Methodology for Modeling the Spatial and Temporal Effects of Vegetation Management Alternatives on Late Successional Habitat in the Pacific Northwest

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Abstract—A 10-step methodology was developed to facilitate the analysis and communication of vegetation management treatments on short-term and long-term late successional habitat and overall landscape stability in eastern Cascade forests. This methodology was first used to evaluate proposed management effects on spotted owl habitat for a large project area within a late successional reserve (LSR) in central Oregon. Modeling tools and analysis techniques included: stratifying and classifying the LSR by focal species habitat and habitat stage; hazard rating systems, Forest Vegetation Simulator (FVS), pest impact models, and most similar neighbor analysis procedures. Data sources used include: stand exams, forest inventory data, field surveys and a photo-interpreted forest layer. Custom event monitor variables and keyword component files (kcp files) were written to describe and evaluate project objectives, proposed silvicultural treatments; and to model key disturbance events where off-the-shelf FVS models were not available. FVS projections to predict long-term effects were composed entirely of kcp files, which were assigned to appropriate stands using specialized software. Results of these projections were imported into GIS and displayed spatially, by treatment alternative, over time. Spatially explicit graphic and numerical displays of effects on spotted owl habitat over time helped demonstrate the need, and develop a base of support, for the management proposed by the project.

Over the past century, eastern Cascade grand fir and Douglas-fir series communities have changed from relatively open stands dominated by large shade-intolerant ponderosa pine (*Pinus ponderosa* Laws.) and Douglas-fir (developed under a low intensity fire regime), to dense multicanopy forests dominated by shade tolerant trees (Hessburg and others 1994). Species such as spotted owl (*Strix occidentalis caurina*) have found this combination of large legacy trees and multilayered dense fir in-growth to be suitable habitat and have established breeding populations in these altered mixed conifer communities. Late successional reserves (LSRs) have been established in these areas with the objective of protecting spotted owl and other species associated with late successional habitat (USDA Forest Service and USDI Bureau of Land Management 1994).

The changes in mixed conifer communities that have resulted in habitat conducive to northern spotted owl, have also resulted in a vegetative shift toward greater instability. Much of the "new" spotted owl habitat may be transient because replacement Douglas-fir and ponderosa pine nest trees are unlikely to develop given the present stand densities (Everett and others 1997). In addition, mixed conifer communities are now much more susceptible to severe impacts from insects, diseases, and wildfires (Agee and Edmonds 1992; Hessburg and others 1994). Thus, broad-scale losses of habitat can occur over very short periods. For example, over a decade, we estimate that 70 percent of spotted owl nesting, roosting, and foraging habitat (NRF) was lost as a result of the combined effects of western spruce budworm, root diseases, and bark beetles in the McCache project area in Oregon (fig. 1).

Given the inherent transience of much of the spotted owl habitat east of the Cascades and given that the USDA Forest Service is directed to manage for spotted owl habitat over time (USDA Forest Service and USDI Bureau of Land Management 1994), the agency is faced with a delicate balancing act for eastern Cascades spotted owl habitat that is both spatially and temporally complex. The agency is challenged with protecting and maintaining a portion of the existing habitat, developing future habitat, and at the same time, maintaining an overall condition of landscape stability.

Silvicultural treatments such as thinning and prescribed burning can be effective techniques to progress toward this goal. However, traditional treatment proposals, analysis procedures, and communication techniques have been inadequate for gaining support for these types of actions. The impacts and benefits of the proposals to late successional habitat are often not clear to wildlife biologists, line officers, or the public. This lack of common understanding among stakeholders has resulted in frustration, heightened controversy, and lawsuits.

To address this problem, the authors have developed a 10-step analysis procedure to help land managers:

- Predict spatially explicit effects to habitat over time
- Communicate these effects
- Evaluate logic and rationale of proposed actions
- Make more informed resource management decisions

A number of analysis tools and data are used including: (1) The Forest Vegetation Simulator (including the western

