AGENDA

CHALLENGE EXPERIMENTAL FOREST

R-5/PSW Field Trip--Thursday, October 27, 1977

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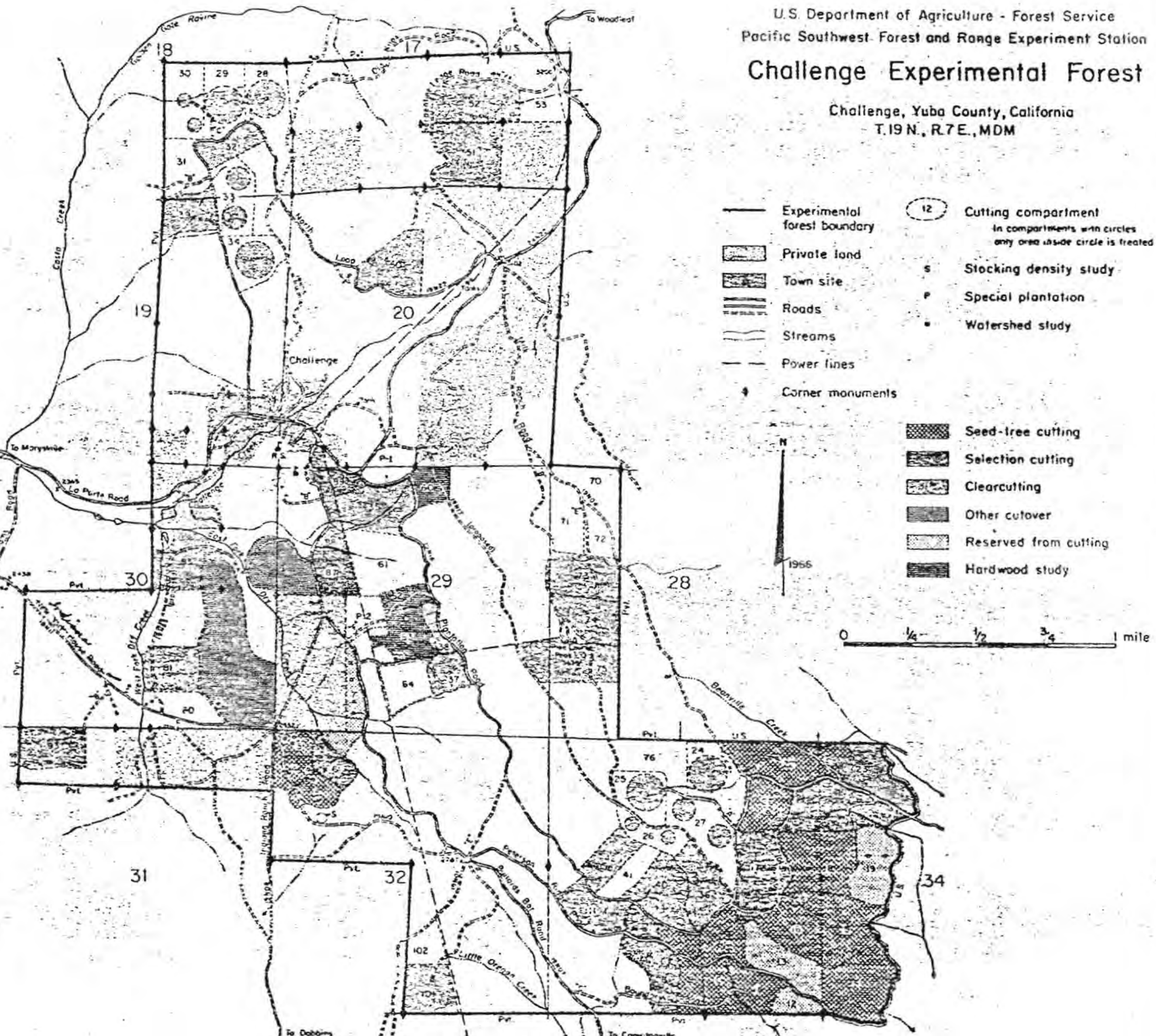


OBJECTIVES AND POLICIES

The basic objective of the Forest Service is to provide progressive national leadership in forestry, embracing the entire field of forestry and its contribution to human welfare. Components of the objective are:

1. Insure that all resources of the National Forest System lands provide products and services to supply their share of national requirements in an economy of abundance.

2. Encourage and assist other owners of forest lands to fulfill their forest-land management responsibilities.

3. Cooperate with states to encourage and assist private owners of forest lands to improve the Nation's forest resources.

4. Maintain forestry research of a size, scope, and competence to meet program needs for research information as the practice of forestry intensifies.

The basic research policy of the Forest Service is to coordinate and gear research activities to management needs for attaining the basic Forest Service objective concerning all forest products and services. This policy relates to the broad field of forest and range resource management and use. Hence, research knowledge attained will be available to all interested agencies, institutions, and individuals.

DEVELOPMENT OF RESEARCH ORGANIZATION

The Forest Service Manual outlines the developments of the Forestry Research program (FSM 1015). In 1905 the forest reserves were transferred from the Department of the Interior to the Department of Agriculture, and the name of the Forestry Division was changed to "Forest Service." Immediately, research by the Forest Service was aimed at solving technical aspects of managing the forest reserves. The first studies were conducted by personnel stationed in Washington, D.C., but decentralization of research began in 1908 with the establishment of the Fort Valley Experiment Station near Flagstaff, Arizona. Other small silvicultural stations in the West were established soon after. These stations were designed primarily to serve the local needs of National Forests, and research staffs were usually responsible to either the nearest Forest Supervisor or Regional Forester.

In 1915 all Forest Service research, except range research, was brought together under the Branch of Research in Washington, D.C., directly under the Chief. Research units in the field began to report directly to the Branch of Research. Range research was assigned to the Branch of Grazing in the Forest Service, but transferred to the Branch of Research in 1926.

In California, the Feather River Experiment Station, near Quincy, was established in 1912. When the California Forest and Range Experiment Station was organized at Berkeley in 1926, the Feather River Experiment Station was absorbed by it. In 1959 the experiment station in Berkeley was renamed the Pacific Southwest Forest and Range Experiment Station.

The McSweeney-McNary Act of 1928 focused national attention on the need for a broad program of forestry research and brought together in a single act numerous existing authorizations, providing a broad charter for research in all phases of forestry. It also authorized a nationwide forest survey and established a system of regional experiment stations.

In 1933 Earle H. Clapp, first chief of the Research Branch, stated policy guides for the development of the research organization and facilities. One of these guides was to provide a suitable research environment, including adequate facilities for good research such as laboratories, libraries, offices, experimental areas and equipment, and, insofar as possible, conservation of scientists' time for research activity.

ORGANIZATION

The research arm of the Forest Service is a line organization with authority descending from the Chief of the Forest Service to the Deputy Chief for Research and to Station Directors. The Deputy Chief for Research has both line and staff responsibilities, and is responsible for overall planning, direction, and coordination. He is assisted by advisors grouped into seven Research Staffs, one of which is Timber Management Research. (Others are Forest Environment Research, Forest Insect and Disease Research, Forest Fire and Atmospheric Sciences Research, Forest Products and Engineering Research, Forest Economics and Marketing Research, and International Forestry.)

