NATURAL REGENERATION FOLLOWING TIMBER HARVEST IN INTERIOR CEDAR-HEMLOCK-WHITE PINE FORESTS

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ABSTRACT

Natural regeneration of interior cedar-hemlock-white pine forests is usually prompt and abundant. These productive sites support up to 10 commercial timber species. Retrospective examination of cutover forest stands allowed determination of variables that are important predictors of regeneration. This report discusses variables such as habitat type, slope, aspect, elevation, residual overstory density and species composition, site preparation, and the number of years since disturbance. These variables can be used to predict stocking, density, and species composition of regeneration. Knowledge of these relationships can also be used to develop silvicultural prescriptions that will result in desired future conditions for these forests.

Advance regeneration is an important component of the total regeneration picture in interior cedar-hemlock-white pine forests. Advance regeneration are those trees that become established prior to the regeneration harvest. Shade tolerant species such as grand fir, western redcedar, western hemlock, and subalpine fir, become established before the harvest, and they usually survive the sudden change in environment caused by reduction in overstory density. Because advance regeneration is present on about 46% of stocked 1/300-acre plots, it is important to carefully consider whether these trees should be retained, especially in such a productive ecosystem. Indian paint fungus is a major consideration for hemlock and true firs in these forests because infection occurs in suppressed advance regeneration.

For this study, adequate historical records were available. Similar studies may be necessary in the future to examine results of new regeneration technologies, to account for shifts in regeneration due to climate change, or to quantify regeneration in other geographic areas. Keeping good records of today's treatments will allow retrospective examination of regeneration success in the future.

Keywords: succession, reforestation, Northern Rocky Mountains

INTRODUCTION

Natural regeneration of interior cedar-hemlock-white pine forests is usually prompt and abundant. Silviculturists have many options to choose from in developing their prescriptions. The major decisions to be made consider the residual overstory (density and species composition), site preparation, planting, control of competing vegetation, insect and disease problems, and whether or not to retain advance regeneration (if present).

Events that take place during and following harvest affect the cutover forest for many years. How we care for the forest determines density, species composition, and site productivity. The time following a regeneration harvest sets the stage for future management options. Thus, it is important for silviculturists to develop and implement prescriptions that produce desired future conditions.

This paper shows the relationships between regeneration establishment and important site conditions/silvicultural practices. Data were obtained from retrospective examination of cutover stands that had received a regeneration harvest 2-20 years prior to sampling. Results of these data analyses can help land managers develop prescriptions that will produce stands of desired density, species composition, and productivity.

DATA

Data were collected in research studies conducted to develop a regeneration establishment model for the Prognosis Model. The Prognosis Model (Stage 1973; Wykoff et al. 1982) is an individual tree, distance independent growth and yield model, originally developed for the cedar-hemlock-white pine forests of northern Idaho and adjacent areas in Montana and Washington. The Regeneration Establishment Model (Ferguson and Crookston 1991; Ferguson and Carlson 1993) predicts regeneration following timber harvests.

Following is a brief description of the study methods. Full details can be found in Ferguson and Carlson (1993). Study stands were selected using stratified random procedures. Lists of previously harvested stands were obtained from major land owners; primarily the Forest Service, U.S. Department of Agriculture. Stands had been harvested between 1959 and 1978 using conventional harvesting techniques. Candidate stands were categorized by regeneration method, site preparation, habitat type, and geographic area. Four to five stands were randomly selected from each category. Historical records were used to determine year of harvest, type and year of site preparation, etc.

Along transect lines, which traversed the stand, sample points were located at fixed intervals. At each sample point, a 1/300-acre circular fixed area plot was installed to sample regeneration, plot conditions, competing vegetation, and overstory density and

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species composition. A plot was stocked if one or more seedlings were established within the plot boundary. Established seedlings were defined as at least 0.5 foot tall for shade-tolerant species and 1.0 foot tall for shade-intolerant species (Table 1). Minimum heights roughly corresponded to the size of 3-year-old seedlings. Maximum size of regeneration was 3 inches diameter at breast height.

Table 1.—Scientific name, abbreviation, and minimum establishment height for regeneration. Species are listed in approximate order of increasing shade tolerance.