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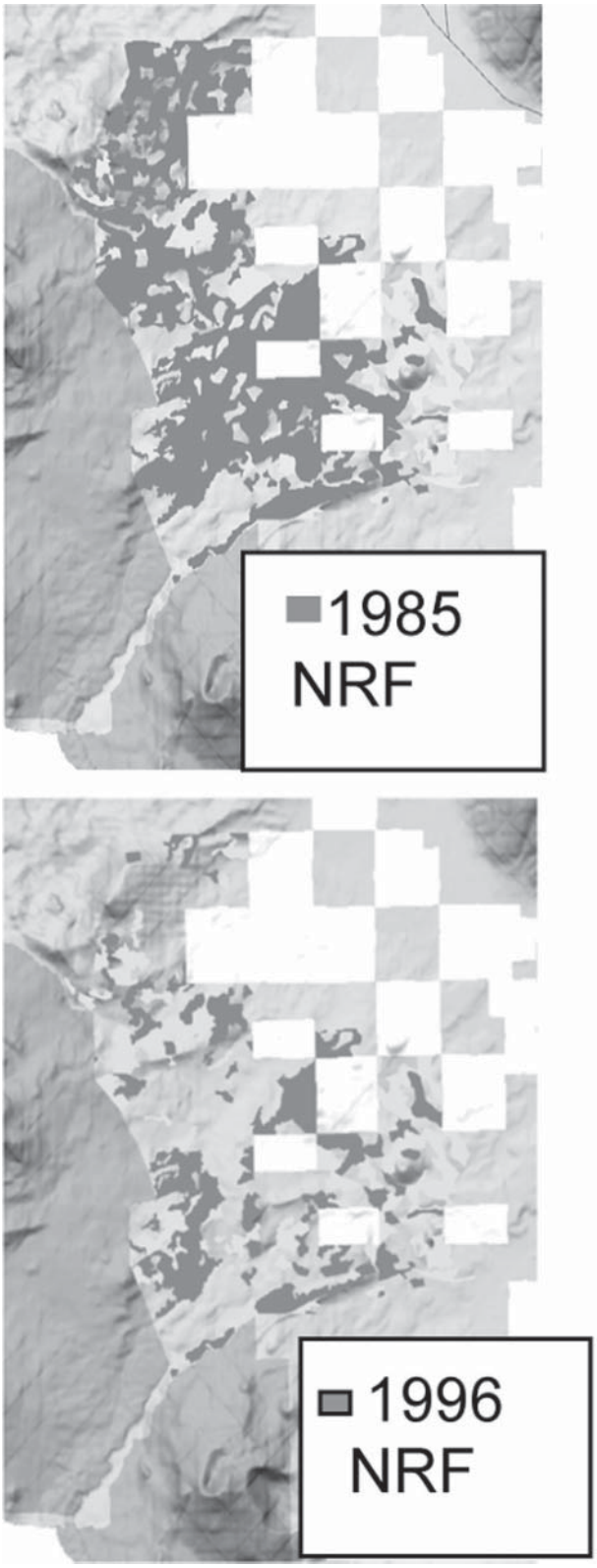


Figure 1—Northern spotted owl nesting roosting and foraging habitat (NRF) mapped in the Cache LSR in 1985 and in 1995. The dramatic change in NRF illustrates the rapid rate at which habitat can become nonhabitat in unstable forest structures. The 1985 condition was developed by reconstructing tree lists for 1985 stands from stand exams done in the early to mid 1990s.

root disease and dwarf mistletoe impact models), (2) stand exams, (3) forest inventory data, (4) global data (in our case, photo-interpreted data), and (5) Most Similar Neighbor inference (MSN) (Moeur and Stage 1994). This 10-step procedure was first applied to alternative analysis for the 15,350-acre McCache Vegetation Management Project area, located in the Cache LSR, on the Sisters Ranger District, Deschutes National Forest. The objective of this paper is to describe the methodology using examples from this initial McCache project analysis.

Methods

Part 1: Defining Existing Condition, Project Goals, and Objectives

Step 1. Stratify the Late Successional Reserve by focal species area. Focal species areas are portions of the landscape that have the best potential biological capability to provide late successional habitat for an identified focal or indicator species. For example, in the mixed conifer plant associations, the late successional focal species is northern spotted owl. For the ponderosa pine plant associations the focal species may be white-headed woodpecker (*Picoides albolarvatus*) or northern goshawk (*Accipiter gentiles*). Many eastern Cascades late successional reserves have more than one focal species because they encompass plant communities with different late successional indicator species. The Cache LSR assessment identified three major focal species areas within the McCache project area. For most of the mixed conifer plant associations the focal species is northern spotted owl. For the ponderosa pine plant associations, white-headed woodpecker is the focal species, and black-backed woodpecker (*Picoides arcticus)* is the focal species for the lodgepole (*Pinus contorta* var. *latifolia*) forest type.

Step 2. Describe the basic structural features of late successional habitat in measurable terms. A shared understanding of what you are trying to achieve is crucial to any successful project. The second step of our analysis methodology is, therefore, to describe late successional habitat in terms of measurable stand structure features. For the Cache LSR northern spotted owl focal species area, spotted owl habitat was quantified based on available scientific literature, adapted to observed local spotted owl nesting and dispersal behavior on the Deschutes National Forest (Thomas and others 1990; Forsman and others 1984; Buchanan and others 1995; Maffei and others 1997; Everett and others 1997). Structural features of two types of spotted owl habitat were described:

1. Nesting, roosting, and foraging habitat (NRF) has all the structural characteristics required for successful reproduction. Spotted owls typically nest low in the canopies of larger, dominant trees. Multilayered canopy cover is required for protection from predators. For the McCache Analysis, spotted owl NRF was described in terms of a sliding scale of numbers of large overstory trees (represented as trees over 21 inches d.b.h.) and canopy cover (table 1).

Table 1

Number of large trees per acre[1]	Percent Canopy Cover[2]
8-10.9	60+
11-14.9	55-59.9
15-17.9	50-54
18-21.9	45-49.0
22+	40-44.9

[1]Large trees are as those with 21 inch or greater d.b.h.
[2]Canopy cover provided by trees larger than 6 inches d.b.h.

