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FOREST REGENERATION AND SEEDLING GROWTH from five major cutting methods in north-central California

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CONTENTS

SUMMARY

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One of the forester's most difficult jobs is to match a silvicultural regeneration cutting method to a given landscape. What he really needs to know is the amount and distribution of the various species of seedlings that are likely to ensue. He also needs some idea of how well each species will grow in that landscape. And he should have some knowledge of the competitive ability of the hardwood and shrub species that threaten his work.

On the Challenge Experimental Forest in north central California this knowledge is available for 9-year-old seedlings from five major silvicultural cutting methods. These are clearcutting, seed tree, shelterwood, group selection, and single-tree selection. All were applied in an area of similar and exceptionally high site quality.

Because bare ground quickly becomes revegetated, various slash disposal and site preparation techniques must be used to prepare the site and reduce competitive hardwood and shrub populations. For each cutting method, these techniques were: clearcut—broadcast burning; group selection—scarifying; shelterwood, seed tree, and single-tree selection—piling by bulldozer immediately after logging, piling just before seed fall, and top lop and branch scatter.

The conifer species evaluated were ponderosa pine, sugar pine, white fir, Douglas-fir, and incense-cedar. Hardwoods evaluated were California black oak, tanoak, and Pacific madrone. Competitive shrub species were whiteleaf manzanita and deerbrush.

Site preparation is just one of the techniques and modifications applied to the cutting methods to make them fit young-growth silviculture and to take advantage of the high site. For example, the traditional shelterwood method was modified from three to two stages to allow earlier establishment of regeneration. Another example is to apply improvement cutting guidelines and remove about 20 percent of the merchantable volume in the initial application of selection cutting. This procedure upgrades the growing stock and harvests would-be mortality.

Each cutting method creates a particular environment in terms of light, moisture, and other factors. A particular environment might favor survival and establishment of one species, but not others. It also might enhance a species survival but not its height growth. Nine years of data and analyses yield trends that provide insight to species potentials in comparative environments.

In the single-tree selection method, ponderosa pine was fairly well stocked, but its height growth was poorer than that of any other species under any cutting method. Opening up the stand just a little more, as in group selection, resulted in nearly twice as many ponderosa pine seedlings and a great improvement in their distribution. It also meant a doubling of the ponderosa pine seedling height growth. But height growth was still only one-third to one-sixth of that in the seed-tree, shelterwood, and clearcutting methods after 9 years.

In the environment created by shelterwood and seed-tree cutting, with slash disposal, ponderosa pine excelled. Stocking was 59 percent (milacre basis) and density was 3620 seedlings per acre (8941 per ha) in the shelterwood, and 61 percent stocked with 2100 seedlings (5187 per ha) in the seed-tree method.

Height growth, however, was held back by the overstory trees. Clearcutting created an environment in which ponderosa pine height growth excelled, but in which seedling density was fair and distribution somewhat clumpy.

The more tolerant conifers (sugar pine, Douglas-fir, white fir) responded much differently to the different environments of the various cutting methods. Seedling stocking and density were best in the selection methods (850 seedlings per acre [2100 per ha] and 40 percent stocking). The shelterwood environment approaches the limit—in terms of light, heat, and moisture—in which seedlings of these species will become established. Plainly, the seed-tree and clearcut environments do not favor the more tolerant conifers. Early seedling height growth, however, became better as the intensity of cutting increased from single-tree selection to shelterwood. Thus the shelterwood environment favored height growth but not establishment of tolerant conifers.

Hardwood regeneration consisted of seedlings and sprouts. Each had a different competitive potential. In general, sprouts were fierce competitors, with rapid growth rates and low mortality. Hardwood seedlings, although prolific, suffered from poor distribution, high mortality, and slower growth rates. The stocking and density of hardwood seedlings and sprouts tended to be high in all cutting methods. Density values varied from 746 to 2937 seedlings per acre (1843 to 7254 per ha), stocking from 24 to 63 percent. Where site preparation was intensive, as in group selection and clearcutting, fewer hardwoods were present.

In all methods, hardwoods were taller than conifer seedlings. But only in the single-tree selection method are hardwoods likely to both outnumber and outgrow conifers in the years to come.