Scientific name	Common name	Abbrev.	Min. hgt. ft.
Pinus ponderosa	ponderosa pine	PP	1
Larix occidentalis	western larch	WL	1
Pinus contorta	lodgepole pine	LPP	1
Picea engelmannii	Engelmann spruce	ES	0.5
Pseudotsuga menziesii	Douglas-fir	DF	1
Pinus monticola	western white pine	WWP	1
Abies grandis	grand fir	GF	0.5
Tsuga heterophylla	western hemlock	WH	0.5
Abies lasiocarpa	subalpine fir	SAF	0.5
Thuja plicata	western redcedar	WRC	0.5

The sampling unit was the 1/300-acre plot. Each plot was made as independent as possible by recording plot-specific variables—habitat type, slope, aspect, overstory density and species composition, site preparation, and topographic position. The number of years since the plot was last disturbed could vary within a stand if site preparation occurred after the year of harvest. Systematic spacing of plots along transects and sampling relatively few plots per stand (average of about 25) helped maintain independence of plots within stands.

All established seedlings on the plot were recorded. A subsample of "best trees" on the plot was chosen by identifying (1) the two tallest seedlings regardless of species, (2) the one tallest seedling of each additional species present, and, if four seedlings were not yet sampled, then (3) the tallest of the remaining seedlings, if present, until at least four were selected.

Sampling the tallest tree of each species ensured recording of each species on the plot. Best trees were cut at groundline to determine age. Seedling height and condition (damages, diseases, insects) were also recorded. Any established seedlings not chosen as best trees are called excess trees. Excess trees were counted by species.

The retrospective nature of the study design allows examination of variables associated with regeneration stocking, density, and species composition. Sampling from a number of harvest years allows the effect of time to be included in the analyses, and it tends to average the sporadic effects of seed crops, weather, insects, diseases, etc. Retrospective studies require a shorter period than prospective studies. In prospective studies, conditions of interest are created but results are not available for many years (up to 20 years for this type of study).

For purposes of this paper, the data are reduced from that presented in Ferguson and Carlson (1993). Data are from four habitat types—*Abies grandis/Clintonia uniflora* (ABGR/CLUN), *Thuja plicata/Clintonia uniflora* (THPL/CLUN), *Tsuga heterophylla/Clintonia uniflora* (TSHE/CLUN), and *Abies lasiocarpa/Clintonia uniflora* (ABLA/CLUN) as defined by Cooper et al. (1991). Further, the data are restricted to areas in and near the Nez Perce, Clearwater, Idaho Panhandle, Kootenai, and Lolo National Forests—roughly the area where white pine is a commercial species in the Northern Rocky Mountains.

This results in 5,342 1/300-acre plots that represent different ages, habitat types, site preparations, topographic positions, elevations, overstory densities, etc. Because these data are unbalanced with respect to the independent variables, they are best analyzed using multiple linear and nonlinear regression (e.g., Ferguson and Carlson 1993). It is also of value to study trends of independent variables that predict regeneration stocking, density, and species composition. This can be done when a large number of plots are available to detect meaningful relationships. The material that follows shows averages for independent variables that are important predictors of regeneration. These results agree with regression analyses of Ferguson and Carlson (1993).

RESULTS

Stocking

Stocking is the percentage of plots on which one or more seedlings were established. Stocking summaries were prepared from analyses of the 5,342 1/300-acre plots. Table 2 shows the TSHE/CLUN habitat type has the highest stocking percentage of the four habitat types in the data. The next highest stocking percentage occurs on the THPL/CLUN habitat type. Next are the ABGR/CLUN and ABLA/CLUN habitat types, which have nearly the same stocking percentage.

The effect of elevation is quadratic; that is, the higher and lower elevations have lower stocking percentages, while intermediate elevations have higher stocking (Table 2). The highest stocking percentages occur at 3,500-4,000 feet elevation.

Residual basal area also has a quadratic effect on stocking percentages with lowest stocking at low and very high densities (Table 2), but there is an interaction with aspect. North slopes do not benefit from increasing residual basal area except at very low densities (less than about 30 sq. ft./ac.) (Figure 1). Beyond about 30 sq. ft./ac. stocking decreases, especially as slope increases. In contrast, south slopes benefit greatly from residual basal area (Figure 2). Increasing basal area, up to about 100 sq. ft./ac., increases stocking.

