Developing Desired Future Conditions With the Landscape Management System: A Case Study of the Gotchen Late Successional Reserve

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Abstract—Changing public values have led to federal land management direction like the Northwest Forest Plan with major land allocations for late successional forest habitat. Restoration silviculture is a tool for maintaining optimum habitat despite risk of catastrophic disturbance due to the combined impact of fire, insects and disease. The Gotchen Late Successional Reserve (LSR) in the Gifford Pinchot National Forest provides an example of the issues of southern Washington Cascades LSR management. The Landscape Management System is a computer model applied to the planning for the Gotchen LSR area to assess alternative management actions, understand the effects of these actions on late-successional habitat and other values, and develop appropriate management.

Issues

Public values attached to forests have changed over time, often in response to economic circumstances. Changes in public values in the United States between 1900 and 1950 generated several laws designed to guide national forest management. Subsequent legal challenges over how federal agencies managed forests within the range of the northern spotted owl (*Strix occidentalis*) resulted in the 1994 Northwest Forest Plan (NWFP).

The system of federal land allocation established by the NWFP was designed to meet the dual objectives of protecting species associated with old-growth forest ecosystems and of producing a sustainable supply of timber and non-timber resources. The allocation system includes seven land use categories, one of which is Late Successional Reserves (LSR's)—areas reserved to provide habitat for late-successional species.

No programmed timber harvest is allowed in LSR's, but "restoration silviculture" is permitted. A distinction is made between silvicultural treatments allowed in LSR's in forests west of the crest of the Cascade mountain range versus those to the east because forest conditions differ. Because of past management practices, such as the suppression of fire, some of the drier, mid-elevation (2,500 to 4,000 feet) forests on the east slopes of the Cascade Mountains have acquired multi-storied, late successional structural characteristics more commonly associated with moist, higher elevation and west-side forests. These drier, mixed-species forests, now multi-storied and with abundant down wood, provide spotted owl habitat but are at an elevated risk from insects, pathogens, and uncharacteristically severe fires. Furthermore, the increased tree density stresses all trees, making them more susceptible to insects and pathogens. Maintaining such late-successional habitat may be inconsistent with natural disturbance regimes, yet is required under current federal law in LSR's in these areas. West of the Cascades, increased urbanization has reduced available spotted owl habitat and, subsequently, increased a demand to provide habitat on eastern Cascades sites where it may not have persisted historically. The Gotchen LSR in the Gifford Pinchot National Forest provides an example of the issues of eastside LSR management.

Site Description

Location

The Gotchen LSR is in the Gifford Pinchot National Forest (GPNF) in southern Washington State. This portion of the GPNF is east of the crest of the Cascade Mountains. The 15,000-acre LSR lies just south of Mt. Adams (T.7N., R.10E.). The northern boundary of the LSR is the Mt. Adams wilderness area, the eastern is the Yakama Indian Reservation, the southern is just inside the Klickitat County line and the western is the White Salmon River (fig. 1).

East of the Cascades, annual precipitation generally decreases on a west-east gradient. In the LSR, this precipitation gradient is modified at the local scale by the 12,307-foot peak of Mt. Adams. One result of this modification is a decline in precipitation from north to south. Annual precipitation at the northern boundary of the LSR is estimated at 90 inches, while at the southern boundary it is just 60 inches