2. Dispersal habitat is used by spotted owls to travel from one NRF area to another. It must have the structural characteristics necessary for owls to travel safely between NRF areas. For the McCache analysis, a stand was defined as dispersal habitat if there was a minimum of 35 percent canopy cover provided by trees greater than 6 inches d.b.h.

Step 3. Describe management objectives in measurable terms. The following objectives probably apply to most eastern Cascades late successional reserves:

a. Protect all or a portion of the existing late successional habitat.
b. Promote the development of future late successional habitat.
c. Promote an overall condition of productivity, stability, and low risk of catastrophic disturbance.

For habitat that is inherently high risk, "protection" of habitat is described in terms of the stability of the landscape around it. We chose to depict vegetative stability on the landscape in terms of hazard to "stochastic" disturbance agents that are likely to promote sudden loss of habitat. For mixed conifer systems we used hazard-rating models for stand-replacing wildfire, western spruce budworm, and bark beetles. Hazard rating for western spruce budworm was based on Carlson and Wulf's (1989) system, bark beetle hazard on local stocking guides (Hall 1987). Stands were rated as having a high potential for severe wildfire based on vertical structure and fuel loading. Stands with high stocking levels and multiple canopies and/or stands with fuel loads in excess of 20 tons/acre were rated as high hazard. Forest diseases, if present and significant, could be described in terms of a hazard-rating system. However, we chose to model the effects of these slow, progressive disturbance agents on habitat directly, using the western root disease model and the dwarf mistletoe impact model. Achievement of habitat is described in terms of the quantifiable features of habitat or in terms of quantifiable benchmark indicators of progress toward the desired habitat structural condition.

Step 4. Classify each stand in the focal species area in terms denoting the stand's present structure relative to the elements needed for habitat (habitat stage). This classification could be approached any number of ways but for our spotted owl focal species habitat areas we assigned each stand into one of four general groups (fig. 2):

1. Stands with sufficient numbers of large trees and levels of canopy cover to presently fit the definition of NRF.

2. Sufficient canopy cover to fit the definition of dispersal habitat. Depending on the number of large trees present, current dispersal habitat could develop into NRF in a short time, a relatively long time, or may not ever develop into NRF.

3. Sufficient large tree structure but not enough canopy cover to be NRF. At this stage, not treating and allowing the process of fir in-growth to continue could foster NRF.

4. Nonhabitat. Insufficient numbers of large tree structure or sufficient canopy cover to be classified as NFR or dispersal habitat. These stands are the furthest temporally away from being NRF because first the large tree structure needs to be developed, followed by the development of a layered, shade-tolerant understory.

Figure 3 shows this classification system applied to the 346 stands in the McCache project spotted owl focal species area.

Step 5. For each habitat stage develop a list of treatment objectives and prescriptions. For each habitat stage, assign a list of possible silvicultural treatment objectives and associated treatments. No treatment is always an option for each habitat category. Table 2 displays assigned objectives and treatment possibilities based on our four-category habitat classification for stands in northern spotted owl focal species areas. Note, that for nonhabitat stands, the prescription to regrow habitat mirrors the long-term two-stage process that initially produced it (grow large-tree-dominated fire climax forest first; then allow fir to grow underneath).

Step 6. For each alternative, the Interdisciplinary Team assigns a silvicultural treatment to each stand (no treatment is considered a treatment in this case). Proposed treatments are not assigned solely on individual stand conditions. Broader landscape considerations will also play an important role. For example, spatial concerns and connectivity issues such as the need for dispersal corridors or continuity of green fuel breaks, and unique stand characteristics, may all drive the final proposed stand treatments.

Part 2: Projection of Future Effects Using FVS

The following steps involve using FVS to model spatially explicit outcomes of the selected alternatives over time. FVS (Stage 1973) and associated software (Crookston 1997; McGaughey 1997) constituted the model of choice because:

- Event monitor allows for the creation of custom variables that tie directly to the project issues and objectives
- The model uses standard field inventory data
- Insect and disease impact models are available
- It is easy to project and summarize, and it spatially displays large amounts of data
- Links to external databases and GIS
- Calibrated to central Oregon
- USDA Forest Service supported and maintained

Step 7. Fully populate the stand exam database for each focal species area. In order to have a data-driven spatial display for future scenarios, it is necessary for each stand to be represented by a sample tree list so that it can