Site preparation interacts with other variables that affect the timing of stocking, species compositions, growth rates, and incidence of disease. Plots with no site preparation have a higher overall stocking percentage than those prepared mechanically or by burning (Table 2). Advance regeneration accounted for the higher stocking percentage for the no site preparation category. Advance regeneration are trees that become established prior to the regeneration harvest and are still less than 3 inches diameter at breast height.

Although plots that received no site preparation have a higher initial stocking percentage than mechanized or burn plots, the increase in stocking over time is less (Figure 3). Thus, if advance regeneration is not present in a stand and site preparation is not done, natural regeneration subsequent to the harvest may not adequately stock the stand in a timely manner. The retrospective nature of the study did not allow determination of whether advance regeneration was not present on mechanical and burn site preparation plots or whether it was present but was destroyed during site preparation. Other implications of retaining advance regeneration are discussed later.

The interaction of slope and aspect is an important predictor of stocking. This interaction is mathematically expressed through regression analysis to predict the probability of stocking (see Ferguson and Carlson 1993). A probability of 0.55 predicts that 55% of all similar plots would stocked with at least one established seedling. The probability of stocking increases as slope increases on north aspects (Figure 4). The opposite is true of south aspects where increasing slopes decrease the probability of stocking quite dramatically. South slopes also have much slower increases in stocking over time than north slopes. East and west slopes are intermediate between north and south slopes.

Density

Trends in density (Table 3) generally mimic those shown for stocking percentages (Table 2). Two exceptions are worth noting. First, density on the ABLA/CLUN habitat type is greater than on the ABGR/CLUN habitat type, even though stocking percentages are nearly the same. This indicates a more clumpy

Table 2.—Stocking summaries. A 1/300-acre plot was stocked if at least one seedling was established within the boundary of the plot.

	Habitat type			
	ABGR/CLUN	THPL/CLUN	TSHE/CLUN	ABLA/CLUN
Stocking %	53.0	60.9	72.8	52.3
No. plots	1,565	1,950	1,255	572

	Elevation (hundreds of feet)					
	24-30	30-35	35-40	40-45	45-50	50-60
Stocking %	55.6	63.5	66.7	59.9	55.9	53.3
No. plots	642	912	1,187	1,435	774	392

	Residual basal area (sq. ft./acre)							
	None	10-20	30-50	60-100	110-150	160-200	210-250	250+
Stocking %	55.5	61.5	65.8	68.6	69.4	62.7	75.0	63.6
No. plots	2,702	807	773	730	232	67	20	11

	Site preparation		
	None	Mechanical	Burn
Stocking %	64.7	54.3	55.8
No. plots	2,994	1,150	1,198

	Years since last disturbance							
	2-4	5-6	7-8	9-10	11-12	13-14	15-16	17-20
Stocking %	52.4	55.5	54.2	60.2	65.8	79.2	74.6	75.4
No. plots	1,044	1,018	882	781	676	467	307	167

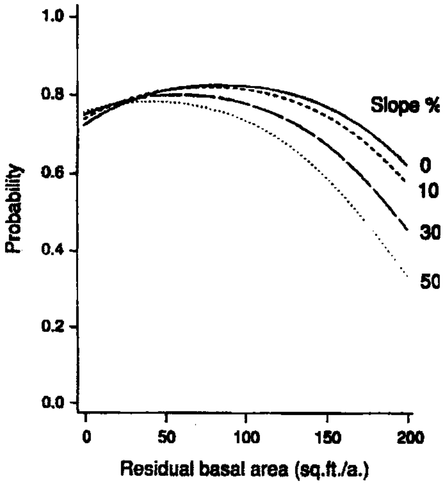

Figure 1.—Effect of residual overstory density on the probability of stocking for a north aspect.

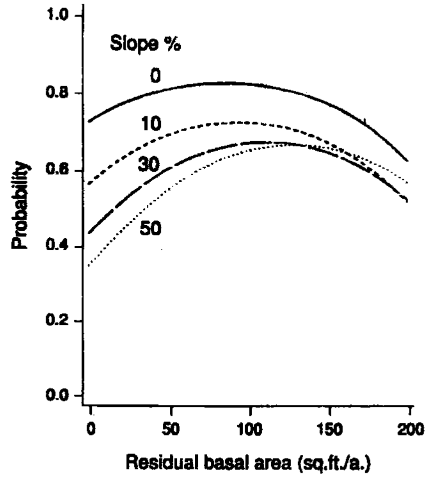

Figure 2.—Effect of residual overstory density on the probability of stocking for a south aspect.