Shrub seedlings also were numerous and well distributed in all cutting methods, except single-tree selection, where the shady environment was not beneficial. Shrub seedlings are most abundant in the clearcuts where they are threatening the conifers and making their distribution more clumpy. They also are overtopping nearly half of the Douglas-fir seedlings, some of the white firs, and a few ponderosa pines. Because broadcast burning stimulates thousands of dormant shrub seeds stored in the surface soil, it is not recommended as a slash disposal technique in conjunction with clearcutting.

This study suggests that each cutting method has unique merits; the forest manager can capitalize on these merits. And he can select from a variety of techniques for site preparation and guides for stand manipulation. He can, therefore, select the combination of methods, techniques, and guides that come closest to meeting his specific management objectives.

The forest manager's repertory contains many cutting methods, slash disposal operations, regeneration alternatives, and stand manipulation guides. These techniques, applied alone or in combination, enable him to practice sound resource management in an atmosphere of increasing and often conflicting production, environmental, and social demands. But before he can apply any of these techniques, he needs to know how the individual species in his forest respond to them. He also must be thoroughly familiar with the invader and pioneer species that can weaken or even ruin his best silvicultural prescriptions.

This paper reports a comparison of five valuable conifer species, three hardwood species, and two abundant and highly competitive shrub species within five different cutting methods in the same area on a site of similar growth potential. Seedling stocking, density, and height growth were compared after a 9-year period. Results indicate striking differences among species and cutting methods, and have strong ecological and silvicultural implications.

STUDY SITE AND METHODS

This study was done at the Challenge Experimental Forest, in north central California. Here, site quality is extremely high. Soils often are more than 100 feet (30 m) deep, and mean annual temperature is 55°F (13°C), and annual precipitation averages 68 inches (1680 mm). These conditions insure that vegetation is both abundant and fast-growing. Indeed, the dominant species, ponderosa pine (*Pinus ponderosa* Laws.), will average 140 feet (43 m) in height in 100 years (Arvanitis and others 1964). Trees 170 feet (52 m) tall at the same age are not unusual.

Other tree species on the Experimental Forest, and the 1.5 million acres (600,000 ha) it represents, are Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), sugar pine (*Pinus lambertiana* Dougl.), white fir (*Abies concolor* [Gord. & Glend.] Lindl.), and incense-cedar (*Libocedrus decurrens* Torr.). Hardwoods, principally California black oak (*Quercus kelloggii* Newb.), tanoak (*Lithocarpus densiflorus* [Hook. & Arn.] Rehd.), and Pacific madrone (*Arbutus menziesii* Pursh), are scattered throughout as individual trees, clumps, or groves (*fig. 1*). Altogether, trees larger than 3.5 inches (8.9 cm) in diameter at breast height (d.b.h.) number 248 per acre (613 per ha) (*table 1*) and contain about 270 ft^2 (62 m^2) of basal area.

Whiteleaf manzanita (*Arctostaphylos viscida* Parry) and deerbrush (*Ceanothus integerrimus* H. & A.) tend to be abundant on the Experimental Forest. Seeds from these shrubs in the duff and surface soil beneath an old-growth sugar pine-white fir forest in central California numbered about 165,000 per acre (410,180 per ha) (Quick 1956). This number probably is conservative for these species in the elevational range of the Experimental Forest. Even after the most drastic site preparation measures, hardwoods sprout. These sprouts, plus frequent and heavy hardwood seed crops, add to the revegetational potential. Conifer seed crops also are frequent and heavy, contributing significantly to revegetation.

Five cutting methods were used in this study: single-tree selection, group selection, shelterwood, seed tree, and clearcutting. Each was applied on three to six compartments having similar topography, soil, and drainage. The total area treated by each method ranged from 18 to 88 acres (44 to 217 ha).