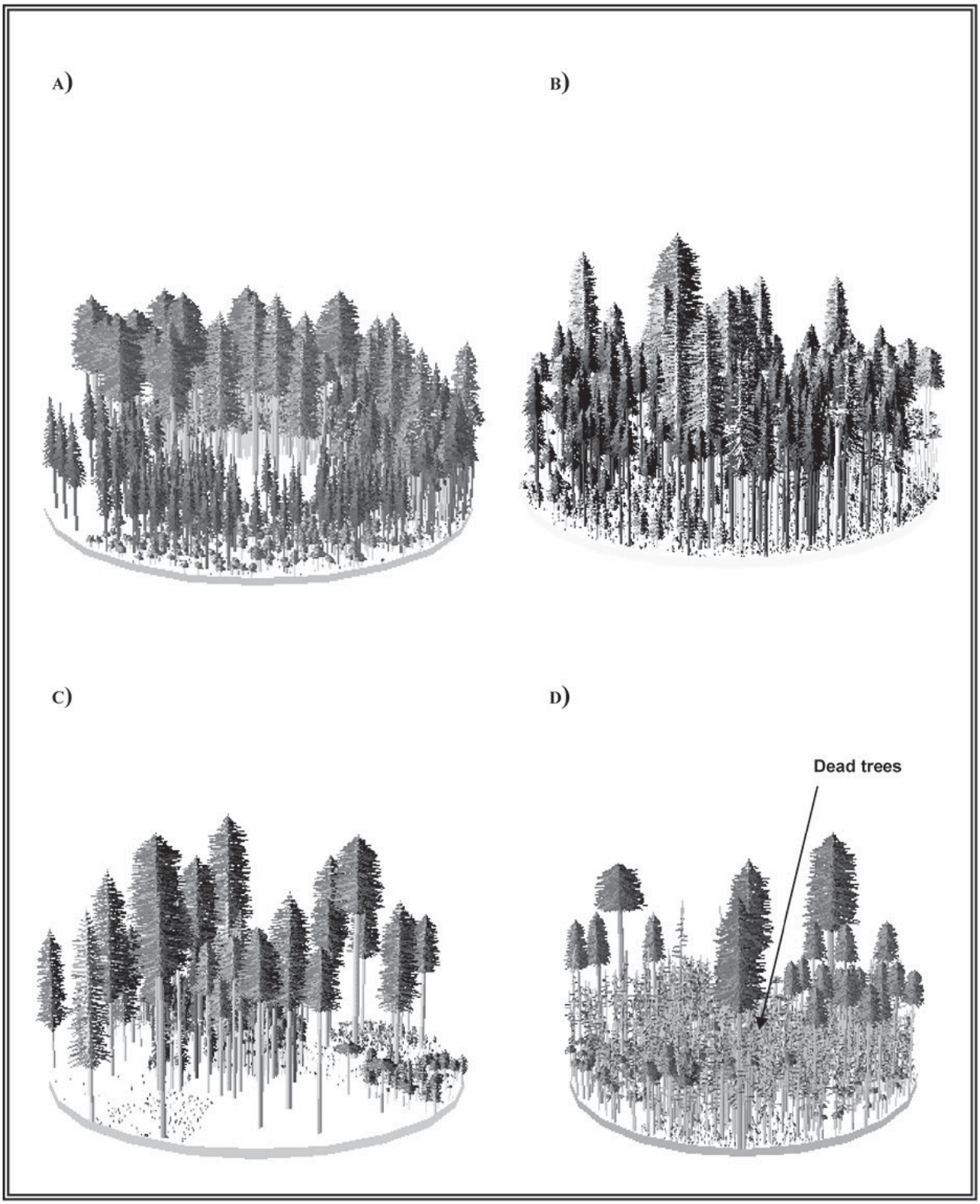


Figure 2—Habitat Stage Classifications for the northern spotted owl focal species area: (A) Stand is nesting roosting and foraging habitat (NRF); (B) Stand is dispersal habitat; (C) Stand has sufficient large trees but not enough canopy cover to be NRF; (D) Stand is nonhabitat — it has neither enough large trees nor enough canopy cover to be considered NRF or dispersal habitat.

