for short term (i.e., 10 year) growth projections.

The herbage production function in the first module is from Clary and Jameson (1981) and takes the following form:

\[ Y = 33.0X_1 + 38.8X_2 - 33.5X_4 - 405 \]

where:

\[ Y = \text{average annual herbage production in kg/ha} \]

\[ X_1 = \text{average annual precipitation in cm} \]

\[ X_2 = \text{pretreatment canopy cover in percent} \]
$X_4 = \text{canopy cover times presence (1) or absence (0) of limestone soil}$

This function was developed from 22 plots scattered across the pinyon-juniper range of northern and central Arizona.

The second multiresource simulation module, ECOSIM, includes wood and herbage production functions based on research in the Beaver Creek Watershed Studies reported on by Rogers and others (1984). The wood production model is based on species-specific linear diameter growth, height, and volume functions.

For pinyon pine the equations are as follows:

$$V = c + bX^p_H$$

where:

$V =$ gross cubic foot volume outside bark to the specified minimum top diameter limit, including stump and limbs, in cubic feet

$c = 0.2768$

$X = D - TD$

$D =$ basal diameter at ground line, in inches

$TD =$ minimum top diameter limit, in inches

$H =$ total tree height, in feet

$b = 0.08789 - 0.03675(11.0 - TD)^{0.35}$

$n = 1.1 + 0.007(11.0 - TD)^2$

The diameter growth function is as follows:

$$GRO = (0.0646 - 0.001077D)(1 - e^{-(2.5 - 2.5COVDEN)2})$$

where:

$GRO =$ diameter growth, in inches

$D =$ current diameter, in inches

$COVDEN =$ % Crown Cover/100
The height function is as follows:

if \( DSH > 2 \) inches, then

\[
H = 10.77 \ln (DSH) - 0.32, \quad \text{else}
\]

\( H = 5 \)

where:

\( H = \) tree height, in feet

\( DSH = \) diameter at stump height, in inches
(Rogers and others 1984)

For all juniper species, the volume equation is as follows:

\[
V = c + aPdXH
\]

where:

\( V = \) gross cubic foot volume outside bark to the specified minimum top diameter limit, including stump and limbs, in cubic feet

\( c = 0.03066 \)

\( a = \frac{(20 - STEMS)}{19} \)

\( n = 2.25 + 0.38130 \times (TD - 1) \)

\( X = 0.00491 \times (D - TD)^{1.8} + \left(1.50147\times10^{-8}\right) \times (D - TD)^{5} \)

\( STEMS = \) number of stems 3 inches or greater in diameter originating within the first 12 inches above the ground line. Trees less than 3 inches in basal diameter are considered single stemmed.

\( D = \) basal diameter at ground line, in inches

\( b = 1.081 + 0.06263 \times (TD - 1) \)

\( TD = \) minimum top diameter limit, in inches

\( H = \) total tree height, in feet

For alligator juniper, diameter growth is as follows:

\[
GRO = (0.071 - 0.000531D) \times (1 - e^{-(2.5 - 2.5COVDEN)^2})
\]
where:

\[ GRO = \text{diameter growth, in inches} \]
\[ D = \text{current diameter, in inches} \]
\[ COVDEN = \% \text{Crown Cover}/100 \]

The height function is as follows:

if \( DSH > 4 \) inches, then

\[ H = 8.0128 \ln (DSH) - 0.9345, \text{ else} \]
\[ H = 8 \]

where:

\[ H = \text{tree height, in feet} \]
\[ DSH = \text{diameter at stump height, in inches} \]

For Utah juniper, diameter growth is as follows:

\[ GRO = (0.055789 - 0.000647D) (1-e^{-(2.5-2.5COVDEN)^2}) \]

where:

\[ GRO = \text{diameter growth, in inches} \]
\[ D = \text{current diameter, in inches} \]
\[ COVDEN = \% \text{Crown Cover}/100 \]

The height function is as follows:

if \( DSH > 2 \) inches, then

\[ H = 0.80 \times (DSH) + 7.03, \text{ else} \]
\[ H = 3.8 \]

where:

\[ H = \text{tree height, in feet} \]
\[ DSH = \text{diameter at stump height, in inches} \]

(Rogers and others 1984)

The herbage production function is as follows:

\[ \text{HERBAGE PRODUCTION} = (2486.1 + 3.48 \times AP - 36.62 \times T + 145.2 \times S_D) \times (\exp(-0.0291 \times BA)) \]
where:

\( AP \) = annual precipitation in inches

\( T \) = mean annual temperature in degrees Fahrenheit

\( S_D \) = soil depth to impending layer in inches

\( BA \) = overstory basal area in square feet per acre

This herbage production function was developed from data collected from the Beaver Creek Watershed Study Area for pinyon-juniper sites (Rogers and others 1984).