Each cutting method was modified to better fit young-growth silviculture, to take advantage of the

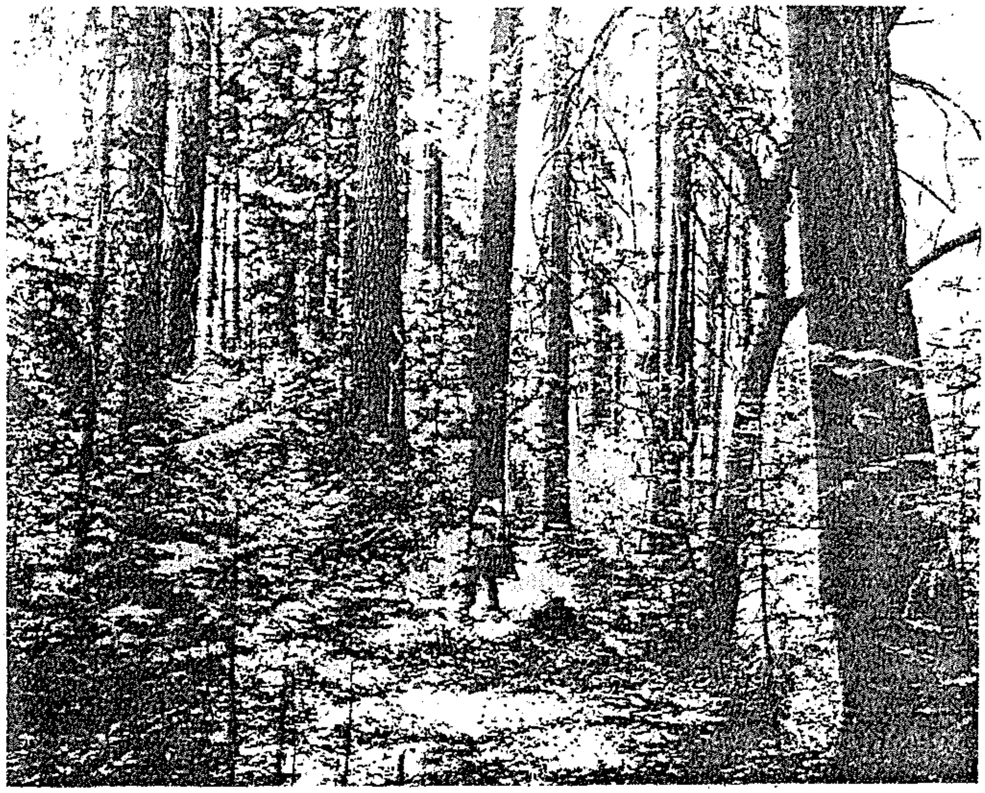

Figure 1—This 90-year-old uncut stand on the Challenge Experimental Forest, north central California, typically has mostly ponderosa pines in the overstory, with hardwoods, incense-cedar and Douglas-fir beneath them.

Table 1—*Stand table before regeneration cuttings, Challenge Experimental Forest, California*

Species	Trees per acre when diameters (inches) were:						
	3.5-8.0	8.1-12.0	12.1-16.0	16.1-20.0	20.1-30.0	30.1+	Total
Conifers:							
Douglas-fir	27	13	7	3	4	2	56
Ponderosa pine	2	4	7	7	17	6	43
Sugar pine	1	0	1	0	1	1	4
White fir	6	2	1	1	1	0	11
Incense-cedar	47	12	4	1	1	0	65
Total	83(205)[1]	31(77)	20(49)	12(30)	24(59)	9(22)	179(442)
Hardwoods:							
California black oak	11	3	2	1	1	1	19
Tanoak	13	5	2	1	0	0	21
Pacific madrone	22	6	1	0	0	0	29
Total	46(114)	14(35)	5(12)	2(5)	1(2)	1(2)	69(170)
Total	129(319)	45(112)	25(61)	14(35)	25(61)	10(24)	248(612)

[1] Value in parenthesis indicates number of trees per hectare.

high site, and to enhance regeneration. The many small trees and the high slash volumes that follow logging (Sundahl 1966) require that some form of slash disposal and site preparation be undertaken after harvesting by each regeneration cutting method.

Basic tenets of the single-tree and group selection methods are frequent cutting and light cuts. Biologically mature and defective trees are constantly removed, and new volume is concentrated on the finest individual stems. In each selection method, cuttings were initial applications. As a marked degree of stand improvement was needed, diseased, damaged, crooked, and over-crowded trees were removed—a worthwhile practice when beginning selection cutting in young-growth stands.

In the single-tree selection method, about 20 percent of the merchantable volume was removed. Large concentrations of slash were piled by a bulldozer and burned in the winter. Otherwise, slash was lopped and scattered. Only a small amount of mineral soil was available, occuring largely where the turning action of the logging tractor mounded the soil, or at the few locations where the slash was piled and burned.