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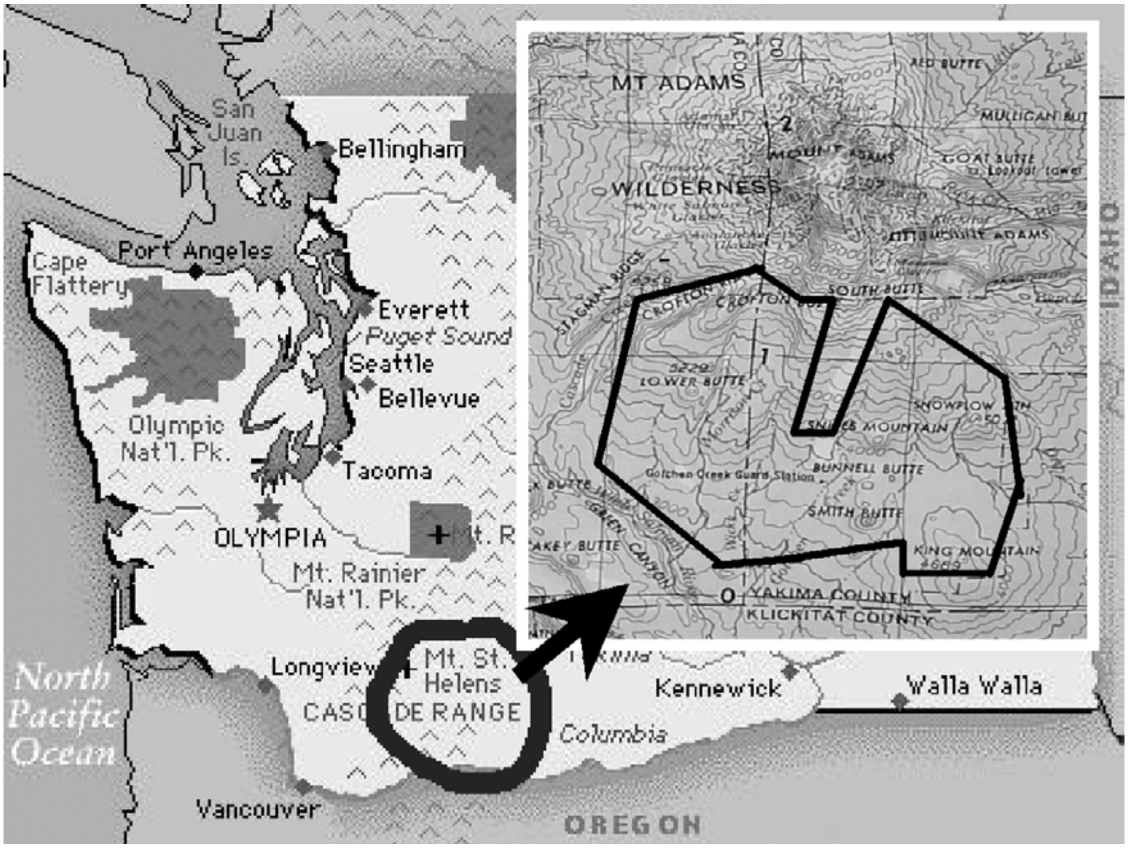

Figure 1—Location of the Gotchen LSR on the Mt. Adams Ranger District of the Gifford Pinchot National Forest.

(Topik 1989). The corresponding change in elevation is from approximately 7,000 to 3,000 feet. On any given site aspect, slope, and elevation influence precipitation. These variables influence the amount of soil moisture at an even smaller scale. Ridgetops and southern exposures, for example, have lower effective moisture than draws and northern exposures. These site characteristics have been implicated in the persistence of late-successional forest refugia in the eastern Cascades (Camp and others 1997).

Flora and Fauna

Effective soil moisture is the key factor regulating the distribution and abundance of vegetation. One method to characterize vegetation is by identifying groups of plants, or associations, that occur consistently within particular environmental conditions. The collection of plant associations that share the same dominant species is termed a "series."

The majority (86 percent) of the Gotchen LSR is within the grand fir (*Abies grandis*) series, which is comprised locally of 11 plant associations (LSRA 1997). This series has warm, moderate environmental conditions and therefore supports plants from both moister and drier habitats (Lillybridge and others 1995). Grand fir is considered the dominant climax tree species on sites that are too dry for more shade tolerant trees and yet provide enough moisture to enable grand fir to out-compete Douglas-fir. Characteristic drier site species include ponderosa pine (*Pinups ponderosa*) and beargrass (*Xerophyllum tenax*). More mesic site plants include Douglas-fir (*Pseudotsuga menziesii*), vanillaleaf, western red cedar (*Thuja plicata*). A transitional association between Western hemlock and Pacific Silver fir is *Thuja plicata-Achlys triphylla*, which occurs in shaded, low slope positions near valley bottoms. The northern boundary of the LSR is at approximately 6,000 feet. At this elevation, colder temperatures result in the replacement of the grand fir series with plants in the mountain hemlock-subalpine fir zone (*Tsuga mertensiana-Abies lasiocarpa*).