The ECOSIM model includes response functions for other resources from the pinyon-juniper type, including water yield and wildlife habitat. We plan to explore the possibilities of including these response functions in the DSS at a later time.

**Operation**

The developed DSS requires the following classes of information to operate:

1. Timber inventory
   a. Diameter distributions and tree counts (i.e., stand tables)
   b. Site quality
   c. Overstory canopy cover
2. Annual and seasonal precipitation
3. Current range condition
4. Soil depth and texture class
5. Treatment costs and output values
6. Management regimes (prescriptions)

To operate, data are first input to the system through the data base management system (R:Base 5000). The multiresource simulator then projects potential outputs (e.g. fuelwood harvest or herbage production) over time based on current stand conditions and alternative management regimes. The optimization model (linear programming algorithm) allocates treatments to specific stands over time based on management objectives (e.g. maximum fuelwood harvest, maximum present net worth, or maximum herbage production) and management constraints (e.g. minimum required harvest or herbage production). The report writer then displays resource outputs over time by alternative, as well as total costs and revenues.

The geographic information system will display the spatial distribution of treatments and stand conditions over time, and with the tabular outputs, will serve as a basis for generating revised alternatives.

**Uses**

We feel this DSS will greatly benefit managers of pinyon-juniper woodlands by providing them with the capability for project-level analysis of alternative treatment regimes. A project can be a 10,000 acre block,
watershed, timber sale area or any other administratively designated, contiguous land area. The DSS can also be used to "disaggregate" Forest Plan Management Area Standards and Guidelines.

The DSS's usefulness falls into three categories: First, it will allow managers to relatively rapidly analyze alternative treatments and to view the consequences of potential management decisions. This will allow managers to play "What if?" games in their management planning. Second, it will shorten the "learning curve" associated with making new managers familiar with the P-J type. Better decisions can be made when managers are more knowledgeable about the resource. And third, the DSS does not replace the decision maker, but makes decision maker more efficient. A DSS is a tool that ultimately depends on human judgement and expertise for a final decision (Covington and others 1988).

Example

To facilitate the development of the pinyon-juniper DSS, inventory data for a management area of approximately 5,000 acres was provided by the Navajo Forestry Department. This management area, known as the Mt. Powell Project Area, is located on the Navajo Reservation northeast of Gallup, New Mexico. The DSS will be used to develop a management plan for the area, with the following four objectives:

1. To understand the magnitude and potential of the resources on the site;

2. To examine multiresource management strategies to optimize land productivity and economic outputs for local residents for the short and long terms;

3. To determine long term impacts of various management strategies on land capabilities; and

4. To determine the effectiveness of a computer-based decision support system in the pinyon-juniper type.

Stands in the project area were delineated based on slope, species composition, aspect, soil type, and crown density. All stands in the project area were inventoried using point sampling with a 10 basal area factor prism. Points were established on a grid pattern to help insure representative samples within each stand, and to aid in ground checking stand boundaries to insure high quality mapping. The inventory was designed to provide the following information for use in the DSS:

1. Species-specific basal areas and tree counts by diameter classes (i.e., stand tables);

2. Tree heights;

3. Range condition and carrying capacity;

4. Fuel risk and ignition hazard;
5. Soil characteristics;

6. Insect and disease infestations;

7. Topography: slope, aspect, and slope length; and

8. "Site Index" (mean height of all trees 6 inches d.b.h. and larger with undamaged tops (feet))

In addition to providing input information to the DSS, a secondary goal of the inventory process was to test the relative efficiency of three different woodland inventory methods. To accomplish this, six stands in the project area were randomly selected for reinventory using two other inventory methods. Six points in each of these six stands were then randomly selected and inventoried using one-tenth acre fixed plots. These same six points also became the base points of 100 foot transects for an inventory using the line-intersect method (Meeuwig and Budy 1981). Although of relatively low intensity, this sampling scheme was the most intense possible for the three designs, while staying within time and budget constraints.

We are currently in the process of inputting the inventory data into the DSS, and we expect our first results sometime in late spring of 1989. At this stage of development of the DSS, we anticipate being able to project fuelwood and herbage production over time, display the spatial and temporal distribution of treatments, and to use the system for sensitivity testing of input requirements to help identify critical data needs.

