A STAND PRIORITIZATION SYSTEM FOR SILVICULTURAL TREATMENTS

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ABSTRACT

The coordination of silvicultural treatments over broad areas is becoming increasingly complex. This complexity is the result of increasing demands for consumptive and nonconsumptive uses of forest lands, more detailed silvicultural prescriptions, and the need to coordinate silvicultural operations over an entire landscape. A prototype expert system rule base has been developed to aid silviculturists with planning and decision-making on the Okanogan National Forest. This system uses variables such as plant association, overstory species composition, stand structure, stand density, presence of diseases and insects, and other variables to trigger decisions. Silvicultural prescriptions are selected using these variables, and other information obtained in interviews with forest management personnel of the Okanogan National Forest. Resulting prescriptions outline necessary treatments (if any), the probability that a specific treatment will be used, an approximate time line for treatments, and changes in stand structure over time. Silviculturists will be able to use this system for identification of high priority stands for detailed stand examinations, for organization of personnel, for long-term scheduling of silvicultural activities, and for anticipating the effects of silvicultural treatments over broad areas.

Keywords: silviculture, stand treatments, expert systems, forest planning

INTRODUCTION

Silvicultural prescriptions are required before any stand management activity can occur within a national forest. The Silviculturist who coordinates the prescription is expected to identify stands needing treatments, assign treatments, organize personnel for implementation, and monitor the effects of treatments over time. In many stands, silvicultural activities are becoming more intensive and more complicated. In other stands, non-timber values are taking a priority over timber values and stands are being managed primarily for wildlife, watershed, scenic, or other non-timber resources. Silvicultural prescriptions are therefore becoming more complex: on one hand, prescriptions for timber production are more detailed; and on the other, silvicultural treatments designed to meet non-timber objectives are becoming an increasingly common part of silvicultural prescriptions.

The effect of silvicultural treatments on forest landscapes is also an important consideration. In some cases, the most appropriate silvicultural prescriptions may be performed within a stand, but the cumulative effect over a watershed or other large area may be undesirable. In addition, a lack of coordination of silvicultural activities among stands can lead to inconsistent periods of demand for labor, machinery, nursery, and other support systems. Silvicultural activities should be coordinated to accomplish both stand level and landscape level objectives, and to maintain consistent levels of demand for support personnel and resources.

The Okanogan National Forest is obtaining a detailed stand data base developed (in part) from Landsat imagery. Because of the increasing difficulty in assigning silvicultural treatments to many stands with diverse stand histories, variable management objectives, and while also managing cumulative effects over broad areas, the Okanogan National Forest initiated the development of a computer based prototype expert system using this data base.

A primary objective for development of this expert system was to prioritize stands for silvicultural treatments on a forest- or district-wide basis. Data for large numbers of stands can be processed simultaneously to rank individual stands based on their need for certain treatments. This system would allow more efficient use of the silviculturist's time, because initial screening of stands could be accomplished without field-checking every candidate stand. This system would also be a valuable tool for project, area, and forest planning. A field check by the silviculturist will still be necessary, but only for high priority stands that are identified by the expert system. This paper describes the organization of the Okanogan National Forest's silvicultural decision rule base.

The Okanogan National Forest is located on the east slope of the Cascade Mountains in northcentral Washington. Plant communities include grasslands, riparian hardwood types, and a wide variety of pure and mixed species conifer stands. Topography ranges from the gentle rolling hills of the Okanogan Highlands on the east, to the rugged peaks of the Cascade Mountains on the west side of the forest. Forest stands are typically mixed species, with species such as interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), western larch (*Larix occidentalis*), and grand fir (*Abies grandis*) among the most common. Stand structures range from single strata, even-aged stands to stands with several strata and several age classes.

METHODOLOGY

Data Sources

Variables used in this system include species composition, plant association, stand structure, stocking, slope, slope

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position, elevation, aspect, and administrative district. In addition, some decision rules, such as the presence or absence of diseases or insects, require information not present in any existing data sources. This information is deduced from other variables, either explicitly from information provided by personnel of the Okanogan National Forest, or from rules-of-thumb (heuristic) processes (as provided by Okanogan National Forest personnel), to estimate probabilities.

Stand types are defined according to the species composition of the overstory and understory (if present), stocking as measured by crown closure, stand structure, and tree size. Plant association (Daubenmire and Daubenmire 1968; Williams and Lillybridge 1983) was also included because it provides information on potential productivity and identifies stand types where severe environmental conditions might impose limitations on silvicultural practices.