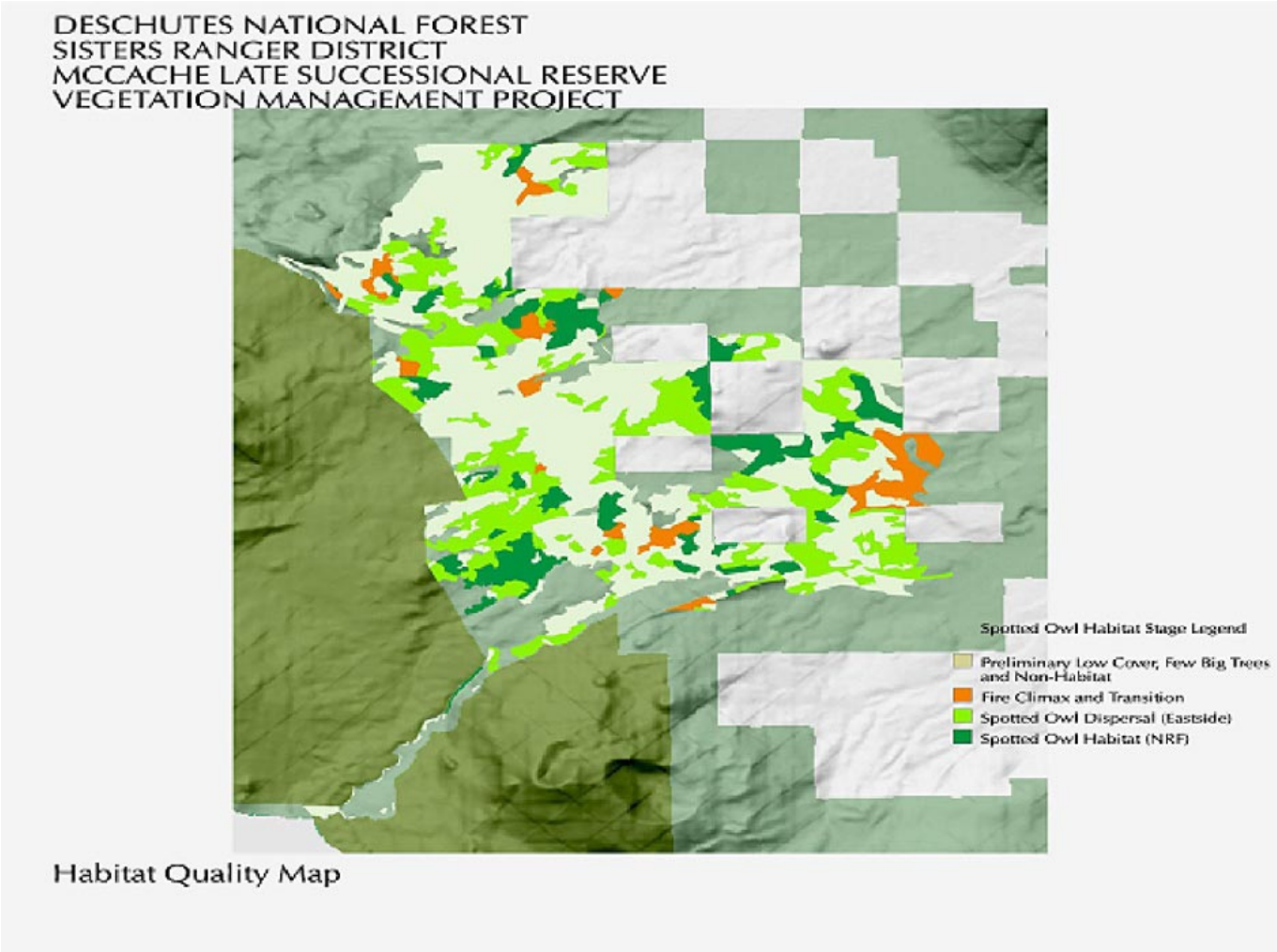


Figure 3—Northern spotted owl habitat stage classifications spatially mapped over the spotted owl focal species habitat area for McCache Vegetation Management Project.

Table 2

Northern spotted owl focal species habitat stage	Probable stand management objectives	Prescription
NRF	Desired condition has already been met	No treatment
Dispersal Habitat	Develop into NRF	No Treatment or
	Reduce fire hazard	Thin from below to 20% below the upper management zone[1]
	Maintain tree vigor and species composition.	
Sufficient Large Trees	Allow fir understory to develop	No Treatment or
	Fire hazard reduction	Thin from below to 20% above the lower management zone[1]
	Maintain health of large trees	
Non-habitat	Retain as travel corridor for other late successional species	No treatment or
	Restore large tree structure as the first step of creating NRF long term	Remove dead trees
		Remove all true fir under 21 inches d.b.h.
	Reduce fire hazard	Thin residual trees or plant a mixture of ponderosa pine and Douglas-fir, if necessary

[1]Stocking levels based on Cochran 1992

be projected in FVS. For the McCache vegetation management project, nearly complete stand exam coverage "with the exception of the plantations" was available. However, partial stand exam coverage is more often the case. We are currently working on another analysis area where only half of the area was inventoried. Stands exams from stands of similar structure (diameter class distribution), density (basal area/acre), and species composition were assigned to the noninventoried polygons to obtain the desired coverage. The assignments were made using the most similar neighbor analysis procedure (MSN) (Moeur and Stage 1994; Moeur and others 1995). Interpreted aerial photography provided the global data layer for the MSN analysis.

Step 8. Construct keyword component files for runstreams; calibrate and select appropriate models and submodels. FVS runs using our technique are constructed entirely of keyword component files (kcp files). These kcp files can be composed of a combination of base and submodel commands as well as custom variables created within the event monitor. For each stand, these keyword component files (kcp files):

- Calibrate the base model
- Call and calibrate appropriate FVS submodels
- Simulate important successional processes not available as off-the-shelf submodels with the user's FVS variant (for example, natural regeneration)
- Assign hazard ratings for important disturbance agents over time
- Simulate proposed silvicultural treatments for each alternative (including followup treatments in later years)

For example, each of the 346 stands in the McCache spotted owl focal species area was assigned four or five kcp files. Kcp files are available upon request:

- The first kcp file calibrated the base model (in terms of site quality and growth); modeled natural regeneration and endemic as well as density-induced mortality from mountain and western pine beetle. In brief, this kcp file addressed live tree regeneration, growth, and mortality processes given the no action alternative.
- The second kcp file initialized and calibrated the western root disease model. Root disease was severe and widespread throughout the area but was not adequately represented in the stand exams. An estimated stand root disease condition was, therefore, assigned based on model ready keyword sets from forest inventory data (Gregg and Goheen 1997) plots in the project area and a 1980s root disease survey of a portion of the project area.
- The third kcp file classified the stand in terms of spotted owl habitat stage, by cycle.
- The fourth kcp file modeled hazard to stand-replacing wildfire.
- The fifth kcp file modeled western spruce budworm hazard.
- The sixth kcp file modeled the prescription assigned to the stand by alternative, including any additional natural regeneration promoted by ground-disturbing activities. This kcp file was not included for untreated stands.

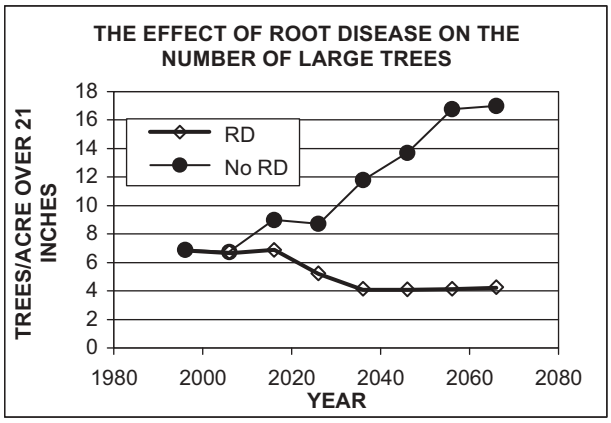
The inclusion of appropriate disturbance models for the long-term projections is critical. For example, the spotted owl focal species area in the McCache project is moderately to severely infected with root disease. As such, root disease will have a significant effect (fig. 4) on the outcomes of proposed alternatives. Without modeling this important disturbance process, future hazardous fuel loads will be underestimated, and projections of spotted owl habitat will be overoptimistic. Figure 4 compares projected habitat development and fuel buildup using and not using the root disease model.

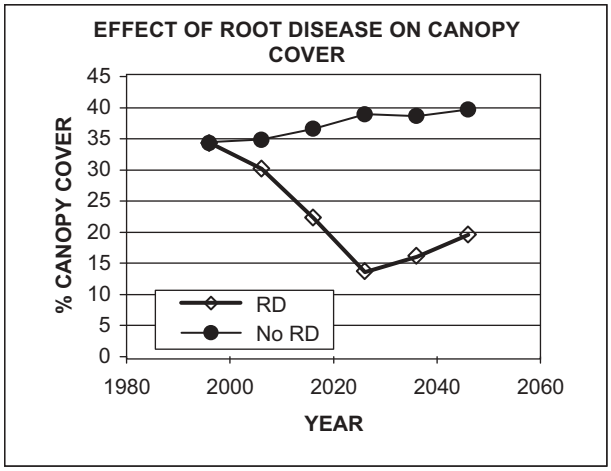
Step 9. Structure runs for processing multiple stands, by alternative, with appropriate kcp files. Because this is a spatially explicit landscape analysis, FVS projection runs commonly consist of many hundreds of stands. Thus, an efficient process for creating the run stream is essential. We recommend that each project share a common Suppose.loc file, but that there be Stand List Files (SLF files) for each alternative. Within each SLF file, kcp files are assigned on a stand-by-stand basis. This assignment is based on the individual stand's focal species area, site quality, insect and disease occurrence, and proposed management treatment. Given the number of stands involved, it would be laborious to manually edit the SLF files and Suppose.loc file to make the necessary kcp files assignments. For the McCache analysis, a project-specific visual basic program was written (by Don Vandendriesche, Forest Management Service Center) and used to expedite the assignment of the kcp files to appropriate stands.

An interactive visual basic program to make these assignments for any project of this type has since been written (by Leo Yanez, Deschutes National Forest). In order to assign stands to groups and/or kcp files to stands, the program edits the Suppose.loc and SLF files referencing user-provided lists of stand exam names. These lists designate group membership and kcp files assigned to the stands. For example, each stand in the McCache LSR project spotted owl focal species area was assigned one of three levels of root disease severity based on forest inventory and survey data. Thus, there are three versions of the root disease kcp file that initialize and calibrate the western root disease model. The user specifies which stand goes with which version in the form of three text file lists of stand names. The process is repeated with other kcp files including the prescription kcp file and the site/quality natural regeneration kcp file. This program is available upon request.

Step 10. Make projection runs, and summarize and display data. Projected variables for each stand can be tied to GIS and mapped so that users can spatially view projected outcomes over time. Tables of outcomes of effects by acres can also be generated with ease as well. Figures 5 and 6 show projections from the McCache LSR comparing the most dramatic action alternative versus the no action alternative, in terms of habitat stage and fire hazard over a 30-year period. Figures 5 and 6 also illustrate the following:

- High fire hazard will persist long term without treatment.
- Damage will continue from disease and insect hazard will increase without treatment.
- Treatment can promote greater stability and initiate the process of developing new late successional habitat.
- Reduced fire hazard comes at the expense of dispersal habitat.