EVALUATION OF THE TEAMS DECISION SUPPORT SYSTEM

Ponderosa pine model

The ponderosa pine version of TEAMS possesses eight of the nine desirable characteristics of a management-oriented DSS. Basic inputs are relatively simple and straightforward, consisting of such data as individual stand tables, soil depth, annual precipitation, timber site index, and current understory vegetation. These data are relatively simple to obtain from field inventories or from existing, published literature sources. Through the use of a menu-driven data base management program, inputting information is quite simple. The system also requires little training to enable users to begin operation. Forestry undergraduates are able to successfully and rapidly enter data into TEAMS, and operate the system, after only about 3 to 4 hours of training. Data and intermediate results are automatically transferred among system components. System components are modular, allowing for relatively simple updating and refinement as new knowledge becomes available. The system runs quite quickly and efficiently. We currently operate TEAMS on both micro and mini computers, depending upon the size of problem. On micro computers, once initial long term simulations are generated, new management alternatives can be developed, run, and examined in minutes for project areas up to 6,500 acres. For larger areas, the mini generates solutions in similar time periods. Outputs consist of exact stand treatment schedules, as well as the specific resource outputs mentioned above. TEAMS produces results in tabular, and graphical forms, allowing for the simultaneous comparison of up to four different management alternatives.
Currently, TEAMS does not have input data self-checking capabilities. As system modules are updated, this feature will be added.

TEAMS has been used as a teaching tool at both the undergraduate and graduate level, and as an operational planning tool to develop project level treatment plans for the Coconino National Forest (e.g., Fox and others 1989) and for forest management on the Navajo Reservation.

**Pinyon-juniper model**

At its current stage of development, the pinyon-juniper DSS does not have all the capabilities of its ponderosa pine companion. Specifically, the pinyon-juniper DSS lacks a comprehensive multiresource simulation algorithm. As a result, the types of outputs, constraints, and objective functions that can be specified in the DSS are limited at this time. It does possess all the same system attributes, e.g., data input requirements, output formats, and automated information flows, as does the ponderosa pine version of TEAMS. In addition, it does have a limited data self-checking capacity.

Even with its limitations, however, we do feel the DSS provides the following benefits:

1. It will greatly assist managers in developing site-specific project level multiresource analyses;

2. Analytical output displays in graphs, tables, charts, and numerical results will be readily understandable;

3. The system will allow for great flexibility in testing input assumptions and management objectives; and

4. It will permit the rapid development of alternative management scenarios.

From our experience with the ponderosa pine version of TEAMS, and our work with pinyon-juniper managers, we have already identified further research needs for the pinyon-juniper model. Once the DSS is fully operational and tested on the Mt. Powell Project Area, we expect to add to this list.

In the area of timber growth and yield, localized functions for specific geographic areas that use easily measured field variables need development. Cost efficient inventory methods appropriate to management objectives, required accuracy in prediction, and the value of the resource need further investigation. Accurate overstory-understory response functions need development, as well as improved quantitative measures of species-specific wildlife habitat quality based on stand structure conditions. Improved quantitative visual quality measures linked to stand structure conditions, and improved measures of resource values (e.g. fuelwood, pinyon nuts, Christmas trees, etc.) also need more research attention. These research areas are all part of the School's current thrust in multiresource forest management in the Southwest.
LITERATURE CITED

Chojnacky, David C. 1988. "Modeling volume growth for Arizona's pinyon-
juniper forests". In: Forest Growth Modeling and Prediction. USDA
Forest Service General Technical Report NC-120. North Central Forest
Experiment Station, Minneapolis, MN. pp. 247-254.

Clary, Warren P. and Donald A. Jameson. 1981. Herbage production following
tree and shrub removal in the pinyon-juniper type of Arizona. J. of

1988. TEAMs: a decision support system for multiresource management.

Service General Technical Report INT-249. Intermountain Forest and
Range Experiment Station, Ogden, Utah. 34p.

Ffolliott, Peter F., William O. Rasmussen, Thomas K. Warfield, and David S.
Borland. 1979. Supply, demand, and economics of fuelwood markets in
selected population centers of Arizona. Arizona State Land Department.

Computer Models for Forest Management". In: Proceedings IUFRO Forest
Simulation Systems Conference, ed. by L. C. Wensel.

Fox, Bruce E., Mary Anne Keller, Andrew J. Schlosberg, and James E.
Environmental Management 13(1): 75-84.

American Forest Products Marketing and Business Development Study. 22p.

Meeuwig, R.O. and J.D. Budy. 1978. Point and line-intersect sampling in
Intermountain Forest and Range Experiment Station. Ogden, UT. 38p.

Rogers, James J., Joseph M. Prosser, Lawrence D. Garrett, and Michael G.
under alternative forest management regimes. Administrative Report.
USDA Forest Service. Rocky Mountain Forest and Range Experiment

Dept. of Agric. Information Bulletin No. 94. 31p.

Region, United States Forest Service. 270p.