Neither plant association nor species composition were believed to be adequate indicators of potential response to silvicultural treatment. Plant associations and species composition classes were therefore integrated to form plant association groups (PAGs-Table 1). Plant association groups encompassed plant associations which supported similar species compositions where vegetation response to silvicultural operations was expected to be similar. A total of 28 plant association groups were formed from 8 species composition classes and 20 plant associations. Each plant association group followed a separate set of decision trees in the rule base.

Table 1.—Species composition classes, the plant association groups (PAGS) that support these species composition classes, and plant associations within each plant association grouping.

B.	Douglas-fir and pondersoa pine, or ponderosa pine overstory Douglas-fir and ponderosa pine understory
PAG#1:	Ponderosa pine-Douglas-fir/beardless bluebunch wheatgrass
PAG#2:	Douglas-fir/bearberry-bitterbrush Douglas-fir/mountain snowberry Douglas-fir/ninebark Douglas-fir/bearberry
PAG#3:	Douglas-fir/pinegrass
PAG#4:	Douglas-fir/huckleberry
PAG#5:	Douglas-fir/pachistima Douglas-fir/snowberry
D.	Douglas-fir and/or western larch and/or ponderosa pine and/or lodgepole pine overstory Douglas-fir and/or western larch and/or ponderosa pine and/or lodgepole pine understory
PAG#1:	Douglas-fir/pinegrass
PAG#2:	Douglas-fir/huckleberry
PAG#3:	Douglas-fir/pachistima Douglas-fir/snowberry

Stand structure classes were used to characterize the stage of development of forest stands. Six single-story stand structure classes were recognized based on tree size (Figure 1). Four multiple-storied stand structure classes were recognized based on size and crown closure of the overstory (Figure 2). Silvicultural treatments for some stand structure classes were similar and so these stand structures were combined. For example, stands with seedling or sapling stand structures were combined in every plant association group, and the multiple-storied stand structures were combined in many plant association groups.

Structure Class	Quadratic Mean Diameter (Inches)	Dominant Height (S.I. 70) (Feet)	Schematic Diagram
Seedlings	0-1	0-15	
Saplings	1-5	15-43	
Saplings and Poles	3-7	15-61	
Poles and Small Sawtimber	7-16	43-83	
Small and Medium Sawtimber	16-24	61-101	
Medium and Large Sawtimber	>24	>101	

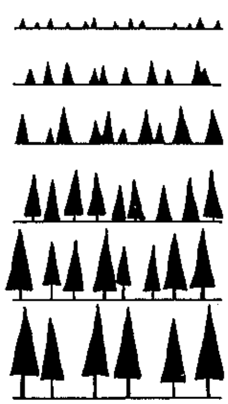

Figure 1.—Descriptions, approximate size ranges, and schematic diagrams of single-story stand structure classes. Quadratic mean diameters and dominant heights are approximations of the average size of trees in the upper crown class when these stands first enter that stand structure class.

Data Acquisition

The information upon which OKXS is based came from: 1) preliminary interviews with individual silviculturists, 2) group interviews with forest management and silviculture personnel, 3) existing results and records from previous research and management activities, and 4) the experience of the authors. Preliminary interviews with Okanogan National Forest silviculturists established a priority for initial decisions when developing a stand prescription. This general order formed the basic format of future decision trees. Decision trees consisted of a series of IF-THEN-ELSE decision rules. A set of decision rules, or one decision tree, were developed for each stand structure class (or grouping of similarly managed stand structure classes) within each plant association group.

Group interviews with the Forest Silviculturist, District Silviculturists, the Area Ecologist, and the Timber Staff Officer of the Okanogan National Forest were used to develop the decision rules. Group interviews helped clarify any differences in silvicultural expertise which might be based on local experience or geographic differences within the Okanogan National Forest. Prescriptions for each stand structure class for a representative plant association group within each species composition class were agreed upon by consensus during the interviews. Rankings of priorities for various management activities for all plant association groups and other points of difference between plant association groups within a species composition class were also determined in these interviews. This additional information was used to develop decision trees and prescriptions for all 28 plant association groups.