The group selection method created openings 30, 60, and 90 feet (9, 18, and 27 m) in diameter. The size of these openings simulated the removal of several small or large trees (McDonald 1966). Each opening was scarified by a bulldozer to provide a mineral-soil seedbed.

The shelterwood cutting, by design, provided some shade for the sugar pine, white fir, and Douglas-fir seedlings that were anticipated. Therefore, the 12 residual trees per acre (30 per ha) were large, full crowned, and thrifty. All other merchantable trees (those above 12 inches d.b.h. [30 cm]) were removed in a single operation, making this a two-stage shelterwood. This variation of the shelterwood method permits much quicker establishment of regeneration —a desirable goal for windfirm species on high sites. Equal areas on each compartment had slash bulldozer-piled immediately after logging, bulldozer-piled just before a good seed crop, and top lopped with branch scattering. Many smaller saplings and poles, and most of the hardwoods, were eliminated by these treatments. Overstory shelterwood trees were present during the entire study.

The seed-tree method consisted of leaving four to eight vigorous seed-producing trees per acre (10 to 20 per ha) for the entire study. Numerous old cones at the base of a tree constituted a major selection criterion for seed trees (Sundahl 1971). Site preparation was similar to that of the shelterwood cut.

All merchantable trees were harvested in each clearcut compartment. Hardwoods and unmerchantable conifers were flattened by a bulldozer in the spring and broadcast burned about a year later. About 98 percent of the surface area in each broadcast-burned compartment was disturbed—13 percent by fire alone, 46 percent by logging alone, and 39 percent by fire and logging combined (Neal 1975). Hand seeding by cyclone seeders with about 2 pounds (2.2 kg) per acre of conifer seed followed. Ponderosa pine, Douglas-fir, and white fir were seeded both alone and in mixture with sugar pine. Portions of the compartments also were treated by a tractor dragging several sections of heavy railroad iron. This treatment helped cover the seeds (Hall 1967) and reduced rodent depredations.

Sampling in all cutting methods followed a random start-systematic procedure. In some instances, sample plots were located along line transects and in others, along radii. Circular milacre plots 44 ft^2 (4 m^2) in area, were examined for all but the group selection method where one-fourth milacre plots were installed. Seedling stocking and density values were converted, however, to the milacre basis.

In this study, density quantifies the number of seedlings per acre, and stocking is indexed by the percentage of milacre plots having one or more seedlings. In this context, stocking percentage denotes the degree of uniformity with which seedlings of each species are distributed throughout the sampling area. High percents usually indicate rather even distribution; low percents indicate either few seedlings or a clumpy distribution.

Sampling intensity in general was proportional to number and size of compartments in each cutting method. It ranged from a total of 90 milacre plots in the single-tree selection method to 653 plots in the clearcuttings. Regeneration was surveyed at annual and other intervals.

Seedling stocking and density were recorded for all conifers and hardwoods. Shrub seedlings (deerbrush and whiteleaf manzanita combined) were evaluated only by stocking percent except in the clearcut compartments, where density also was recorded. Seedlings were surveyed initially when they were about 2 months old. Each was marked and studied individually. Seedlings from numerous other seed crops became established, but exerted little influence, and were not considered.

In 1960, major seed crops for ponderosa pine, white fir, and incense-cedar were produced as well as fair crops of sugar pine and Douglas-fir. Seedlings from these seed crops were studied in the single-tree selection, shelterwood, and seed-tree methods. The group selection method was installed in 1963 and benefited from a major seed crop of ponderosa pine, sugar pine, white fir, and Douglas-fir in 1964. In the clearcuttings, seedlings of these four species originated from artificial seeding in 1965. In all cutting methods, seeds from at least four different conifer species fell or were distributed. Because overstory composition was heavily weighted toward ponderosa pine, natural seedfall was also. In all methods, seed fell or was distributed 1 or 2 years after cutting. In addition, seedlings in all methods benefited from an equal number of years with good weather, and suffered through at least one of below-average precipitation.

Conifer seedlings examined in this study were 9 years old. The age of most hardwood seedlings could not be determined accurately because many died back to the root crown after disturbance, but resprouted. Thus, above-ground hardwood ages ranged from 4 to 13 years. Most brush seeds germinated immediately after cutting or site preparation.