Table 3.—Average number of trees per stocked plot and average density (trees per acre). Average trees per acre is the product of the ratio of stocked plots (Table 2), the number of trees per stocked plot given in this table, and 300 (the inverse of the plot size used in sampling).

Average No. of::	Habitat type: ABGR/CLUN	THPL/CLUN	TSHE/CLUN	ABLA/CLUN
Trees/stocked plot	4.2	8.8	10.2	5.7
Trees/acre	672	1,601	2,235	894

	Elevation (hundreds of feet): 24-30	30-35	35-40	40-45	45-50	50-60
Trees/stocked plot	8.3	8.9	10.5	6.4	4.9	4.1
Trees/acre	1,389	1,697	2,097	1,157	829	660

	Residual basal area (sq. ft./a.): None	10-20	30-50	60-100	110-150	160-200	210-250	250+
Trees/stocked plot	5.8	8.4	9.4	9.6	11.1	11.6	9.3	8.4
Trees/acre	967	1,552	1,855	1,982	2,321	2,185	2,085	1,609

	Site preparation: None	Mechanical	Burn
Trees/stocked plot	8.6	7.9	5.1
Trees/acre	1,662	1,301	849

	Years since last disturbance: 2-4	5-6	7-8	9-10	11-12	13-14	15-16	17-20
Trees/stocked plot	5.4	7.6	6.8	8.5	7.2	13.3	7.4	5.2
Trees/acre	847	1,278	1,098	1,535	1,417	3,157	1,650	1,18

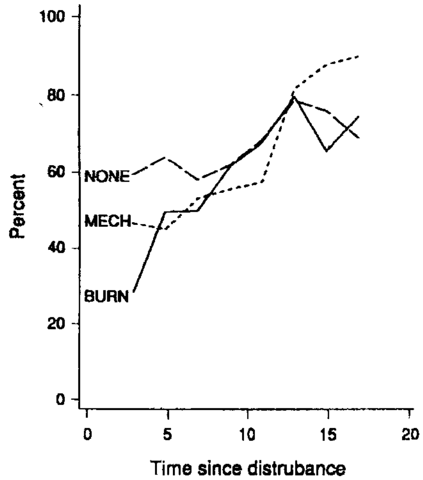

Figure 3.—Effect of site preparation on stocking over time.

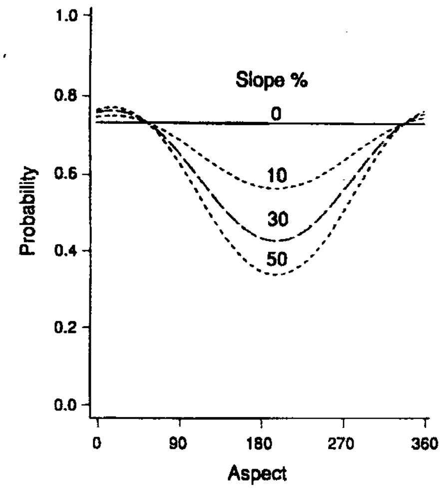

Figure 4.—Effect of slope and aspect on the probability of stocking.

nature to regeneration in the ABLA/CLUN habitat type. Second, there is similar trend for mechanical and burn site preparations. Both had about 55% stocking, but mechanical site preparation has about 1.5 times the seedling density of burn site preparation.

Density as a function of the number of years since last disturbance increases up to about 14 years but then decreases with increasing time. This agrees with Wellner (1940) who noted that stands begin to close at about 15 years of age, and active competition among trees begins. As seedlings become larger, self-thinning begins to decrease density (Table 3), yet stocking remains high (Table 2).

Species Composition

The important variables related to predicting species composition of regeneration are habitat type, site preparation, species composition of the overstory, and the interaction of slope and aspect. Of these, habitat type is the best predictor, which should be expected because habitat types are defined on the presence or absence of certain conifer species.

Table 4 shows species occurrence of best trees on stocked plots by habitat types. Species with low occurrence in these four habitat types are ponderosa pine, western larch, and lodgepole pine. Ponderosa pine is usually only found on the ABGR/CLUN and THPL/CLUN habitat types. The occurrence of western larch is relatively low in northern Idaho but it increases east of the Bitterroot Divide in Montana (Ferguson and Carlson 1993). Lodgepole pine is scattered among the four habitat types.