The variety of plant associations in the Gotchen LSR results in an array of structures suitable for wildlife species associated with early- to late-successional forests. Late succession-associated wildlife species that have been documented in the Gotchen LSR include bald eagle (*Haliaeetus leucocephalus*), northern spotted owl (*Strix occidentalis caurina*), black-backed woodpecker (*Picoides arcticus*), and American marten (*Martes americana*). These species are all either classified as "Threatened," "Endangered" or "Species of Concern" and are terrestrial, dependent on large-trees (>21 inches d.b.h.), and have either a large (>1,000 acres) or medium (60 to 1,000 acres) home range. Snags and down logs are important structural features used by these species (LSRA 1997). Unfortunately, much of the mid-elevation forest in the Gotchen LSR is comprised of small diameter, shade tolerant grand fir. A gap exists in the 40 to 80-year age class (fig. 2); therefore future late-successional stands may not develop for years. An active western spruce budworm outbreak, in combination with previous management activities, is generating an accumulation of fuels in the Gotchen LSR. A high-intensity fire could be fatal to the owls. The challenge, therefore, is to provide late-successional habitat while minimizing the risk of a stand replacement fire in the Gotchen LSR.

Objectives

The objective of this study is to test the utility of the Landscape Management System:

- For assessing alternative management actions.
- For understanding the effects of these actions on late-successional habitat and other values.
- For developing, implementing, and monitoring appropriate management (including the possibility of no active management) in the Gotchen LSR.

This paper discusses the preliminary results to date. The application of the Landscape Management System (LMS) to management planning is based on the ecological sciences and on the management science disciplines of systems approaches and decision analysis.

Management Science

Systems Approach

"Systems" approaches keep people from being overwhelmed by complex problems. This is accomplished by dividing problems into groups, by working on each group, and by then addressing interactions among groups. A group can be divided into subgroups, which can be further subdivided. Forest ecosystems, for example, can be grouped, studied, and managed at many levels to address their complexity (Tansley 1935). Management is often focussed at the individual organism level for silvicultural operations (for example, planting, thinning, etc.), the stand level for managing stand structures, and the landscape level for managing landscape values such as between-stand diversity and commodity flows. Coordinating among these levels requires generalizations from one level to the other. Such coordination can create "bottlenecks" in the flow of information among levels. Rapid decisions made at the most localized level possible, with only key information passed on to the next highest level, helps ensure that understanding and managing the system does not bog down and become overwhelmingly complex.

Decision Analysis Approach

Modern concepts in decision analysis involve many aspects of the systems approach (Morgan and Henrion 1990; Oliver and Twery 1999) and have been institutionalized in federal forestry through the Environmental Impact Statement or "E.I.S." process. The objective of this process is to present the decisionmaker with an array of alternative choices, displaying the effect of each choice on the various possible objectives the decisionmaker may have (fig. 3). The decisionmaker can then understand the tradeoffs among objectives and reveals values by the choice of alternatives and tradeoffs made.

The "rational, iterative approach" is probably most appropriate for forest management (and is included in the E.I.S. process). It entails a series of analytical steps. It is "iterative" for two reasons.

1. Instead of the decisionmaker *a priori* stating and weighting the different objectives for the analysts to achieve, the decisionmaker is presented with an array of alternatives to fit multiple objectives and allowed to choose a management approach after seeing the range of choices and their effects.

2. The decisionmaker is presented with increasing depths of understanding of choices and their effects by developing a "mental model" of the system being developed (Senge 1999). For example, the decisionmaker can first be presented with a simple numerical rank of the effect of each choice on each objective. As the grasp of the choices grows, the decisionmaker can be presented with increasingly deeper explanations of the effects of choices on the landscape, through time, and even at the individual stand level.

The role of the professional in modern decisionmaking is becoming increasingly defined. The professional is responsible

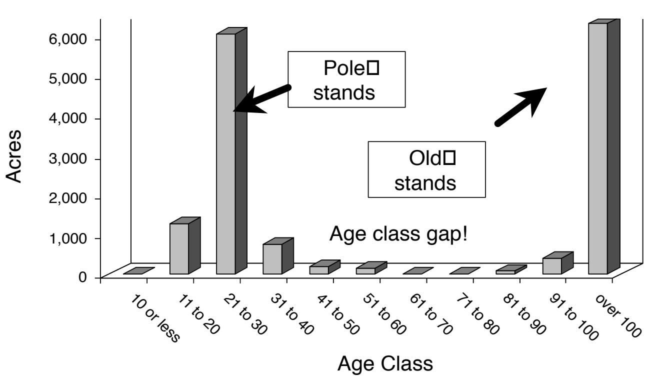

Figure 2—Gotchen Late Successional Reserve Acres by age class.