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Structure Class	Quadratic Mean Diameter (Inches)	Dominant Height (S.I.70) (Feet)	Crown Closure (Percent)	Schematic Diagram
Small-Large Sawtimber over Seedlings & Saplings	9- >24 0-5	> 101 0-43	5 TO 30	
Small-Large Sawtimber over Seedlings & Saplings	9- >24 0-5	> 101 0-43	30 TO 60	
Small-Large Sawtimber over Saplings & Poles	9- >24 3-7	> 101 15-61	5 TO 30	
Small-Large Sawtimber over Saplings & Poles	9- >24 3-7	> 101 15-61	30 TO 60	

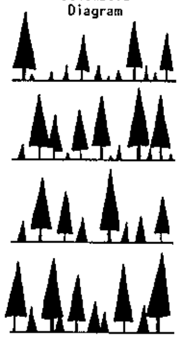

Figure 2.—Descriptions, approximate size ranges, crown closure, and schematic diagrams of multiple-story stand structure classes. Quadratic mean diameters and dominant heights are approximations of the range of tree sizes in the upper strata, and the average size of trees in the upper crown classes of the lower strata when these stands first enter that stand structure class. Crown closure ranges for multiple-story stand structure represent only the uppermost strata.

SYSTEM ORGANIZATION

The organizational structure of this expert system's decision rules is shown in Figure 3. Stands are first assigned to plant association groups, then to species composition classes, and then to stand structure classes. Each stand structure class (or grouping of similar stand structure classes) has a decision tree which triggers the rule base decisions.

Table 2 presents a typical decision tree. The first decision node, or IF-THEN-ELSE decision rule, in this tree concerns the probability that root rot is present in the stand. The experts estimated that for this stand structure and plant association group that the probability of root rot would be 70%. If no root rot were present, one would proceed to the next decision node in the tree. If root rot were present, the experts consensus was that a shelterwood treatment would be prescribed. Each possible stand condition for each stand type, structure, and circumstance was evaluated in this fashion. Probabilities associated with each node are used in lieu of actual knowledge of the particular prescription listed in the tree.

Continuing down the decision tree (Table 2), if root rot were not present (a 30% likelihood), then the next concern would be for the presence of bark beetles in the stand. Note that these decision nodes are independent and sequential. Root rot is dealt with first, whether or not any other problems may occur in the stand. If root rot is not present, then bark beetle problems are considered, independently of any additional problems.

In the case of bark beetle problems, stand density is a decision variable. If stand density is high and insects are present (a 50% probability), then the possible management prescriptions are shelterwood (a 70% probability) or thinning (30% probability). If stand density is low or acceptable then the probability of a shelterwood increases to 90% and thinning declines to 10%.

The "S4" and "T1" in parentheses (Table 2) designate specific shelterwood and thinning treatments which are presented in Table 3. These two treatments are two of 85 included in this expert system. In this shelterwood treatment, the stand will be marked and a first cut made in year 1. For site preparation, a low burn or some type of mechanical treatment are most likely to be prescribed. Regeneration would probably be natural, and a final cut would be prescribed in year 15. Table 3 also shows the thinning treatment prescribed in Table 2. A stand receiving this thinning treatment would be marked, thinned from below, with the slash disposed with a low burn.