Engelmann spruce and subalpine fir have much higher occurrences on the ABLA/CLUN habitat type (Table 4). Western redcedar is found on the THPL/CLUN and TSHE/CLUN habitat types while western hemlock is found nearly exclusively on the TSHE/CLUN habitat type.

Douglas-fir is found on all four of the habitat types used in the analyses with similar percentages among the habitat types (range 23-32%). White pine occurrence is higher on the THPL/CLUN and TSHE/CLUN habitat types than on the ABGR/CLUN and ABLA/CLUN habitat types.

Grand fir has the highest percent occurrence of all 10 species, occurring on all four habitat types. On the ABGR/CLUN, THPL/CLUN, and TSHE/CLUN habitat types, occurrence ranged from 68-75%. Occurrence drops to 37% on the ABLA/CLUN habitat type. Grand fir decreases in occurrence east of the Bitterroot Divide in Montana (Ferguson and Carlson 1993).

Site preparation usually increases occurrence of shade-intolerant species but decreases occurrences of shade-tolerant species (Table 4). Shade-intolerant species—ponderosa pine, western larch, lodgepole pine, and Engelmann spruce—benefit from mechanical or burn site preparation. Shade-intolerant species—grand fir, western hemlock, and western redcedar—have decreased occurrence on mechanical or burn plots. The high occurrence of these shade-tolerant species on plots that were not site prepared reflects the high incidence of advance regeneration in these forests.

Not surprisingly, the species composition of the overstory plays a big role in species composition of the regeneration. Every species has higher occurrence when the same species is present in the overstory (Table 4). Increases range from a 1.4 fold for Douglas-fir and grand fir to a 6.5 fold for ponderosa pine.

Species occurrence is also related to the interaction of slope and aspect. Table 4 lists optimum aspects, which are the aspects where occurrence is highest. They are calculated using the procedure described by Stage (1976). The poorest aspect for occurrence is 180° from the optimum.

Six species have optimum aspects of northeast: western larch, Engelmann spruce, Douglas-fir, grand fir, subalpine fir, and western redcedar. Figure 5 shows the general shape of the curves and the probability of occurrence for grand fir. The probability of occurrence for western hemlock is similar to grand fir except the optimum aspect is north and the differences between north and south aspects are greater.

Table 4.—Species occurrences of best trees on stocked plots. Percentages can sum to more than 100% because more than one species may become established on a plot.

	Habitat type				
Species	ABGR/CLUN	THPL/CLUN	TSHE/CLUN	ABLA/CLUN	All habitat types
PP	6.0	4.0	0.2	0.3	3.1
WL	3.5	5.6	7.8	9.4	6.0
LPP	9.7	3.8	6.2	3.3	5.9
ES	5.5	7.4	8.8	22.4	8.7
DF	31.7	23.3	25.9	27.4	26.6
WWP	9.5	12.5	16.1	6.7	12.2
GF	75.0	74.9	67.8	37.5	69.6
WH	0.0	0.1	40.5	0.7	11.5
SAF	4.2	2.7	8.4	49.2	9.0
WRC	0.4	36.8	21.4	1.3	19.8

	Site preparation		
Species	None	Mechanical	Burn
PP[1]	2.0	6.7	12.0
WL	3.8	8.0	10.8
LPP	4.3	9.3	7.5
ES	4.8	12.8	16.3
DF	24.5	25.3	33.9
WWP	12.7	13.3	10.0
GF	79.0	60.8	50.1
WH[2]	48.0	31.3	28.2
SAF3	58.8	58.1	27.0
WRC[4]	32.9	27.1	23.7

	Same species present in the overstory	
Species	No	Yes
PP[1]	4.0*	26.2*
WL	6.1	12.1
LPP	5.5	22.6
ES	8.2	27.8
DF	25.4	35.5
WWP	11.8	24.6
GF	60.5	87.1
WH2	32.5	67.7
SAF[3]	43.1	73.3
WRC[4]	20.0	56.1

Species	Optimum aspect
PP	not significant
WL	northeast
LPP	not significant5
ES	northeast
DF	northeast
WWP	west
GF	northeast
WH	north
SAF	northwest
WRC	northeast

[1] ABGR/CLUN and THPL/CLUN habitat types only.
[2] TSHE/CLUN habitat type only.
[3] ABLA/CLUN habitat type only.
[4] THPL/CLUN and TSHE/CLUN habitat types only.
[5] The occurrence of lodgepole pine decreases with increasing slope.
* This is an example of how to interpret this portion of the table. On plots where no ponderosa pine were in the overstory (10 factor prism), only 4% had ponderosa pine seedlings. On plots where ponderosa pine was in the overstory, 26.2% had ponderosa pine seedlings established on the plot.