Authority within Stations descends to Assistant Director for Research, and, thence, to Project Leaders.

EXPERIMENTAL FORESTS

Experimental forests have been created to enhance research programs. Proposals to establish experimental forests must be approved by the Chief. Proposals covering National Forest land must also be approved by the Forest Supervisor and Regional Forester.

The Station Director has the responsibility for planning and executing research on experimental forests and for determining if any other proposed uses are compatible with research objectives. Coordination of all activities on each experimental forest and operation of that experimental forest is assigned by the Station Director to a specified Project Leader. The Project Leader will exercise control over the research installations and activities required to carry out the research program and to protect research investments.

Experimental forests, generally consisting of sizeable areas, are dedicated to research and provide several advantages. They enable a variety of experimental treatments, including large scale tests, to be established close together, providing valuable demonstrations for training.

Conditions suitable for future study, including problem areas, can be produced. Detailed records generally are maintained so that the researcher has good knowledge of past conditions and trends. Most experimental forests maintain natural compartments which serve as benchmarks against which research results can be measured. Use of experimental forests avoids the time-consuming process of preparing memorandums of understanding necessary before studies are established on national forest, other federal, state, or private lands, and gives the researcher maximum control of the ground where experiments are underway. Finally, use of experimental forests is efficient, eliminating much travel time.

REVIEW OF SILVICULTURAL SYSTEMS

I. Introduction

Theoretically, timber can be grown either in evenaged or unevenaged stands. Evenaged stands are grown to rotation ages which are determined by the products desired and site-production potentials, and then are harvested. These methods of harvest-cuttings can regenerate evenaged timber stands. The method-of-cutting chosen will depend upon the silvical characteristics of the tree species involved and upon the characteristics of the location.

II. Descriptions

One evenaged management method-of-cutting is clearcutting where all trees are cut in one operation. (In some cases, particularly in stands where timber volumes are high, trees are felled and yarded in stages. The second stage, and any stages following, are completed soon after the first stage. Consequently, all stages constitute one operation.) Under clearcutting, reproduction is established naturally by seeds falling from trees bordering the cutting, or artificailly by artificial seeding or planting.

The second method-of-cutting for evenaged timber management is seed-tree cutting. Under this system trees selected for their characteristics and distribution are left standing to produce seeds for regenerating the timber stands. As few as two trees per acre have regenerated some areas successfully. Generally, more seed trees are left. Since seed trees should be the most valuable individuals in the original timber stand, foresters prefer to remove them when reproduction has been established. However, under this system, seed trees may be left until the new stand is thinned commercially or harvested. The seedtree method is not a rational method-of-cutting when seed production by the tree species involved is unreliable.

The third evenaged management method-of-cutting is shelterwood cutting. This system implies that shelterwood trees will perform two functions, those of seed production and site amelioration--generally reduction of heat, but sometimes protection from frost. The shelterwood method may involve three cuttings. The first may be a preparatory cutting, the purpose of which is to open the stand to increase windfirmness in the final shelterwood, and to increase the vigor of trees and their seed-production potential. This first kind of cutting generally is omitted in the system. Hence, the system usually begins with a cutting, commonly called the seed cutting, which creates the shelterwood stand. The last step removes the shelterwood after adequate regeneration has become established--an action required to eliminate competition from the overstory trees.

Evenaged stands may be subjected to cuttings before final harvesting and regeneration of the stands. These cuttings, all termed intermediate cuttings, generally are aimed at maintaining healthy trees and desirable levels-of-growing-stock. They include release, thinning, improvement, sanitation and salvage cuttings.

To be classified as unevenaged, a timber stand must be composed of at least three age-classes. The age-classes should be distributed about evenly chronologically, and the aggregated amount of ground occupied by trees in each age-class should be about the same. Attempts at unevenaged timber management have been applied to forests of mixed species. To be successful, a desirable mixture of tree species must be maintained, and trees in all age-classes must remain vigorous enough to use efficiently ground released to them when the stand is logged.

For unevenaged management the forester must determine the size of the largest trees to be grown and the age that these trees will be, the basal area of the trees which should be carried on the site, the number of age-classes, and a factor which, when multiplied by the number of trees in any age-class, will give the number of trees in the next older class. These data are the bases for computing the ideal number of trees which should be carried in each age-class.

The concept of a rotation age does not apply to unevenaged stands. Instead, unevenaged stands are logged periodically to regulate the number of trees in each age-class. Consequently, once ideal, or near-ideal, stocking is obtained in each age-class, any logging operation will remove trees from all age-classes to maintain proper stocking as increments of trees move from younger to older classes. This kind of timber harvesting is called the selection method-of-cutting.

At least one hybrid method-of-cutting, called group selection cutting, exists where small groups of trees are delineated and harvested. In reality, the small openings created which regenerate successfully generally do not differ biologically from small clearcuttings. Consequently, discussion of group-selection cutting as a separate entity has little merit, if any.

III. Pollutant Sources

Methods-of-cutting can be ranked by the severity of their immediate impacts upon an ecosystem and their potential to create or aggravate sources of pollution. Clearcutting has the greatest immediate potential for damaging environmental quality and is followed in decreasing order by seedtree cutting, shelterwood cutting, and selection cutting.

That methods-of-cutting and associated common practices can have profound effects on some pollutant sources follows. For example, clear-cutting will remove completely the forest canopy. Immediate effects are maximizing solar radiation reaching the ground, maximizing the exposure of mineral soil, and creation of the greatest possible amount of slash.

Slash generally is reduced by broadcast burning, or by bunching into piles or windrows and burning. A practice associated too often with clearcutting is delayed slash burning. If slash has lain too long, burning will be intense enough to produce the maximum amount possible of ash and alter the surface soil structure and chemical composition, and possibly create hydrophobic surface soil.

Under the clearcutting method no one is concerned about protecting residual trees. Consequently, an associated common practice is the indiscriminant movement of logging equipment over the area. Under certain site conditions, this unrestricted movement of machines plus the high volumes and numbers of logs removed can lead to excessive compaction and channelization.

No need to protect residual trees on clearcuttings, and the attendant assumption that movement of equipment needs no control, have led to a related, severe, undesirable practice of using ground-skidding equipment on slopes too steep for this method-of-logging. Tractor roads have been gouged diagonally across contour lines so that tractors could climb the steep slopes. Logs then have been yarded downhill almost vertically to contour lines. The tractor return roads undercut the slopes, in many cases severely, and the downhill yarding creates potential water courses which converge eventually at landings.

A delayed effect of logging which might be significant on steeper slopes, particularly after clearcutting, is the decay of root systems of harvested trees, and consequent loss of mechanical reinforcement of the soil mass on slopes.

Abuses under clearcutting have included the creation of openings which are too large, cutting without regard for water courses, including live streams, and preparation of firelines for broadcast burning without constructing waterbars, outsloping, or other water control measures.

Abuses leading to creation or aggravation of pollutant sources under methods-of-cutting other than clearcutting may not be as severe as for clearcutting, but can be similar. In this respect, seedtree cuttings are most similar to clearcuttings. However, seed trees provide some shade and transpire enough to reduce soil moisture significantly. The seedtree method-of-cutting requires slash treatment, but slash must be moved away from the residual trees to protect them from fire. Slash can be piled and burned, but opportunities for windrowing and burning slash in seedtree cuttings generally are absent. The need to protect seedtrees from logging damage restricts the movement of logging equipment and eliminates some of the abuse caused by indiscriminant travel over a cutting unit.