Seedling heights were measured after the ninth growing season. Where several seedlings of a species of this age grew on a single plot, heights of the three tallest were measured to represent the species on that plot.

Values for seedling stocking, density, and height were analyzed for each compartment, and examined closely for trends. As data for all compartments within a given cutting method were quite similar, they were combined. Stocking, density, and height values then were calculated for each cutting method.

Large differences in compartment numbers and sizes, and differing sampling patterns and intensities precluded statistical analysis. Nevertheless, species relationships are expressed strongly within and between cutting methods.

RESULTS

Within Each Cutting Method

After 9 years, pronounced differences in seedling stocking, density, and height of the various species were apparent. Hardwoods, ponderosa pine, and white fir were better stocked and most dense in the single-tree selection method (*table 2*). The same species performed well in the group selection method, although ponderosa pine led all species in stocking and density. The shelterwood and seed-tree cutting methods favored ponderosa pine, hardwoods and shrubs, as did clearcutting. Shrub species were notably prolific in the clearcut compartments, and their density exceeded 6500 seedlings per acre (16,000 per ha).

Table 2–*Stocking and density of 9-year-old seedlings, by species and cutting methods, Challenge Experimental Forest, California*

	Single-tree selection		Group selection		Shelterwood		Seed tree		Clearcut	
	Stocking (pct.)	Density (seedlings/ acre)	Stocking (pct.)	Density (seedlings/ acre)	Stocking (pct.)	Density (seedlings/ acre)	Stocking (pct.)	Density (seedlings/ acre)	Stocking (pct.)	Density (seedlings/ acre)
Ponderosa pine	23	860	44	1500	59	3620	61	2100	42	1115
Sugar pine	10	111	10	185	8	240	4	75	5	51
Douglas-fir	11	308	6	134	4	80	5	174	4	157
White fir	22	400	22	565	7	192	5	66	4	166
Incense-cedar	4	44	1	16	8	470	5	67	–	–
Hardwoods	52	1330	31	807	53	2225	63	2937	24	746
Shrubs	10	–	43	–	41	–	40	–	51	6523

The arrangement of species based on seedling height growth presented a much different picture. In the single-tree selection cutting, hardwoods and shrubs grew tallest. Next in order of decreasing average height were white fir, sugar pine, incense-cedar, and Douglas-fir (*table 3*). Height growth of ponderosa pine rated poorest among all species (*fig. 2*).

Species behavior in the group selection method was quite similar, although Douglas-fir outgrew incense-cedar and equalled white fir and sugar pine. Ponderosa pine and incense-cedar ranked poorest.

In the shelterwood cutting, conifer species were starting to catch up to hardwoods and shrubs. Of the conifers, white fir and ponderosa pine grew best, with sugar pine a close third. Even incense-cedar grew well where this method was applied.

In the seed-tree cutting, ponderosa pine outgrew other conifers. Hardwoods also performed well. And in the clearcuttings height growth of ponderosa pine accelerated faster than that of other conifer species (*fig. 3*). Shrub height growth also was rapid, and that of the hardwoods, more so.

Figure 3—A 9-year-old ponderosa pine seedling in a clearcutting has grown to be about 6 feet (1.8 m) tall.

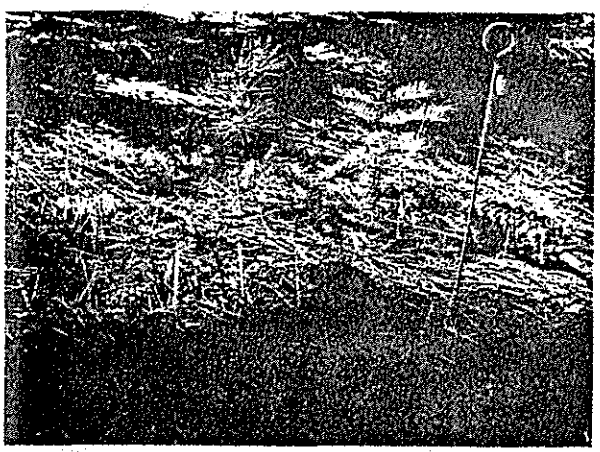

Figure 2—Nine-year-old seedlings in the single-tree selection cutting method. Compare vigor and height of the two ponderosa pine seedlings in the left foreground to that of the sugar pine and white fir.