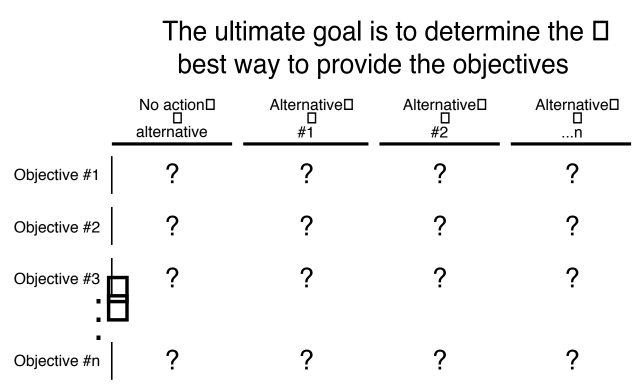

Figure 3. A decision matrix for showing decisionmakers the consequences of alternative management actions using the "rational, iterative" decision analysis process.

(and liable) for giving the best opinion of the consequences of different alternatives. Sometimes, such as within the USDA Forest Service hierarchy, the professional is given decisionmaking authority. In the fields of medicine, land surveying, engineering, and (increasingly) in forestry, the professional is being held accountable for the quality of his analyses; he is expected to present analyses accurate within the reasonable knowledge of the profession. Consequently, professional forest managers and analysts are becoming culpable for misusing or misinterpreting models and other diagnostic criteria, for not using models when they should have, for doing the wrong analysis, and for delaying or avoiding an analysis when one could have been made.

The Landscape Management System

Many tools are available which help forest ecosystem managers with decision analyses and implementation by performing many of the routine, complex, repetitive calculations needed to manage among operation, stand, landscape, and other scales (Oliver and Twery 1999). This paper describes the use of the Landscape Management System (LMS), a PC-based "point and click" interactive system (McCarter and others 1998). LMS allows the manager to import inventory and other stand and landscape information, to "grow" any stand or the entire landscape by sending the inventory data to various computer growth models (for example, FVS and Organon) (Donnelly 1996; Teck and others 1996), to treat stands silviculturally, and to present results. These results may be in terms of inventory; wind, fire, or other hazards; habitat conditions; timber volume; or other factors. The results can be presented as summary tables, graphs, visualizations at the stand and landscape levels (McGaughey 1997), and files exportable to spreadsheet analyses. LMS can be a valuable tool if the strengths as well as the shortcomings of the component analyses are understood.

LMS is a series of about 40 programs written primarily in C++ and Python that link various existing models (for example, Uview, Utools, FVS, and Organon) on a Windows® platform. It is being developed at the Silviculture Laboratory, College of Forest Resources, University of Washington in cooperation with the USDA Forest Service, Pacific Northwest Station. It is available to anyone free of charge, and the model, a users' manual, and e-mail "help" address is available at: http://silvae.cfr.washington.edu.

Methods

To use LMS for preliminary analyses of the Gotchen LSR, district-level stand inventory data were first entered into electronic form. For "legacy" stand exams done prior to 1980 (stand exams dated from 1974 to 1999); a migration program being prepared by the USDA Forest Service Decision Support team in Fort Collins will considerably improve the speed of this important first step. In the absence of this migration program, other conversion programs were written to change the Gotchen LSR data into a form acceptable to LMS. Although good inventory data lead to more accurate analyses and management, the use of LMS can begin with incomplete inventory. This is accomplished by extrapolating inventory among stands of similar ecological characteristics. Aerial photos can assist in assigning stands to ecologically similar groups. Inventory and other data can be refined systematically during the subsequent management process.

Extrapolation of data can lead to a professional dilemma: is the professional acting more responsibly by using the best available, incomplete science, or by delaying analyses until complete inventory data are available? This dilemma can be partly addressed after the analysis by examining the consequences of the "do nothing" management alternative.

Once the data are loaded into LMS, analyses can be done rapidly. For example, part of the scoping, the development of measurable criteria, and the development and analyses of alternatives (steps one through four, below) was done for a 60-year period by three people in two days. Other aspects, however, require more stand-specific expertise and decisions of local Interdisciplinary Teams. Applications of LMS can follow the "rational, iterative" decision analysis steps described below.