The shelterwood method-of-cutting leaves enough trees to protect the site from excessive radiation, and potential problems caused by reduced transpiration are eliminated. Practicable slash treatment under this method is limited to bunching in small piles and burning. Equipment movement on the ground will be restricted if damage to shelterwood trees is avoided. Another significant difference of the shelterwood method-of-cutting is that new trees will be well-established before the shelterwood is cut. Therefore, new ground cover and new root systems will provide significant site protection by the time the shelterwood is removed.

Superficially, the selection method-of-cutting seems to be the most gentle site treatment for harvesting timber. However, selection cutting may create overwhelming management problems. First, the desirable tree species composition will be changed in most timber stands to favor less valuable, and in some cases worthless, species. Second, the costs of management will be inordinately high. These two problems do not concern creation of pollutant sources, nor movement of pollutants to receiving waters. They do cast doubt upon the efficacy of the selection system.

Concern has been expressed over the frequent stand entries for selection cutting required under the unevenaged management system. That some undesirable conditions, like soil compaction and significant fuel increases, would accumulate through these frequent logging operations, and further, that sites would not recover naturally, has been suggested. More information is required to establish facts.

IV. Pollutant Movements into Receiving Waters

What effects result from the conditions and abuses described for clear-cutting and other methods-of-cutting? The complete removal of the tree canopy and maximum exposure of mineral soil will accelerate the streamward movement of detached soil particles caused by the impact of raindrops.

Soil compaction reduces soil macropore space and water infiltration. Therefore, if rainfall is intense enough, surface waterflow will be increased and will carry sediment with it. Creation of significant amounts of hydrophobic soils will affect surface flow and soil particle transportation similarly.

Water concentrated by converging skid trails can generate enough energy to erode channels and form gullys which can generate high volumes of sediment by downward and headward cutting.

The quantities of ash produced from intense slash fires on large clearcuttings can change the site chemical balance and might significantly affect downstream chemistry. Some intense slash fires have volatilized nitrogen and have injured severely both soil structure and chemistry.

Loss os transpiration with consequent deep soil moisture increases, the undercutting of slopes by tractor roads, and the loss of mechanical stabilization by the tree root systems may singly or together cause mass soil wasting.

Large clearcuttings located and logged without regard for watercourses and live streams can heat streams significantly and add significantly to sediment loads. Logging debris allowed to remain in water courses can deflect water against banks to undercut them. The undercut banks eventually will slough or collapse into the channels.

V. Control Opportunities

Several significant opportunities exist for controlling pollution (including adverse hydrological characteristics, chemical pollution, and heat pollution) from methods-of-cutting operations, or, simply, final harvesting of timber stands. Some of these opportunities may be unique to a given method-of-cutting. Many are universal.

Control opportunities for properties managed by large organizations begin with certain personnel policies now prevalent. Forestry, which implies management of timber stands, has been recognized as a combination of science and art. Science provides knowledge which has general application. Art includes the techniques by which knowledge can be applied, but also includes the recognition of nuances concerning specific sites and times, the knowledge of which is necessary for successful timber management. Under present personnel policies many individuals responsible for timber management do not remain long enough in a position--including both activity and location--to develop the art required for good management, nor, if acquired, do they have the opportunity to apply it.

Another opportunity to improve pollution control concerns job assignments in some organizations. Timber management activities often are partitioned into planning, harvesting operations, and cultural activities aimed at timber stand regeneration and tending. Timber operations may be planned five or more years before logging. Personnel involved with harvest-planning often are employed elsewhere by the time timber is logged. And the foresters who are responsible for the quality of the logging operations, and those responsible for stand regeneration had no planning input for the operation. That quality of management could be improved by increasing tenure of individuals in timber management positions, and by assigning responsibilities for all timber management activities to a closely integrated team, seems obvious.

Inadequate inventorial data, lack of continuity of records for specific sites, and inability to retrieve specific site information form another barrier for pollutant control. Organizations need to build information on the consequences of management practices under site-specific conditions, and this information must be processed so that it will be retained over time, so its existence will be well-known, and so that it will be available readily. Knowledge of this kind would enhance timber management planning and the results of stand treatments, including reduction of pollutant hazards.

Pollutant control could be enhanced significantly by organizing the ground within each major watershed into landscape facets to form small natural units for management in the future. Organization of the ground into these compartments implies that a transportation system to serve these units will be planned simultaneously, and that the transportation system will include consideration for the methods-of-logging and the location of landings. Ground organization and careful transportation planning will result in several beneficial effects. Particularly important will be the beneficial effects in maintaining slope stability, and avoiding both water excess and concentration.

Pollutant hazards can be reduced by controlling the size, shape, and orientation of cutting units, especially in clearcutting and seedtree cutting. A corollary and extreme opportunity for controlling pollutant sources would be clearcutting in narrow (120 to 200 feet) strips while leaving adequate leave strips. Careful planning for the sizes, shapes, and orientations of cutting units so that they fit the site would limit downslope distances, acceptable lengths being governed by factors such as steepness, soil textures, and precipitation patterns. Limitations to downslope distances would limit water concentrations and velocities, and excess water, and protect slope stability. The timbered borders of well-planned cutting units would cast proportionately more shade than on poorly-planned units, and solar radiation would be reduced.

The yarding operation moves logs from locations where trees were felled to landings where the logs are loaded, generally on trucks, for transportation to mills. The method-of-logging and the specific equipment used should be appropriate for conditions on a cutting unit. After designating aerial, cable, or tractor yarding, equipment can be regulated. For example, cable logging can be by ground-lead, high-lead, or skyline which, in order, vary in degree of ground disturbance from heavy to medium, to light. For tractor yarding, rubber-tired skidders cause the greatest compaction, and true track-layers (like the FMC tractor) cause the least.

Several practices concerning yarding constitute opportunities for controlling pollutant sources. For example, the locations of landings, skid roads, and skid trails can be planned. One objective of detailed planning for the yarding operation would be to limit the area occupied by skid roads and skid trails. One limit suggested which seems reasonable is 15 percent of the cutting unit. Skid roads and skid trails should be located on the ground and designated visually by flagging. Tractors then can be required to stay on those roads and trails. Under this restraint, logs must be winched (endlined) to the tractor. All these practices would reduce soil compaction, exposure of mineral soil, and water concentration.

Other tractor yarding or yarding-related controls should be considered. These are:

1. Limit length of logs for yarding. In general, shorter logs can be maneuvered to skid trails in shorter distances than longer logs.

2. Prohibit tractor skidding on steep ground--generally slopes greater than 30 to 50 percent, depending upon site characteristics.

3. Avoid severe soil compaction by regulating the time of logging to acceptable soil or soil surface conditions like frozen ground, ground covered with snow, or soil moisture less than a determined critical content. These criteria apply equally to mechanical slash disposal activities.

4. Limit the loads of tractor skidders according to their ground-surface bearing pressures and site conditions including slopes, soil textures, and soil moisture contents.

5. Require directional tree felling away from water channels and toward designated skid roads and trails.

6. Require felling and yarding in stages. Felling beds can be reused and skid trails can be reduced, as well as tree breakage and the resultant slash.