Table 3—*Height (feet) of 9-year-old seedlings, by species and cutting methods, Challenge Experimental Forest, California*

Cutting methods	Ponderosa pine	Sugar pine	Douglas-fir	White fir	Incense-cedar	Hardwoods	Shrubs
Single-tree selection	.5	1.0	.7	1.4	.9	2.4	2.1
Group selection	1.0	1.5	1.5	1.5	.9	2.4	2.9
Shelterwood	2.7	2.6	2.1	2.9	1.9	2.9	3.1
Seed tree	3.7	3.4	3.1	3.7	2.7	4.3	3.7
Clearcut	6.2	5.5	4.2	4.0	–	12.6	7.8

Between Cutting Methods

Differences between cutting methods are illustrated best by species comparisons. Ponderosa pine stocking and density increased as the intensity of the cutting method increased from single-tree selection to shelterwood. Seedling stocking was best (about 60 percent) in the seed-tree and shelterwood methods, while seedling density peaked under the shelterwood regime at 3620 seedlings per acre (8941 per ha). In the clearcuttings, stocking and density of ponderosa pine seedlings were lower than that of the group selection, shelterwood, and seed-tree methods.

In all cutting methods, ponderosa pine seedling stocking and density outranked that of the more shade-tolerant conifers. Douglas-fir, sugar pine, and especially white fir became established best in the cool, shady habitat provided by selection cutting. Stocking of white fir reached 22 percent and density 565 seedlings per acre (1396 per ha) in the group selection method. Incense-cedar regenerated poorly in all cutting methods.

Hardwood stocking and density were high in all cutting methods. Lower densities and stocking percentages were found in the group selection and clearcut methods, probably because site preparation was more complete in them. The small openings created in group selection were scraped free of hardwoods, and hardwood clumps were uprooted purposely in the clearcuttings. In the other cutting methods, and particularly where slash was lopped and scattered, few hardwoods were eliminated. In fact, they were enhanced. Many small misshapen hardwoods died back to the root crown. Sprouts then burst forth, fueled by sprout vigor (McDonald 1969a).

The percentage of plots stocked by shrubs ranged from 10 to 51, and was lowest in the single-tree selection cut and highest in the clearcuttings.

On the basis of seedling height, species comparisons among cutting methods showed a definite pattern. Without exception, height of every species, whether conifer, hardwood, or shrub, increased as the intensity of the cutting method increased.

DISCUSSION

Each of the five classical silvicultural cutting methods creates a specific environment in terms of light, moisture, soil surface temperatures, and other factors. Seedlings of each species also have specific, but different environmental tolerances. One would think an ideal species-cutting method combination would result for each species within the range of cutting methods studied.

This was so for most species. Ponderosa pine is a good example. In the single-tree selection cut, not enough bare mineral soil was provided. Seeds germinated readily in the duff and litter, but seedling roots seldom penetrated the organic debris on the soil surface fast enough to stay ahead of the rapidly advancing soil drying front in late spring. Consequently, 30 to 40 percent of the ponderosa pine seedlings died during the first growing season. Those that survived lacked thrift and vigor, probably because of inadequate moisture and light. Indeed, many seedlings were only 0.2 feet (6 cm) tall after six growing seasons. Soon, competition from the better adapted, more tolerant species will increase, and light levels will decrease even further. High ponderosa pine seedling mortality will continue, and even if another cutting cycle is applied, most of these seedlings will die.

This same process applies to the group selection method. In the 30- and 60-foot (9- and 18-m) openings, ponderosa pine seedlings closely resemble their puny counterparts in the single-tree selection cut. Only in the center of the 90-foot (27-m) openings have ponderosa pine seedlings become vigorous and robust. But how long this will continue is a moot point.

The shelterwood and seed-tree cutting methods, along with the site-preparation and slash-disposal techniques applied, enhanced the establishment of ponderosa pine. Seed fall was prolific, mineral soil was plentiful, and moisture and light were adequate. The shelterwood and seed trees existed however, at the expense of the seedlings, and seedling height growth was decreased beneath their crowns. If seedling density and distribution meet acceptable standards under this method, seed trees should be removed when seedlings are 2 years old (Mc Donald 1969b).