Step 1: Scoping

Local professional and public knowledge and scientific and technical analyses of the area help the scoping process. In addition, stand and landscape visualizations and information on the species composition, elevation, site, aspect, and other factors can be displayed through LMS (fig. 2). The information can be electronically transmitted for rapid distribution among groups in the management hierarchy.

Step 2: Determining the Objectives

The primary objective for managing the Gotchen LSR is to maintain habitat for late-successional species, especially the spotted owl. This objective is assigned from broader hierarchical levels such as laws and policies. In addition, some objectives emerge from local conditions—such as fire safety, since it is perceived that the grand fir stands in the Gotchen LSR are at high risk for fire. Such "emerging objectives" do not need to be pre-approved by the decisionmaker, and thus ignore the effects of alternatives on these objectives. It would be irresponsible, however, for the analyst to overlook a blatant emerging objective.

Step 3: Converting the Objectives to Measurable Criteria

Converting the objectives to measurable criteria requires professional expertise. The LMS program uses forest inventory information to develop certain criteria; for example, to classify stands by structure classes; to classify stands as suitable habitat for different species; to estimate each stand's wind and fire susceptibility; and to estimate the standing, harvested, and snag and log volumes. These criteria are then used, or further converted and used, as the measurable criteria for the objectives shown in figure 7. Other measurable criteria can also be developed easily in PC spreadsheets using data from LMS.

How well the objectives are met through time under different management alternatives can be projected using

LMS (fig. 4). For higher management levels, a summary value can be calculated for each objective that incorporates the objective and its change through time. In addition, the meaning of each summary value and its previous measurable criteria—its shortcoming and strengths—needs to be communicated clearly to the decisionmaker. This need for the decisionmaker to understand the measurable criteria further emphasizes the importance of the iterative decisionmaking process. It also emphasizes that the analysts need to be unbiased—even disinterested—relative to the objectives and alternatives.

Another professional question arises about the quality of the measurable criteria. The criteria need to be constantly improved and preferably refereed (or at least peer reviewed). In the meantime, the professional will be held accountable for whether the criteria are the "best available science," whether other criteria are chosen, or whether it is more reliable not to use LMS or other analysis tools. Giving decisionmakers a clear explanation of the measurable criteria and their limitations helps maintain the quality of the professional's position.

Step 4: Developing Alternatives and Comparison With the Objectives

The Gotchen LSR contains 141 stands. Developing management alternatives that are both realistic and present the range of alternatives would be difficult and time consuming if each stand is considered individually. A stratification or grouping process avoids the "bottleneck" of too many decisions at the landscape level and relies on more accurate, site-specific decisionmaking.

Using information developed during the scoping process, the Gotchen landscape was stratified into six groups of similar site attributes and stand age. The attributes considered were elevation, aspect and slope, which are particularly important indicators of site moisture availability in the eastern Cascades. The groups which were selected as most appropriate for this LSR are: "young" stands, "hot, pole" stands, "cool, pole" stands, "flat, pole" stands, "hot, old" stands, and "flat, old" stands.

Five alternative silviculture pathways were developed for a typical stand in each group (fig. 5). These five pathways included a "no action" alternative plus a range of thinning intensities and schedules. Each alternative pathway was projected for a 60-year planning period for each of the six groups using LMS. The results of all possible pathways were then summarized by decade. Different proportions of each group's total area could then be assigned to each pathway (fig. 6). An optimization program evaluated the contribution of any set of pathways to a specific objective, as well as effects on other objectives.

A range of alternatives was then developed and displayed as a matrix (fig. 7) for the decisionmaker to choose among. The background information was also readily available through LMS for iterative discussions with the decisionmaker. No decision has been made yet on the Gotchen.

Step 5: Making the Decision

The next step is for the decisionmaker to understand the tradeoffs and to choose an alternative (or request an alternative intermediate between existing ones). The decisionmaker's values may become apparent by the tradeoffs.