Another way to reduce the quantity of slash is to reduce utilization standards for minimum merchantable logs. The smallest log diameter can be decreased and the amount of acceptable decay or other defect can be increased. Although slash reduction generally is a worthy objective, slash disposal should not be overdone. Some slash enhances the ecosystem by providing habitats for a myriad of organisms (including fungi, insects, amphibians, snakes, birds and animals), by providing a nutritional pool from which nutrients will be released, and by providing mechanical barriers to downhill movement of detached soil particles. Slash also can ameliorate the site by breaking up patterns of solar radiation and air movement. Consequently, thorough slash removal is desirable only in live streams and other water courses.

Clearcuttings should be planted or artificially seeded as soon after slash disposal as practicable unless advantage of visible seed crops can be taken. Tree stocking from either artificial or natural sources on any cutting unit should be monitored, and sometimes protected from livestock, during the period when regeneration is becoming established so that remedial treatments to adequately restock the cutting unit can be instigated if required.

The last suggestion for a protective treatment for cutting units is to find some kind of lesser vegetation which can be established soon after slash treatment. These plant species could be either ephemeral, like some exotic fireweeds, or be able to enhance the site while not competing with the new tree stand. Some nitrogen-fixing plants possess these characteristics.

HISTORICAL BACKGROUND AND PHYSICAL DESCRIPTION

Research began at Challenge in 1958. Reasons for locating this experimental forest here are:

a. Need to study young-growth forests.

b. Need to study a mixture of economically promising conifer and hardwood species.

c. Need to get research results fast. A high site gives fastest response to vegetative manipulation; and Challenge is a super site.

d. Intensive forestry is a coming wave.

e. A large audience of forest landowners on 1.5 million acres of high site land.

f. A need to have most major forest cover types under study on experimental forests. Previously established experimental forests covered all but the westside Sierra Nevada ponderosa pine types.

Site quality is outstanding. It is Site A--better than Dunning I. Ponderosa pine will average 140 feet in height in 100 years. The major dominant species is ponderosa pine. This species forms two major forest cover types: Pacific ponderosa pine and Pacific ponderosa pine--Douglas-fir. Past stand history of logging and fire are the reasons for the young-growth, even aged, mixed conifer and hardwood forest present today.

Soils are 30 to 100 feet deep and fertile as forest soils go. Average annual precipitation is about 66 inches per year. Mean annual temperature is 55 degrees F. Elevational range of the Experimental Forest is 2400 to 3500 feet.

Cooperative Tree Improvement Study

PROGENY EVALUATION SITE FOR PONDEROSA PINE

This is one of several sites selected for outplanting and evaluation of those progeny derived from phenotypically superior ponderosa pine parent trees as part of the Regional Tree Improvement Program.

The method adopted in the Master Plan is to select superior trees in wild stands and graft the superior germ plasm into seed orchards while concurrently establishing their progeny in evaluation plantations. Evaluation of progeny performance represents a more precise determination of the genetic worth of the parents and it provides the basis for roguing seed orchards. After roguing only those parents with the most valuable genes remain to mass produce seed for reforestation. Thus, two stages of improvement are involved:

1. initial phenotypic selection, and
2. family selection based on average performance of progeny in plantations.

The final stage which generates the greatest improvement corresponds closely to the time when orchards come into full production (i.e. about 10 to 15 years of age).

The progeny of parent trees on parts of the Lassen, Plumas, and Tahoe National Forests will be tested on this site as well as three others. The four sites were chosen to represent the environmental diversity encountered in Breeding Zone 2. The objective is to select those families that are consistently above average in performance across these sites and thus broadly adapted to environments within the Zone.

This Challenge site has several important advantages:

1. it has the highest site quality and those should allow fullest expression of genetic potential;
2. it has excellent environmental records due to previous research studies;
3. it meets stringent criteria of accessibility, location, etc;
4. it provides a valuable opportunity to improve silvicultural practices in plantations of known and improved genetic stock through cooperative studies with research scientists at PSW;
5. its proximity to other research studies will assure frequent visitation and thus have high demonstration value.

A Memorandum of Understanding, signed by the Regional Forester and the Station Director, was established to clarify responsibilities and intent of the long-term use of the land. This memorandum states specifics of plantation locations and timing of cutting and site preparation for them. Additional plantation sites for progeny evaluation also are specified for sugar pine and white fir.

A confounding problem, which must be dealt with strongly, is the rapid regrowth potential of tanoak and bearclover. Both of these species sprout from extensive root systems that are impossible to eliminate by mechanical site preparation. Lack of adequate treatment with herbicides could result in biased comparisons among tested families. An Environmental Analysis Report by the zone geneticist notes that the potential impact of a 2,4-D treatment is minor. Such a treatment is anticipated before planting this spring.

CLEARCUTTING (Comps. 127 & 129)

These areas are two of several clearcuts created since 1963 for studies of regeneration establishment and development, slash disposal, and winter logging feasibility. Regeneration methods studied have been natural seeding from surrounding timber, natural seeding from seed on the ground at the time of logging, and artificial, or direct, seeding. The studies of natural seeding by surrounding timber include studies to determine the optimum and maximum sizes of clearcuts that can be thus regenerated. Sizes have ranged from 2 to 60 acres. Slash disposal methods studied include broadcast burn, pile-and-burn, and windrow-and-burn. Since 1968 we have included all residual vegetation except leave trees in "slash." We have also made clearcuts with similar slash treatment in connection with other studies to create uniform conditions and reduce the number of variables.

Comp. 127 (to the west) is a 60-acre clearcut logged in 1969 for a study of natural regeneration from surrounding timber. Slash disposal was windrow-and-burn. The stand was identical to the adjoining timber--100 years old, 40 M bf per acre, 80 percent ponderosa pine, and no old growth residual. Seed crops occurred in 1970, 1973, and 1976. This is the largest clearcut we have made. At the time the study was planned it was expected that it would be too large to be adequately regenerated in the center of the block; however, seedlings from all three crops are established in the center of the block. Though the wind is usually from the south and southwest, most seed apparently is shed during dry north and northeast winds. Overall milacre stocking is currently about 56 percent with an average of about 2,250 seedlings/acre in the outer 200 feet of the block and about 600 per acre throughout the remainder of the block, including the center. Virtually all the regeneration is ponderosa pine. Brush, from long-lived seed on the ground at the time of logging, is dense and vigorous but probably will not seriously inhibit the growth of the pine in this block; in other areas on the Experimental Forest a two-year delay in the establishment of regeneration was fatal to regeneration success. Successful natural regeneration of a clearcut block this large has important implications for both research (e.g., how large should a regeneration study block be to achieve adequate isolation and avoid contamination from surrounding stands?) and management (e.g., how large must a block be for successful stocking or species control by artificial regeneration?).