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Clearcutting followed by artificial seeding presents a paradox. While the quantity of light, moisture, and mineral soil are nearly optimal for ponderosa pine, seedling distribution tends to be somewhat clumpy. This phenomenon probably results from a number of factors: less seed than with natural seeding, hotter soil surface temperatures, especially on south and southwest exposures, and influence of competitive vegetation. Even with a near-complete burn, as this was, pioneer species like bracken (*Pteridium aquilinum* [L.] Kuhn), poison oak (*Rhus diversiloba* T. & G.), and mountain misery (*Chamaebatia foliolosa* Benth.) resprout quickly after burning. Numerous stems surge upward from characteristically dense and extensive root systems. Broadcast burning stimulates thousands of manzanita and deerbrush seeds in the surface soil. Together, they compete vigorously with pine seedlings. In addition, those hardwoods that are not eliminated by dozing and burning quickly sprout. With competition of this magnitude, a clumpy distribution is not surprising.

An ideal species-cutting method combination for the more tolerant conifer species is not as apparent as for ponderosa pine. Individually, the more tolerant conifer species were less numerous than ponderosa pine, and also produced higher proportions of unsound seed, particularly young-growth white fir and Douglas-fir (McDonald 1973). Individually, a stocking value of 22 percent for white fir in the single-tree and group selection methods is quite good. Collectively, a value of about 40 percent and a density of about 850 seedlings per acre (2100 per ha) for the more tolerant conifers also is good. This corresponds to a 6- by 9-foot (1.8- by 2.1-m) spacing if seedlings are well distributed. The environmental regime of mineral soil, relatively cool soil surface temperatures, and short intervals of overhead light favor the more tolerant conifers. Mortality has been low. Their height growth rate has been increasing. Thus white fir, sugar pine, and Douglas-fir should become the dominant conifer species in the selection cutting methods. These species are better adapted to this environment than the numerically superior, but slower growing ponderosa pine.

For more tolerant conifers, the shelterwood cut fulfills a transitional role between selection and other cutting methods. Although ponderosa pine stocking and density are high, white fir grows faster than ponderosa pine, and sugar pine grows almost as fast as it. Apparently, the amount of shelter provided aids the more tolerant conifer height growth, but not establishment. Conversely, it favors ponderosa pine and hardwood establishment, but not height growth.

In the more intensive seed-tree and clearcutting methods, the more tolerant conifers fall victim to the higher ambient and soil surface temperatures. These cutting methods plainly do not favor the more tolerant conifers.

In all cutting methods, hardwoods are taller than conifer seedlings, but whether or not they will remain so is questionable. Preliminary analysis of hardwood sprouts, growing beneath fairly dense stands and in full sunlight, suggests that Pacific madrone and California black oak sprouts have a reduced height growth rate in shade. Tanoak sprout growth was less affected by shade. Also, the relatively poor 9-year height growth of the more tolerant conifer seedlings is the result of very little above-ground growth during the first 3 or 4 years. Now, some of these seedlings, especially white fir, are beginning to accelerate in height growth. Nevertheless, tanoak and Pacific madrone sprouts and seedlings will outnumber conifers in the new community brought about by single-tree selection cutting.

With group selection cutting and scarification, the more tolerant conifers probably will accelerate ahead of all hardwoods except the few tanoak sprouts. All conifers but incense-cedar should outgrow hardwoods in the shelterwood and seed-tree methods. In the clearcuttings, hardwood sprouts are outgrowing conifers, but fortunately there are less of them.

While stocking and height growth of shrubs are high in general, they are not expected to be a major factor in any cutting method, except possibly clearcutting. Here, most of the pines and some of the more tolerant conifers will dominate. At present, 47 percent of the Douglas-firs, 11 percent of the white firs, and 2 percent of the ponderosa pines in the clearcuttings are overtopped by shrubs. These conifer seedlings are smaller, more slender, and less vigorous than their free-to-grow brethren. On high sites, such as this, the trend is toward shorter intervals between harvests. These smaller trees will not reflect the true potential of the site in, for example, 40 years. In an economic sense, they constitute a loss.

Evaluation of a cutting method depends on more than seedling stocking and density. Seedling height growth is particularly helpful. The number, distribution, and growth of shrub and hardwood species also should be known. The differential ability of each species to dominate in a specific habitat having certain parameters of light, moisture, and vegetative competition also must be considered when comparing cutting methods.

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