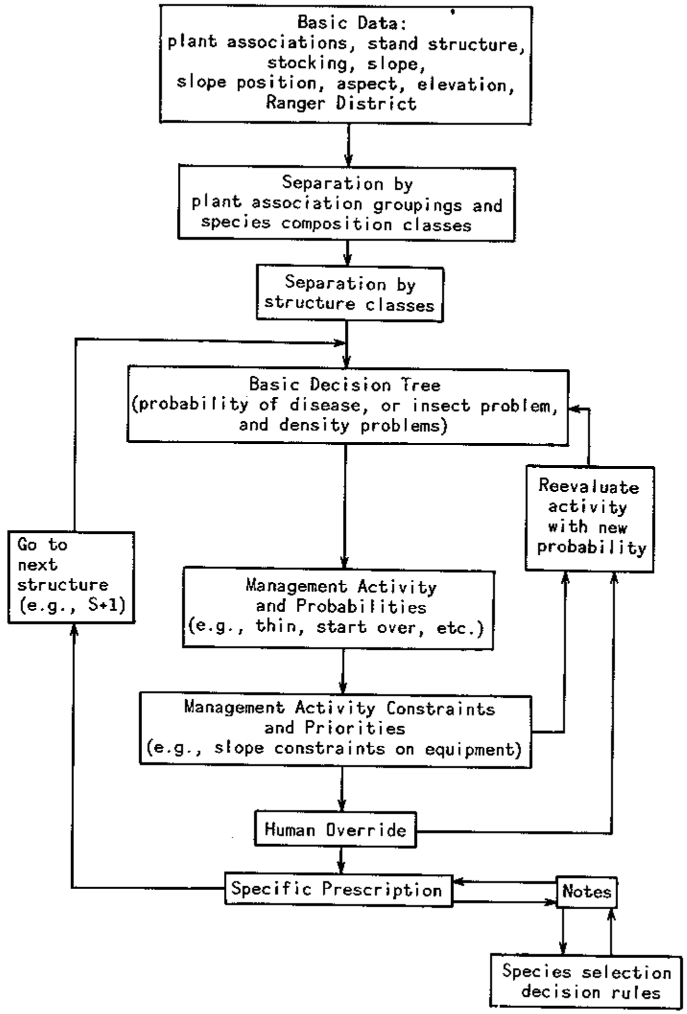

Figure 3.—Flowchart showing organizational structure of Okanogan National Forest's stand prioritization rule base.

The next decision tree node (Table 2) concerns the presence or absence of dwarf mistletoe (*Arceuthobium* spp.). Additional decision nodes provide silvicultural prescriptions for stands with defoliating insects present and stands of different densities.

Table 4 presents a decision tree for the Douglas-fir/huckleberry plant association group when the overstory species consist of Douglas-fir, western larch, lodgepole pine, or ponderosa pine. In comparison with Table 2, where the same plant association group supports a ponderosa pine/Douglas-fir overstory, a greater probability of root rot exists, as does a lower probability of bark beetle problems. The recommended silvicultural activities are also different. For example, in Table 4 clearcutting and seedtree systems are recommended instead of shelterwood systems and thinning treatments (Table 2).

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Table 2.—Decision tree for Douglas-fir/huckleberry plant association grouping when species composition class was Douglas-fir and/or ponderosa pine overstory/Douglas-fir and/or ponderosa pine understory, and stand structure is either small and medium sawtimber, or medium and large sawtimber.

IF root rot present		(p#.7)	THEN	shelterwood	(p=1.0) (S4)
ELSE					
IF barkbeetles present	AND density = high	(p=.5)	THEN	shelterwood thin	(p=.7) (S4) (p=.3) (T1)
ELSE					
IF barkbeetles present	AND density = low or acceptable	(p=.3)	THEN	shelterwood thin	(p=.9) (S4) (p=.1) (T1)
ELSE					
IF mistletoe present		(p=.5)	THEN	shelterwood no action	(p=.9) (S4) (p=.1)
ELSE					
IF defoliators present		(p=.1)	THEN	shelterwood thin no action chemical treatment	(p=.4) (S4) (p=.3) (T1) (p=.2) (p=.1) (Q1)
ELSE					
IF density=acceptable			THEN	shelterwood no action unevenaged mgmt.	(p=.7) (S4) (p=.2) (P=.1) (U7)
ELSE					
IF density=high			THEN	shelterwood no action unevenaged mgmt.	(p=.7) (S4) (p=.2) (p=.1) (U7)

Table 3.—Prescriptions for shelterwood and commercial thinning treatments.

S4 Shelterwood				
mark	p=1.0			year 1
first cut (N12)	p=1.0			year 1
site preparation	p=.4	low burn		year 2
	p=.3	mechanical	(N7)	year 2
	p=.15	chemical		year 2
	p=.1	none		
	p=.05	grazing		year 2
regeneration	p=.5	natural		
	p=.4	plant	(N1)	year 3
	p=.1	seed	(N1)	year 2
final cut	p=1.0			year 15
T1 Commercial thin				
mark	p=1.0		(N6)	year 1
cut	p=1.0	from below	(N7)	year 1
slash disposal	p=.5	low burn		year 2
	p=.3	none		
	p=.2	mechanical	(N7)	year 2
C5 Clearcut				
site preparation	p=.8	broadcast burn		year 1
	p=.2	mechanical	(N7)	year 1
regeneration	p=.8	plant	(N4)	year 2
	p=.2	natural		
competing vegetation control	p=.8	none		
	p=.2	hand release		

Table 4.—Decision tree for Douglas-fir/huckleberry plant association grouping when species composition class was Douglas-fir and/or western larch and/or ponderosa pine and/or lodgepole pine overstory/Douglas-fir with Douglas-fir and/or western larch and/or ponderosa pine and/or lodgepole pine understory. Stand structure class is either small and medium sawtimber, or medium and large sawtimber.