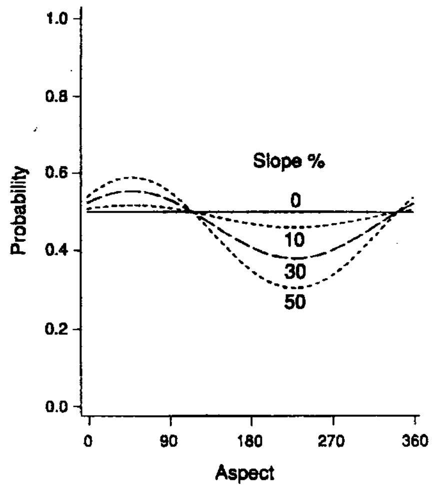

Figure 5.—Effect of slope and aspect on the probability of subsequent grand fir

The optimum aspect for white pine is west, which surprised long-time silviculturist Chuck Wellner, who authored many research papers on white pine. He expected more white pine regeneration on east aspects. Chuck then recalled a paper he co-authored with Virgil Moss (Moss and Wellner 1953) in which they reported that *Ribes* sp. were found infrequently on south and west aspects. Because *Ribes* sp. are the alternate host for white pine blister rust (*Cronartium ribicola*) and *Ribes* plants are less abundant on south and west aspects, perhaps this accounted for white pine regeneration being more abundant on west, rather than east, aspects.

An optimum aspect for ponderosa pine was not found when analyzing the data for this paper. Ferguson and Carlson (1993) found an optimum aspect of south for ponderosa pine when all the data, which included drier habitat types, were used in the analyses. Lodgepole pine also did not have an optimum aspect for the four habitat types being discussed in this paper. However, as slope increases the occurrence of lodgepole pine decreases. This suggests that for these four habitat types, lodgepole pine regeneration occurs mostly on gentle topography associated with cold air pooling.

Advance Regeneration

Advance regeneration occur as the result of natural succession and openings in the overstory canopy when larger trees die. Advance regeneration usually survive the sudden exposure to full sunlight if they are not destroyed by harvest and site preparation operations.

The amount of advance regeneration is impressive. For this study, one or more advance best trees were found on 46% of stocked plots. This percentage agrees with other regeneration studies in the Northern Rocky Mountains (McCaughey and Ferguson 1988). Growth response to release varies with species as well as tree and site conditions. McCaughey and Ferguson (1988) reviewed literature on regeneration response to release for species in the Northern Rocky Mountains.

A major consideration in the management of advance regeneration is Indian paint fungus (*Echinodontium tinctorium*), a heart rot of hemlocks and true firs. The life cycle of Indian paint fungus makes it a major consideration when releasing hemlocks and true firs (Filip et al. 1983).

Infection by Indian paint fungus occurs on stubs of small, shade-killed branchlets. About 40 years of suppressed growth produces the conditions that result in infections. Because the trees are suppressed, the broken off branchlets do not heal rapidly, and Indian paint fungus can enter the wound. After the stub heals over, the fungus can remain dormant for long periods of time. Later, when the trees become larger, infections are reactivated by mechanical injury, such as logging scars, broken tops, broken branches, frost cracks, or insect attacks.

Land managers should use this information in prescribing treatments for stands containing hemlocks or true firs that are or were suppressed. Infected trees will probably have increased decay as trees become older. Therefore, they may not be suitable for uses such as timber production, snags for cavity-nesting birds, or leave trees in partial cuttings. They may be fully suitable for other uses in the ecosystem.