Comp. 129 (to the east) was originally a 10-acre clearcut block logged in November of last year to study: (1) natural regeneration from seed on the ground at the time of logging, (2) the feasibility of winter logging, and (3) the feasibility of windrow and burn treatment of winter-logging slash during the same winter that it is created. Slash disposal was windrow-and-burn. Though results were very good for all three objectives, the results are invalidated by the unusual dry weather during the winter of 1976-1977. Milacre stocking measured after the rains of last month and before the clearing for the superior tree testing plantation was about 88 percent with about 2,000 seedlings per acre. This is the most regeneration we have obtained from seed on the ground at the time of logging. We have accidentally obtained fair regeneration this way on several occasions, but the only other time we tried it on purpose was a total failure. Reasons for success and failure have not been determined but probably satisfactory results with the method require a heavy seed crop (18-acre, and possibly larger, clearcuts can be satisfactorily regenerated from the surrounding timber with only medium seed crops); also, probably the sooner logging occurs after seedfall the greater the chances of satisfactory results. About 3 acres on the east side of the block is excluded from the superior tree testing plantation and is available for present and future observation of the regeneration.

Studies of direct seeding of ponderosa pine in clearcut blocks at Challenge indicate that established-seedling/seed ratios of about 20 percent can be expected in normal years, and that one pound of ponderosa pine seed per acre (6,500 to 8,000 viable seed per acre) will produce at least 400 established seedlings per acre in the worst of weather conditions for regeneration likely at Challenge. Seed in these studies had endrin-arasan-aluminum dust coatings. We have no evidence that rodent control prior to seedings is beneficial.

Direct seeding studies also indicate that for regeneration purposes windrow-and-burn slash disposal is much superior to broadcast burning. The attached table shows the proportional amounts of various conditions that were present after our broadcast burns and their relative efficiency as seedbeds in direct seeding studies. The total proportion of area mechanically disturbed (about 2/3's) was about twice what was disturbed in logging; the additional disturbance resulted when hardwoods and submerchantable conifers were pushed over with the tractor before burning. After windrow-and-burn slash disposal only two seedbed types are present in significant amounts--the mechanically disturbed unburned type and the mechanically disturbed hard burn type. Windrows, and therefore the area of hard burn, occupy 10 to 12 percent of the total area of clearcuts. The overall seedling/seed ratio in broadcast burned clearcuts one or two years after seeding was about 11 percent. Six years after seeding, direct seeded windrow-and-burn areas still average seedling/seed ratios of about 15 percent.

We have found that windrow-and-burn slash disposal has additional advantages relative to broadcast burning.

1. Can be burned under conditions which allow virtually no chance of escape (in the dead of winter after 30 or more inches of rain).
2. Seldom necessary to hold over because of unsuitably dry or wet conditions.
3. Burning can be accomplished with a minimum of manpower and equipment (for the past two years the entire burning job has been done by one man with matches and a shovel).
4. Can always be burned to peak when air pollution effects are minimum.
5. Most of area can be regenerated even if windrows must be held over.
6. Results in less competition to conifer seedlings during establishment period, if seeded promptly, and perhaps throughout the rotation.
7. Reduces the hardwood component in the new stand.
8. Probably reduces rodent populations, and seed depredation due to them, through greater reduction in rodent food and cover.

Natural plant successions following the two slash disposal methods are different--broadcast burning seems to result in more deerbrush than windrow-and-burn.

Windrow construction rates with D-7 tractor and brush rake average around 2.50 to 2.75 acres per day, depending on slope, original and residual stands, weather, and other factors.

Burning costs are consideraly higher for pile-and-burn slash disposal than for windrow-and-burn because of the need for more fire sets and the greater likelihood of piles becoming too wet to burn.

Table --*Proportional area and efficiency index, by type, of available seedbed, averaged for 19 broadcast-burned subcompartments, broadcast seeded with ponderosa pine, Challenge Experimental Forest, California, 1967-68*

Seedbed type	Proportion of available seedbed area[1]	Times observed	Proportion of established seedlings	Seedbed efficiency index[2]
	Percent		*Percent*	
Mineral soil, ≥37.5%:				
No mechanical disturbance:[3]				
Unburned[4]	2.0	49	0.2	0.08
Light burn[5]	9.8	245	4.7	0.48
Hard burn[6]	0.5	20	0.1	0.21
Subtotal or average	12.3	314	5.0	0.41
Mechanical disturbance:				
Unburned[4]	35.9	628	50.9	1.42
Light burn[5]	26.6	611	24.4	0.92
Hard burn[6]	3.4	137	2.0	0.59
Subtotal or average	65.9	1376	77.3	1.17
Mineral soil, <37.5%	11.4	313	6.6	0.58
Unclassified[7]	10.4	192	11.1	1.06
Subtotal or average	21.8	505	17.7	0.81
Total or average	100.0	2195	100.0	1.00

[1] Total available area averaged 98.6 percent of total area. Most commonly, seedbed was unavailable because of stumps.

[2] Percent seedlings divided by percent area.

[3] Disturbance, if any, did not extend to mineral soil. Causes of disturbance include tractor activity, felled trees, skidded logs, etc.

[4] Both litter and uppermost soil layers essentially unchanged by slash burning.

[5] Litter layer changed but uppermost soil layer unchanged by slash burning.

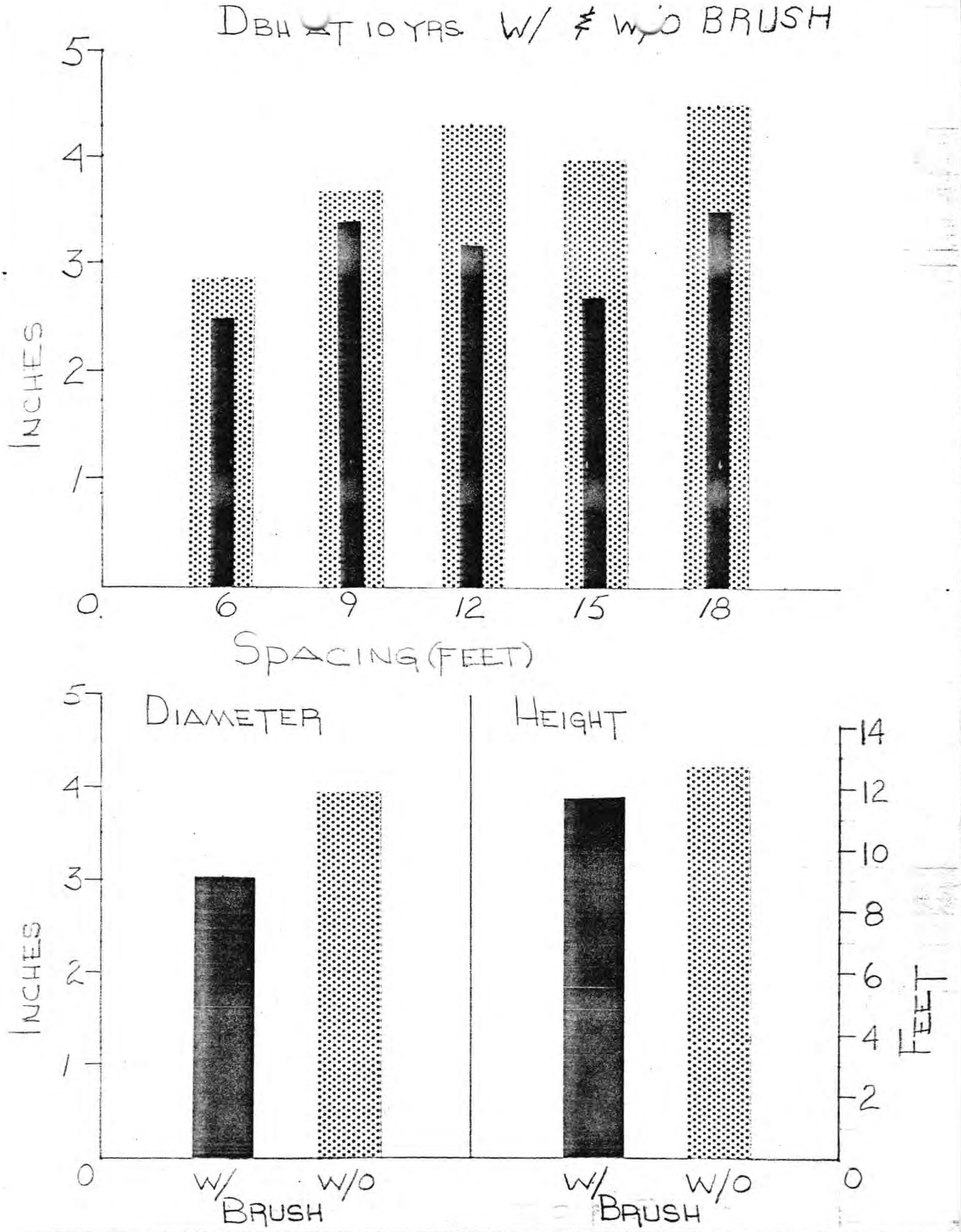
[6] Litter layer removed and uppermost soil layers changed by slash burning.