IF root rot present	(p=.9)	THEN	clearcut seedtree	(p=.6) C5) (p=.4) (V1)
ELSE				
IF barkbeetles present	(p=.1)	THEN	seedtree no action	(p=.7) (V1) (p=.3)
ELSE				
IF mistletoe present	(p=.7)	THEN	seedtree no action	(p=.7) (V1) (p=.3)
ELSE				
IF defoliators present	(p=.7)	THEN	no action chemical treatment	(p=.8) (p=.2) (Q1)
ELSE				
IF density = low		THEN	seedtree no action	(p=.7) (V1) (p=.3)
ELSE				
IF density = acceptable		THEN	seedtree no action	(p=.8) (p=.2)
ELSE				
IF density = high		THEN	seedtree no action	(p=.9) V1) (p=.1)

The rule base also includes management activity constraints which limit certain activities. The constraints are indicated in

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the prescriptions (Table 3) with a "N" followed by a number. For example, the "N7" in the shelterwood treatments (Table 3) with a "N" followed by a number. For example, the "N7" in the shelterwood treatments (Table 3) provides a cautionary statement for use of heavy equipment on steep slopes. In this event, the selected management activity would be excluded by a decision rule and the second most likely management activity would be selected. A human override is also provided (Figure 3) which permits the user to exclude a management activity and assign the basic decision tree to select the next most likely management activity. For example, certain management activities may not be possible (e.g., because of budgetary or manpower limitations) and could be overridden by the user and a different silvicultural activity selected.

Once a specific prescription is selected certain notes are called (also designated with an upper case "N" followed by a number; Table 3) which determine the desired species through the use of a series of species selection decision rules. Notes that select the desired species are based on the presence of disease, the plant association, the management activity, and the stand structure. The species selection decision rules used in the prescriptions in Table 3 are shown in Table 5.

Table 5.—Rule base system notes (cautionary statements) and species selection decision rules. Plant association group codes (e.g., B4 or D2 refer to plant association groups in Table 1).

N1.	If plant association group = B4 the preferred shelterwood species (if available) is ponderosa pine.
N4.	If plant association group = D2 and elytroderma is not present then preferred clearcut species (if available) is ponderosa pine.
	If plant association group = D2 and elytroderma is present then preferred clear cut species (if available) is Douglas-fir.
	If plant association group = D2 and root rot is present then preferred clearcut species (if available) is lodgepole pine.
N6.	For stand structure class = poles and small sawtimber: a precommercial thinning treatment may be more appropriate than a commercial thinning treatment.
N7.	Caution! Management activity may be dependent on non-sensitive ground.
N12.	This shelterwood system does not include a second cut.

The last part of the prescription involves projecting the decision tree to the next stand structure. Following a clearcut, a stand is always projected back to a seedling stand structure (Figure 1), whereas following a precommercial thinning a stand is projected to the next oldest structure (i.e., from a sapling to a sapling and pole stand structure). Following the shelterwood prescription shown in Table 3, a stand would be projected to the seedling stage whereas following the thinning prescription (Table 3) a stand would be projected to the multiple-story small to large sawtimber over seedling and sapling stand structure class (Figure 2).

Average site index values for the primary overstory species within each plant association (Williams and Lillybridge 1983) were used to estimate the time required for a stand to grow from one stand structure class to the next. In plant association groups with more than one plant association, site index was an average of the site index values in that plant association group. Ages for the two-storied stand structures (Figure 2) are for the largest trees in the LOWER strata. These trees were assumed to grow at the same rates as trees of similar size growing in the upper-canopy of single-story stands.

CONCLUSIONS

This expert system rule base represents a prototype version of a system that is designed to prioritize stands for silvicultural treatment. A final version of this system will enable the silviculturist to identify stands for immediate management action, and to organize personnel, equipment, and other support systems. It will also serve as a valuable long-term planning tool which will provide projections of future silvicultural activity and resulting effects on forest stand structures over time. Lastly, it provides a tool for coordination of silvicultural treatments over broad areas to meet landscape objectives for non-timber resources.

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