CONCLUDING THOUGHTS

Regeneration success can be predicted from the independent variables discussed here. These variables are commonly used by foresters in the Northern Rocky Mountains. Still, results of the regeneration process are highly variable. With each regeneration harvest, uncontrollable chance events will play a role in determining stocking, density, and species composition. The odds of obtaining successful regeneration can be stacked in one's favor by using the results of this retrospective study in developing silvicultural prescriptions.

The years of stand harvests in this study (1959-1978) mean that results are somewhat historical; that is, they are a function of the climate, insects, diseases, and management practices of that period. Current management practices may have improved regeneration success, and future practices should be even better. Studies should be conducted periodically to keep current with new technology and to assess changes in the regeneration picture due to insects, disease, climate change, ozone depletion, etc. Keeping good records today will allow such studies in the future.

The four habitat types discussed in this paper usually regenerate successfully, although there are exceptions. Examples of areas with poor regeneration success are south slopes, frost pockets, sites excessively site prepared (hot burns, excessive soil disturbance, erosion, soil compaction), treatments that favor pocket gophers (*Thomomys* sp.), and shrubfields. Compared to adjacent forests, these four habitat types are among the easiest to regenerate and are the most productive forests in the interior Western United States. Most silvicultural prescriptions will result in adequate regeneration, given enough time.

Human activity plays a major role in regeneration stocking, density, species composition, and site productivity. For example, this study found high numbers of shade-tolerant species, such as grand fir, cedar, and hemlock. The following human activities could account for this:

- Harvesting practices have removed valuable shade-intolerant species and left less valuable shade-tolerant species. Early managers of cedar-hemlock-white pine forests recognized the potential of shade-tolerant species to crowd out the more valuable western white pine, calling it the "inferior species problem" (Koch 1923; Neff 1928). Marvin Foiles' first assignment as a newly hired researcher was to investigate ways to poison low-value overstory hemlock (Foiles 1950).
- Protection of forests from wildfires has allowed secondary succession to progress. This results in a higher proportion of shade-tolerant species. Over time, as shade-intolerant species die, they are replaced by shade-tolerant species.
- Vastly reduced numbers of western white pine due to mortality from white pine blister rust probably has resulted in a higher proportion of shade-tolerant species, particularly grand fir. Haig et al. (1941), in a regeneration study conducted in the 1930s, showed 38% western white pine and 12% grand fir. Results of the study reported in this paper show only 12% western white pine and 69% grand fir. Haig et al. (1941) do not give details of their study design, so it is difficult to know how similar their study was to the one reported here. However, it appears reasonable that grand fir filled the niche previously occupied by western white pine.
- Shade-tolerant regeneration has survived harvest and site preparation operations in large numbers. Advance regeneration usually survives the sudden change in stand conditions caused by overstory removal (McCaughey and Ferguson 1988). Shade-tolerant species do not always grow as fast as seral shade-intolerant species, nor are they as valuable (except for western redcedar). In the productive cedar-hemlock-white pine forests, the decision to retain advance regeneration should be carefully compared to other alternatives.

Current forest management trends are toward more partial cuttings and fewer clearcuts. Partial cuttings will also increase shade-intolerant species compared to clearcuts. This is even more true if the partial overstory is retained long after the stand is adequately regenerated. Longer (or permanent) retention of the overstory will be better aesthetically, but the overstory will favor shade-tolerant species over shade-intolerant species.

Site productivity is also altered by management practices. Site preparation helps seral species become established. However, we must be careful not to degrade the productivity of the site. We take giant steps backward if site preparation is conducted to obtain regeneration but site productivity is harmed. Examples are excessive removal of organic matter from the soil, removing the humus layer, soil compaction, creation of permanent shrubfields, nutrient depletion that leads to future insect or disease problems, and soil erosion. The volcanic ash cap present in most cedar-hemlock-white pine forests substantially increases site productivity. If it is removed during site preparation or allowed to erode, we lose valuable component of this ecosystem.

We have an ecologically based land classification system to help us manage cedar-hemlock-white pine forests. Cooper et al. (1991) provide a habitat type classification framework for climax and near-climax forests. Two additional pieces need to be put in place to help land managers develop prescriptions that meet objectives. First are descriptions of successional pathways that lead to climax forests. For example, Zack (these proceedings) studied early succession on hemlock habitat types in northern Idaho. Second is continued research to systematically develop management implications by habitat type (or groups of habitat types). This information could be stored in an artificial intelligence system to help managers develop prescriptions that meet objectives.

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