[7] One or more elements of the seedbed type could not be determined because of alteration with time (0.6 percent of the total available area) or post-seeding dragging in three subcompartments (9.8 percent of the total available area).

INITIAL SPACING AND TREE GROWTH

The effect of initial spacing of ponderosa pine on growth is under study at two locations on the Challenge Experimental Forest. In one study, growth of saplings spaced 3x3 to 18x18 feet on a polar coordinate grid is being evaluated with nitrogen fertilizer applied at the rate of 0, 200, and 400 pounds per acre. Early response data have not been analyzed yet.

In the other study, we are testing five different spacings (6x6 to 18x18 feet) in a more conventional plot layout. In addition, we are studying how the spacing-growth relationships are altered by the normal influx of understory vegetation. The trees are 12 years old. Some of the results we found after 10 years growth are illustrated in the following graphs.


DBH AT 10 YRS. W/ & W/O BRUSH
5
4
3
2
1
INCHES
0.
6
9
12
15
18
SPACING (FEET)
DIAMETER
HEIGHT
INCHES
FEET
14
12
10
8
6
4
2
0
W/
W/O
BRUSH

METHOD-OF-CUTTING--SEED TREE

SEED TREES (Comp. 92)

Several of our study blocks are visible from this location. In the 1/4 section immediately visible we have four clearcut blocks 10, 4, and 3 years old, and three seed-tree blocks 3, 2, and 1 years old. Portions of all three seed-tree cuttings are in a small area centered on the road junction. This small area is our main interest at this stop.

Objectives here are:

(1) To quantify the effects of time on the establishment and growth of regeneration obtained 1, 2, and 3 years after logging.

(2) To evaluate the efficiency of 2 seed trees per acre in regenerating cutovers.

(3) To evaluate the effect of the seed trees on the growth of the new trees.

(4) To evaluate the efficiency of windrow-and-burn slash disposal with 2 seed trees per acre.

The entire seed-tree area will be used for objectives (1), (3), and (4); but only about 10 acres here at the center of the 1/4 section will be used for objective (2), with the rest of the 1/4 section serving as isolation for the central 10 acres. A better arrangement would have been three 160-acre seed-tree blocks, but that was impractical at the time this study was planned. Temporary roads will be obliterated when the seed trees are removed from the rest of the area.

The original stands here were 105-year-old young-growth mixed conifer with about 50 M bf per acre and about 15 percent of the volume in highly defective old growth that remained after the logging of over 100 years ago. The regeneration objective is ponderosa pine, but many of the seed trees are species other than ponderosa pine because the original mixed conifer stand did not have enough suitable ponderosa pine trees. Because of the species mix, regeneration will probably be similar to that in adjoining clearcuts regenerated by the then surrounding mixed conifer forest--about 60 percent ponderosa pine regeneration with most of the rest Douglas-fir.

As planned, we had the desired seed crop last fall. Seed production measured in the three cuttings in the central 10 acres ranged from 13,000 to 33,000 seeds per acre, close to the theoretical average for two seed trees per acre of 25,000 seeds per acre. We have not yet examined the regeneration, if any, but again the drought will invalidate whatever the results might be. These areas are therefore more likely to provide information on regeneration obtained 4, 5, and 6 years after logging than the planned 1, 2, and 3 years.

This study is restricted to 2 seed trees per acre because we already know that 4 or more seed trees per acre are more than adequate for regeneration. The effect of 4 seed trees per acre on the growth of the new stand has been and is being studied in some of these other areas.

Windrow-and-burn slash disposal has proven to be efficient in areas with 2 seed trees per acre, but we do not yet know exactly how production, costs, and other items compare with those for the same treatment in clearcuts. Windrow-and-burn slash disposal seems impractical with 4 or more seed trees per acre. Pile-and-burn accomplishes much the same thing but with higher burning costs in these cases. Windrow-and-burn is currently being tested with 3 seed trees per acre.

SEED-TREE CUTTING WITH EMPHASIS ON, AND SUCCESSION OF LESSER VEGETATION

This method has been tested intensively at Challenge, and several publications are available on it. In this study, however, two different objectives were paramount: (1) To emphasize Douglas-fir (previous trials left mostly ponderosa pine seed trees), and (2) To identify and quantify all species of lesser vegetation in terms of phenology, presence, density, coverage, and height. Above-ground biomass and plant succession also are being studied.

This particular area was logged in 1972. It consists of 95 acres surrounding circular clearcuttings from a previous study. Four seed trees per acre were retained with species composition favoring Douglas-fir, ponderosa pine, and sugar pine in that order. Slash disposal and site preparation were by piling and burning in 1972 and 1973.

In 1974, all living vegetation including seedlings, saplings, sprouts, woody shrubs, forbs, and grasses was sampled on 267 milacre plots located randomly along six temporary transects.

Density and milacre stocking of selected plant species for years of 1974, 1975, and 1976 are shown on included table.

Density and presence totals by year are: 1974 - 57 species and 16,994 plants per acre; 1975 - over 100 species and 74,237 plants per acre; 1976 - over 115 species and 77,290 plants per acre.

Before one can manage a vegetative resource, he needs to know the factors that influence its establishment and growth. Competition-form lesser vegetation has been known to be a competitive factor for years, but it has not been quantified. Now it is.

This is a small part of a larger effort that quantifies lesser vegetation in different cutting methods and artificially established plantations on sites of different quality.