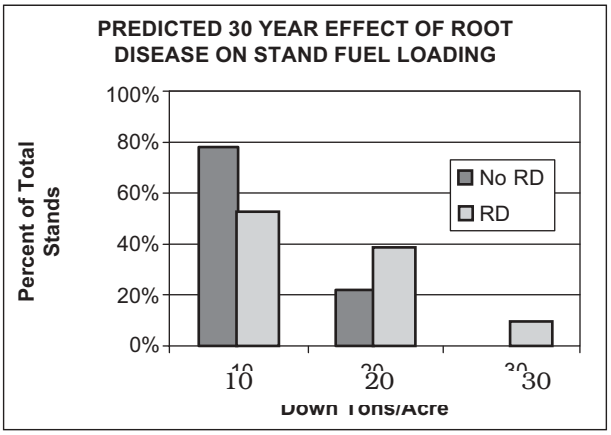


Figure 4—Predicted effects on two key components of spotted owl habitat—large tree structure and percent canopy cover provided by 6 inch d.b.h., or greater, trees and fuel loading. A stand in the McCache project area was projected over a four-decade period using FVS. Projections were made both with and without incorporating the impacts of root disease via the western root disease model. Levels of root disease used for the projections were the actual levels found in the stand.

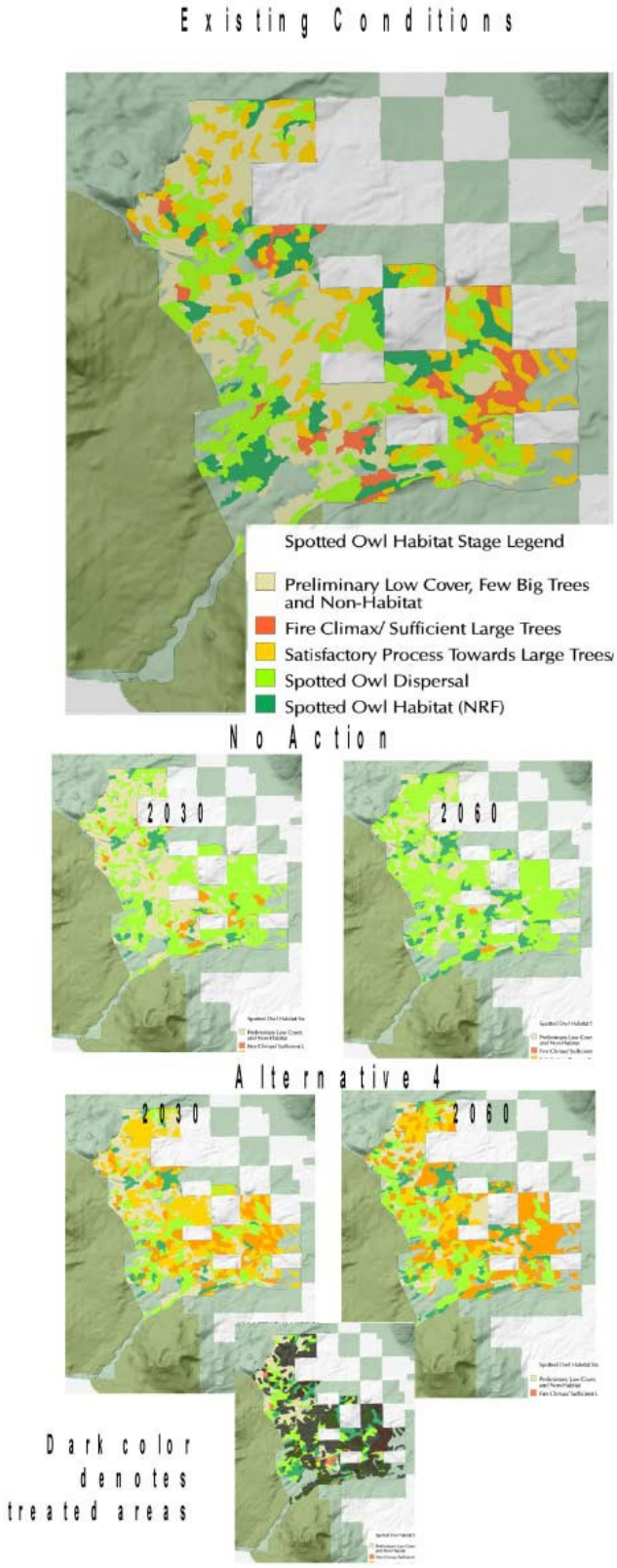


Figure 5—Projected spotted owl habitat stage over time for most dramatic treatment alternative versus the no action alternative for the spotted owl habitat focal species area in the McCache project area.