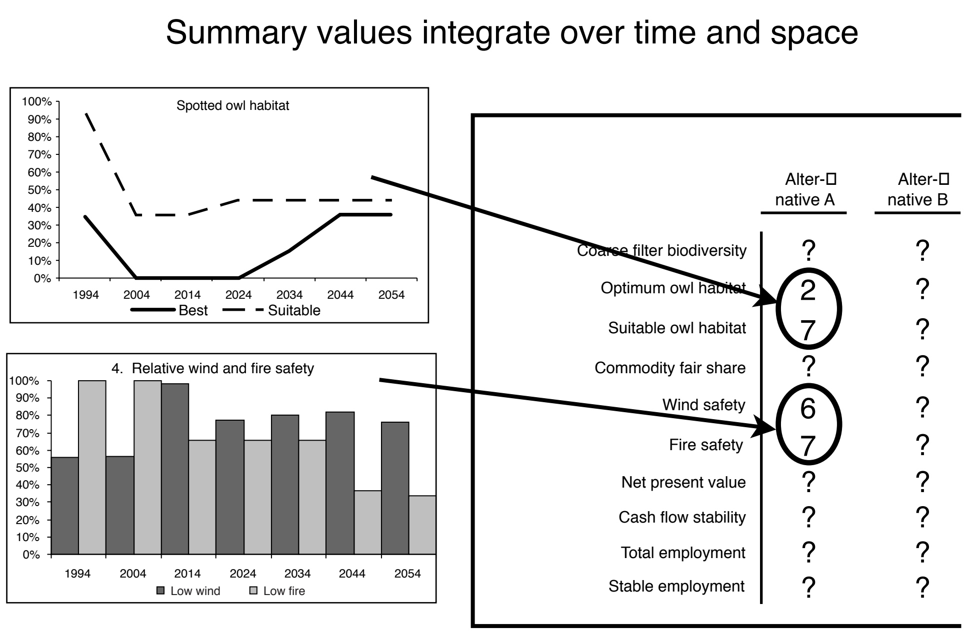

Figure 4—LMS can project the degree to which each objective is realized on each stand and on the forest as a whole with each treatment approach. These values can be integrated across time into a summary value.

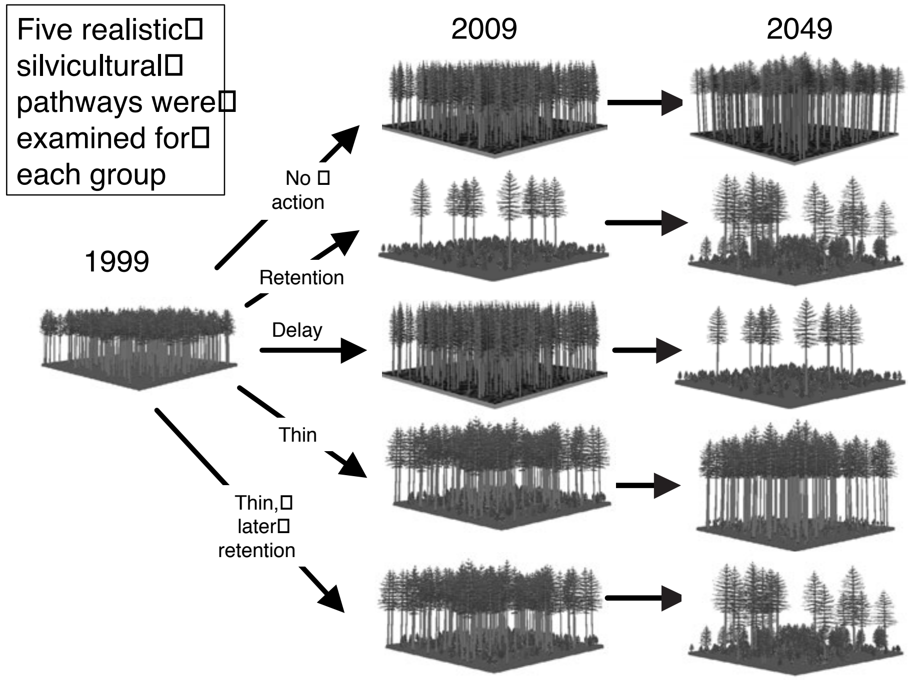

Figure 5—An example of five alternative silvicultural pathways for the “hot, pole” ecological group.