Species	1974 Density	1974 Stocking	1975 Density	1975 Stocking	1976 Density	1976 Stocking
Douglas-fir	921	45	412	33	250	18
Ponderosa pine	951	51	706	49	1380	63
White fir	206	14	106	9	30	3
Manzanita	876	35	1788	59	970	42
Deerbrush	3453	64	2893	61	1800	72
Wild rye grass	82	3	1035	21	1410	18
Hairgrass	26	1	1270	12	2700	14
Brome grass	-	-	T	T	1950	16
Thistle (Bull)	5992	69	20,627	80	25,620	87
Prickly lettuce	1438	32	16,735	65	9010	59
Bracken fern	1532	17	1788	34	4250	27
Clarkia	-	-	1729	13	4200	20
Epilobium	-	-	4575	18	10,050	41
Spanish Clover	-	-	4551	7	1130	4
Gumweed Madia	-	-	2553	4	1470	13

TIMBER MANAGEMENT RESEARCH
AT CHALLENGE EXPERIMENTAL FOREST

Stop No. 6

Study

"Effects of Silvicultural Systems on Nutrient Cycling on a Highly Productive Site."

Scientist in Charge.

Robert F. Powers

Cooperators.

University of California, Berkeley, (John McColl)

Purpose.

In undisturbed forests, nutrient losses through leaching are believed minimal and at a steady state. However, losses may increase greatly following disturbance, and productivity may decline. The purpose of this study is to evaluate effects of timber harvest on nutrient leaching by comparing soil solution chemistry in undisturbed, shelterwood, clearcut, and reforested plots.

Schedule.

Fall 1976: cruise and map plots, install soil solution tubes

Fall 1976-Spring 1978: Monitor nutrient concentrations and soil moisture at 20 and 100 cm soil depth in each plot

Spring 1978: Clearcut 3 acres (53,500 bd ft/acre); shelterwood cut 3 acres (21,000 bd ft/acre), leaving 85 ft sq/acre in the latter. Prepare site for regeneration and continue monitoring for 1 decade. Compare trends with control plot and develop a model (see figure). Using intact cores from each plot, conduct greenhouse fertility trials to determine differences in soil nutrient availability to trees.

MIXED-CONIFER PLANTATION
EXPERIMENTAL DESIGN AND RESULTS

This plantation was designed to show how a mixed-conifer stand develops and what role each of the five species (ponderosa pine, sugar pine, white fir, Douglas-fir, and incense-cedar) plays in that development. The dynamics of mixed-conifer stand development was to be quantified by measuring the growth of each species in competition with many combinations and proportions of itself and each of the other form species.

To achieve these objectives in one study required a complex field design. Unfortunately, high mortality of all species except the ponderosa pine destroyed the field design and original objectives, both of which are being revised. Meanwhile, Bob Powers has used a portion of the area for his nutrient studies.

TIMBER MANAGEMENT RESEARCH
AT CHALLENGE EXPERIMENTAL FOREST

Stop No. 7

Study.

"Response of Mixed-Conifer Regeneration to N and P Fertilization on a Productive Forest Site."

Scientist in Charge.

Robert F. Powers

Purpose.

Fertilization trials have focused on poor sites supporting monocultures, or near-monocultures. Nothing is known of mixed-species response in California on more productive sites. This study examines the growth response potential of five conifer species to N and P fertilizers on a highly productive site.

Schedule.

Spring 1973: Measure and tag 542 seedlings of PP, SP, IC, WF, and DF. Apply 1 of 9 treatment combinations of N and P at following levels: 0, 150, and 300 lbs N/acre as urea (N_0, N_1, N_2); 0, 1, and 2 foliar applications of 1500 ppm P as phosphoric acid (P_0, P_1, P_2).

Fall 1973-Fall 1975: Sample soil and foliage for nutrient content. Measure seasonal growth patterns (see figures).

Winter 1975: Determine root distribution. Harvest representative trees and determine biomass and nutrient distribution (see figures).

Results.

Species showing growth response
to following fertilizer combinations

	N_0	N_1	N_2
P_0			PP, IC, DF
P_1	SP	SP, WF	IC, SP
P_2	SP, WF		SP, WF

SHELTERWOOD CUTTING

In 1958, a mixed-conifer stand on a high site was logged to two-stage shelterwood specifications. The primary goal was to test the applicability of a modified shelterwood method to a young-growth stand. Changes in species composition and stand structure, seedfall, regeneration, and growth of the residual stand were evaluated.

Because slash volumes are high and aggressive hardwood and brush populations build up quickly after logging, combination slash disposal and site preparation techniques must be applied. Treatments compared were piling by bulldozer immediately after logging, piling just before seedfall from a heavy cone crop, and top-lop and branch-scatter.

Cutting removed 68 percent of the stand basal area and 70 percent of the merchantable volume. Most of the remaining volume was in the 12 trees per acre that constituted the shelterwood.

These trees produced seed abundantly during the 5-year period after logging. In fact, fifteen conifer and two hardwood seed crops were produced, and four out of five conifer species generated at least one moderately heavy seed crop. Cone counts proved valuable in assessing the number of trees with cones and the number of cones per tree, but were poor quantifiers of sound seed. Seed trap catches gave more accurate results, indicating a total seed production of 134,000 sound seed per acre during a 3-year period. In general, young-growth trees, even on this high site, produced high percentages of unsound seed.

Regeneration was exceptional on the prepared ground beneath the shelterwood. After 50 months, about 3700 ponderosa pine seedlings per acre and 600 shade-tolerant conifer seedlings were established. Corresponding stocking values were 62 percent for ponderosa pine and 19 percent for the tolerant conifers. An additional 320 26-month-old tolerant conifer seedlings per acre also were present.

Seedlings survived better when slash was piled just before seedfall than when it was piled immediately after logging, or when branches were lopped and scattered.

Hardwood seedlings and sprouts also were abundant, numbering about 3000 per acre, but the seedlings were poorly distributed and rather slow growing. Sprouts were the most serious competitors of the conifer seedlings, especially of the more tolerant conifers.

In general, the species composition of the new stand regenerated by this shelterwood application closely resembled that of the stand before logging.

Seedfall and regeneration were compared to a control block. Nine times more seeds were produced in the shelterwood, more seeds were sound, more sound seeds germinated, more seedlings resulted, a lower proportion of the seedlings died, and the seedlings were better distributed throughout the area.

Basal area growth of individual trees in 5 years exceeded that of the control for nearly all conifer and hardwood species and diameter classes. In the shelterwood, sugar pine responded best to cutting, and its basal area growth rate was twice that of ponderosa pine and Douglas-fir.

Increased amounts of seed and seedlings, plus accelerated growth rates of residual trees, are gains in productivity that the landowner may realize from applying the shelterwood method to young-growth stands. Because reforestation is accomplished by natural regeneration rather than by expensive nursery stock, the shelterwood cutting method is attractive to a wide range of forest landowners, including those having small acreage and limited capital.

Methods of Cutting

SINGLE-TREE SELECTION CUTTING

The single tree selection system seems to be the most gentle of all regeneration cutting systems. When attempting to convert an essentially even-aged stand to an uneven-aged stand through the selection system, the first harvesting operation will remove only biologically mature trees scattered throughout the entire stand, along with a few crooked, diseased, or slow growing members, are cut. This procedure is then repeated several times--usually at short intervals of 5 to 10 years, until a desired distribution of age classes has been created. Reproduction fills the gaps in the stand created by logging, and the forest is thus continuously renewed. Because three or more age classes of trees are present, tree crowns and branches tend to form a vegetative continuum from ground level to the top of the dominant trees. A deep, dense, and protective canopy results. This shelters the forest floor from wind and sun and the beating action of rain. Moreover, the protection is uniform with time: a phenomenon directly opposite of clearcutting, which periodically bares the soil.