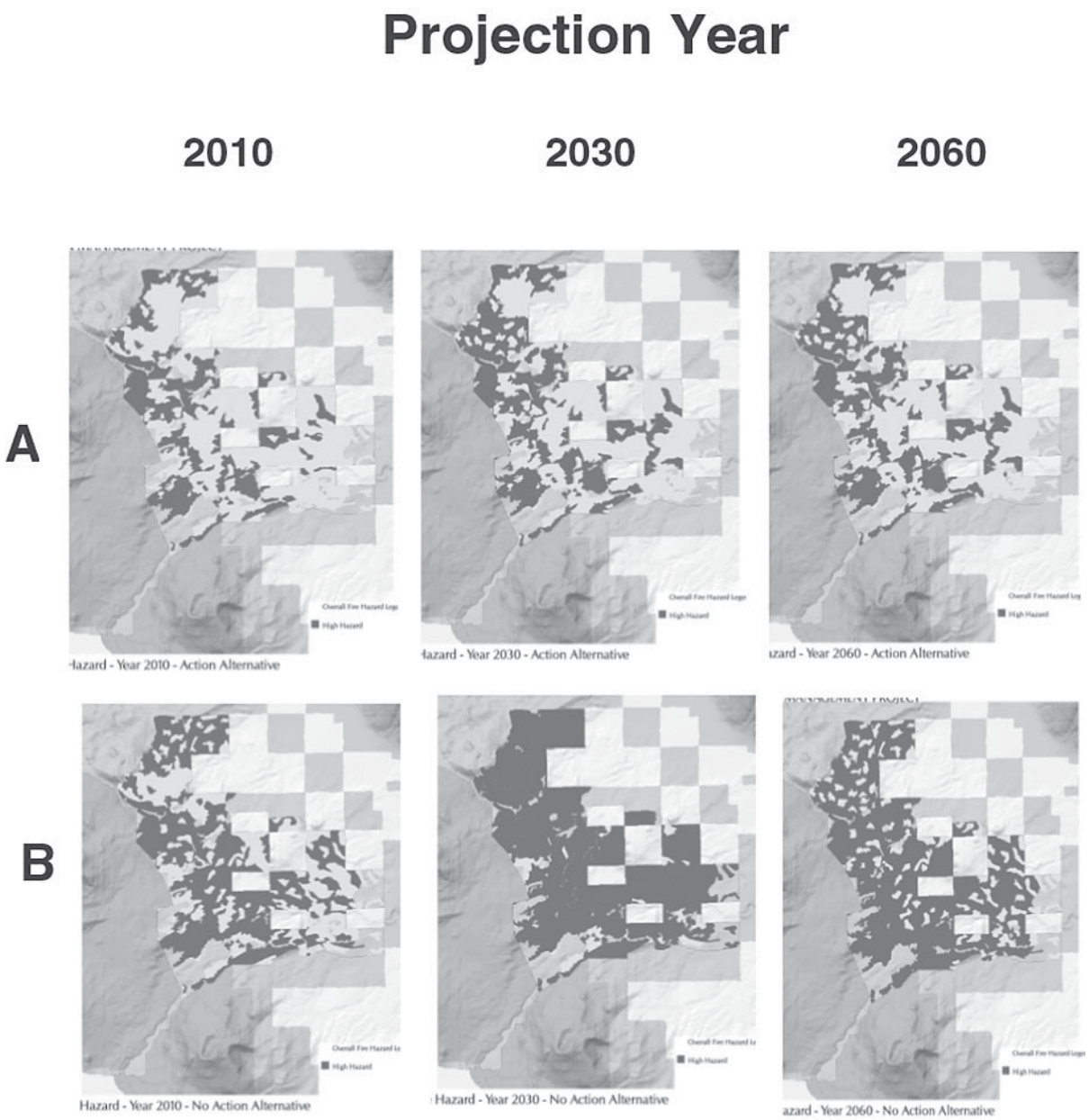


Figure 6—Projected fire hazard over time for most dramatic treatment alternative (A) versus the no action alternative (B) for the spotted owl habitat focal species area in the McCache project area.

Results

In the case of the McCache analysis, the clearly depicted effects established agency and interagency support for the most dramatic action alternative proposed. It demonstrated that, without treatment, late successional habitat was unlikely to regrow on its own (primarily due to insect and disease activity) and that susceptibility to severe wildfire impacts would continue over the long term. The proposed treatments would result in lower fire hazard and promote redevelopment of late successional habitat. The decision notice for this project was recently signed.

Conclusions

We believe this methodology is a helpful and objective landscape analysis tool for evaluating vegetation management projects in late successional reserves and other old growth areas. At the least, it can help convey to stakeholders a common understanding of the logic and rationale driving the proposed actions. It can also help clarify the expected immediate and long-term benefits and tradeoffs between alternatives in terms of the resource of interest, late successional habitat. Spatially explicit graphic and numerical displays of effects on spotted owl habitat over time helped

explain the logic and rationale of the project, demonstrate the need for treatment, and communicate expected effects of alternatives to stakeholders. As a result, understanding and a base of support were developed among stakeholders for the active management proposed by the project.

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