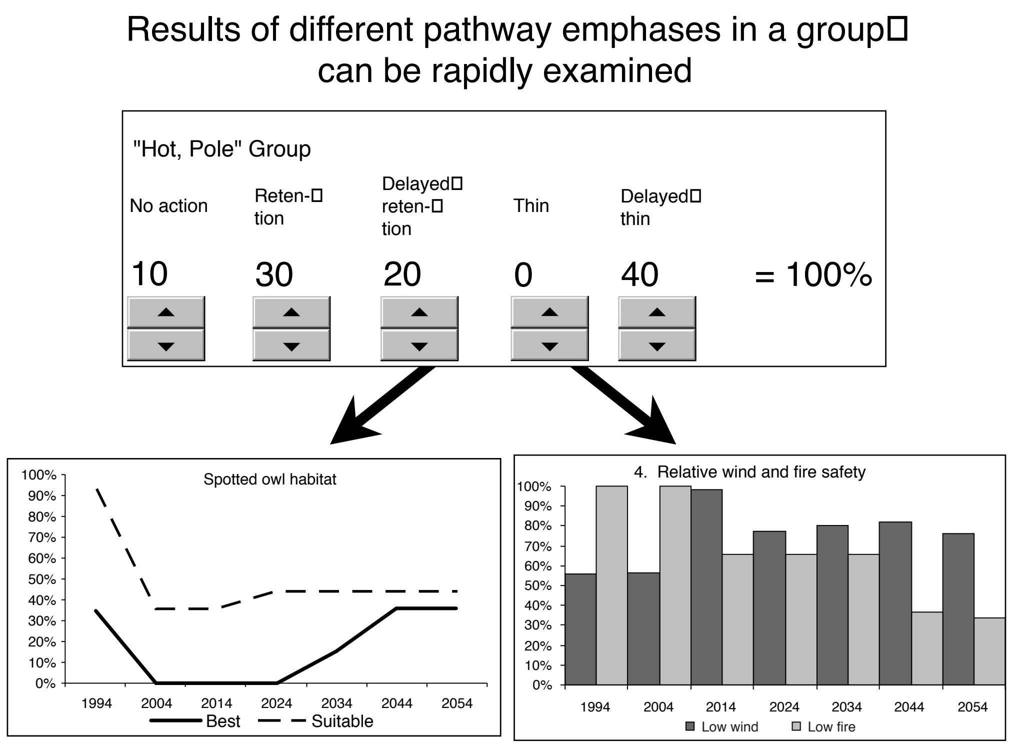

Figure 6—Different proportions of the ecological group’s area could be assigned to different pathways and the consequences simulated through LMS.

	No action	Alternative A	Alternative B	Alternative C	Alternative D
Coarse filter biodiversity	4	5	5	5	5
Optimum owl habitat	0	2	2	2	2
Suitable owl habitat	6	6	6	7	6
Commodity fair share	0	8	8	7	5
Wind safety	9	7	7	7	8
Fire safety	7	9	9	9	9
Net present value	0	2	2	2	0
Cash flow stability	3	9	9	9	10
Total employment	0	7	7	7	5
Stable employment	0	1	1	1	0

Figure 7—The range of alternatives is developed and summary values of the effects on the potential and explicit objectives are displayed in a matrix. After understanding the consequences, the decisionmaker can choose an alternative.

Implementing the Chosen Alternative

Refining the Plan at the Stand Level

The chosen alternative—the proportion of stands in each ecological group to follow each pathway—will be given to field foresters, who will visit each stand and determine its ability to be treated along each pathway (fig. 8). Some stands—such as those with low height/diameter ratios or low spruce budworm defoliation—may be more suitable for a "no action" alternative than others. These subtleties can best be determined by "on-the-ground" inspection of stands. The best assignment of the proportions of pathways to specific stands can be developed using field-based information combined with landscape projections of LMS.

Treating the Forest as a "Portfolio"

The local forester will then have a complete list of what stands are to be treated, in which way, and what the expected outcomes are for the next planning period. (In this case, it was 10 years, but LMS can also work in 5-year or shorter periods.) The forester can then be opportunistic in treating the stands—as funds, markets, weather, and similar conditions warrant.

Making the Expected Plan Visible

The final assignment of each treatment to each stand can then be projected using LMS to create expected stand and landscape visualizations, charts, and other information. These images and charts can be made publicly available (for example, brochures and electronic postings) so the public and such economic users as tour guides and timber harvesters will know what and where to expect future benefits (fig. 9).

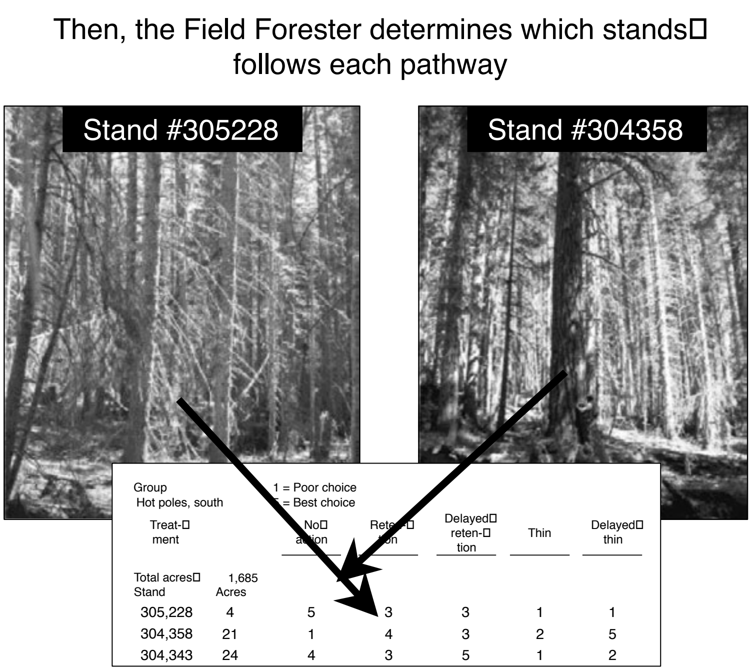

Figure 8—The field forester then decides which stand within a group has greatest ability to be managed along each pathway, eventually summing the acres within each pathway to meet the targeted amount.

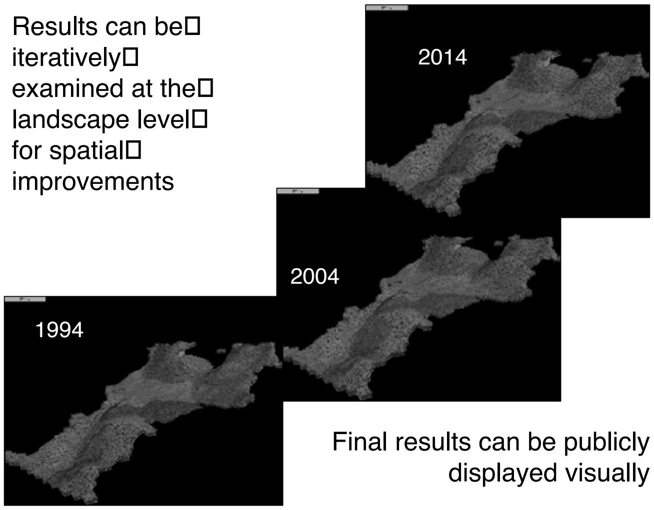

Figure 9—These stand-specific prescriptions can be fed into LMS and refined to create a landscape plan. Visualization and charts can help make the plan visible to the public and can be used to monitor at various intensities.

Implementing the Silvicultural Operations

The stand-level visualizations have also been found to be helpful to "treatment layout foresters," timber sale administrators, and loggers because it can provide a visual image of the "before" and "after" expectations of the stands.

Monitoring/Feedback

As the plan is being implemented, monitoring and improvement can be facilitated with the LMS programs. Monitoring at future times can follow a sampling scheme, with all stands cursorily examined and progressively fewer examined in more detail. The visualization component imbedded in LMS allows all stands to be visually monitored quite readily.

At future dates (for example, immediately before and after silvicultural operations and 5 or 10 years in the future), the expected (as projected by the management plan) and the actual (as determined in the field) conditions of different stands could be compared. Such visualizations readily identify gross inconsistencies between expected and observed stand structures.

A sub-sample can be examined in more depth by comparing expected and actual inventories. In addition, the expected areas providing habitats for different animal species can be compared with places where they are actually found.

Where inconsistencies are found between expected and actual future conditions, the causes of the inconsistencies can be determined and the management (for example, operations, LMS, or errors) can be corrected for the next planning cycle following the well developed "continuous quality improvement" processes (Feigenbaum 1951, 1983).

Future Steps

The Gotchen LSR analysis within LMS will be redone using more alternative pathways and refined measurable criteria. If a decision is made, the implementation steps will then be undertaken. The same procedure shown here can be used to coordinate several landscapes on larger scales using the systems approach, decision analysis, and assistance tools (Oliver and others 1999).

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