Near complete site utilization also is accorded the tree selection system. Just as branches occupy nearly all the space above ground, so do roots below. Roots from the various sized trees, which are often of mixed species, tend to fully occupy the soil and efficiently utilize available water and nutrients. Theoretically, the selection forest produces wood more efficiently than does an even-aged forest like that which arises from clearcutting. Further, because poor trees are constantly removed in selection cutting, new volume is concentrated on the finest individual stems.

Another attribute of the tree selection system is that abundant natural regeneration is almost a certainty. The method is particularly useful for regenerating shade tolerant species and enhancing the survival of tolerant advance reproduction. Conversely, the shady environment inhibits germination of dormant brush seeds in the surface soil, and reduces size and vigor of those that do become established.

Single-tree selection cutting trials were installed at Challenge in 1958. Ten to 25 percent of the merchantable volume was removed. A few large old trees were taken as well as many smaller, poorer trees that were crooked, diseased, suppressed, or overcrowded. Thus, in the initial entry, with selection cutting, a large element of stand improvement was performed. This is a legitimate and recommended practice. Slash disposal was by lop and scatter or occasional pile and burn. Small hardwoods, in particular, were removed when piling.

Altogether, these light treatments left an almost fully stocked stand. Trees 3.5 inches d.b.h. and larger numbered 148 per acre after logging. Reduction by size class was:

D.b.h. class (inches)	No. removed per acre
12.1-16.0	14
16.1-20.0	4
20.1-30.0	3
30.1	2

Saplings, 4.5 feet tall to 3.4 inches d.b.h., numbered 16 per acre. Advance reproduction, stems up to 4.5 feet tall, numbered 2285 conifers and 2233 hardwoods per acre.

A good seed crop occurred in 1960 for all conifer species except incense-cedar. Seedling stocking and density were exceptional in 1961. By 1965 both had decreased precipitously. Stocking is an example:

	Milacre stocking (percent)	
Species	1961	1965
Ponderosa pine	80	30
Conifers other than ponderosa pine	70	17
Hardwoods	30	8

Subsequent seed crops of all species were numerous and thousands of seedlings, especially of ponderosa pine, got started, struggled for awhile, and then died. Today the regeneration plots are essentially barren except for an occasional tanoak seedling.

GROUP SELECTION CUTTING

As its title implies, this type of selection cutting entails the creation of small openings in the stand. In this study, openings of 30, 60, and 90 feet in diameter simulated the removal of 1, 2, or 3 large dominant trees. Major goals were to evaluate establishment, survival, and growth of 5 conifer and 3 hardwood tree species, plus all lesser vegetation in these sizes of openings. An additional goal was to find a method for converting from the predominant ponderosa pine to a stand containing more of sugar pine, Douglas-fir, and white fir. The nonindustrial forest landowner of small acreage, and foresters in general, are interested in writing off regeneration costs as early as possible. Christmas trees of Douglas-fir and white fir are one way of doing this. Sugar pine has high demand in the marketplace.

Regeneration results show that group selection is an ideal method for converting from ponderosa pine to a mixed-conifer forest, and density and height growth of brush and hardwoods is low. Number of hardwood advance seedlings is well below "background" count of the uncut stand.

The study was installed in 1964; slash disposal was by faring-out of slash on the edge of openings or by pile and burn. The first major seed year was in 1965 when 4 conifer species produced at least a medium crop. By 1971, 1900 ponderosa pine, 800 white fir, 275 sugar pine, and 150 Douglas-fir seedlings per acre had become established.

A second seed year for these same conifers again occurred in 1971. By 1976, 4600 ponderosa pine seedlings, 275 sugar pine, and 35 incense-cedar seedlings had become established. Other seed crops also were produced and these in turn led to established seedlings. A key concept emerges here. With even-aged methods, seedlings from the first seed crop become established and lead to crop trees. Subsequent seed crops are in vain; but in group selection the moderated environment allows seed crop after seed crop to establish seedlings. On a high site at least, it appears that stocking might actually become too dense.

Height growth of seedlings is the key to future species composition. After 9 years, ponderosa pine height growth is one-third less than that of sugar pine, Douglas-fir and white fir. Ponderosa pine seedlings persist for up to 10 years, but eventually die. Only in the center of 90-foot openings do they equal or exceed their more tolerant species.

After 10 years, hardwood seedlings, including sprouts, numbered about 475 per acre or about one-fourth that of single tree selection stands. The combination slash disposal-site preparation techniques are responsible for this reduction.

SILVICULTURE-ECOLOGY OF THREE NATIVE CALIFORNIA HARDWOODS ON HIGH SITES IN NORTH CENTRAL CALIFORNIA

Pacific madrone, tanoak, and California black oak are potentially the most manageable and economically promising native California hardwood species. Volume and value data indicate upward trends in growing stock levels and prices received for products from them. These trends are likely to continue, which in turn has accelerated interest and need for knowledge on the species. Particular needs concern: (1) seed fall and regeneration, (2) sprout growth and development, (3) stand growth and yield, and (4) species adaptation and strategy.

The ability to produce copious amounts of seed at frequent intervals is a hallmark of Pacific madrone and tanoak, and only slightly less so for California black oak. Over two million seed per Pacific madrone tree and the equivalent of one million tanoak acorns per acre exemplify this fact. Few of these seeds result in trees, however, but enough do so as to insure continuous environmental tuning of the species.

Beneath Pacific madrone trees, invertebrates (slugs), post-emergence fungi, and probably allelopathic substances are found. Thus a seedbed free of a substantial organic layer is best for naturally regenerating this species. A partially shaded environment is best for natural development of the oaks. Reversing polarity of tanoak and California black oak acorns speeds up germination and enhances seedling survival and growth.

Fertilization with nitrogen and phosphorous significantly boosted California black oak seedling height growth, but was less effective for tanoak. In spite of irrigation, fertilization, shading, and use of containers, survival of tanoak seedlings in a competition-free plantation was only 33 percent after 4-6 years. Also, dieback and deformation were rampant. It appears that tanoak cannot be established successfully in conventional plantations. Survival of California black oak was 64 percent after 7 years and establishment in standard plantations is recommended for this species.

The hardwood species studied sprout profusely from the root crown following gross disturbance. Free-to-grow sprouts initially number up to 150 per clump, but after 10 growing seasons decrease to less than 35. Height and crown width after 10 years is about 20 and 10 feet, respectively, with only minor differences among species. In contrast, sprouts in a shelterwood environment are about half as tall and three-fourths as wide. The initial number of root crown sprouts from trees over 3.5 inches d.b.h. number about 65,900 per acre.

Diameter, bark, and height data formed a large sample which led to prediction equations and volume tables to 3 top-utilization standards for each species. Diameter and basal area growth of trees in stands thinned from 85 to 141 square feet per acre were less than that attributed to eastern oaks on comparable sites. Cubic volume growth, however, bettered that of eastern oak--ranging from 48 to 93 cubic feet per acre per year with indications that thinning to 100-125 square feet of basal area per acre was best. Alternating growth surges on the various members in a clump made timing of release difficult to ascertain.

A serious degrade of bole quality of California black oak is epicormic branching. Small, suppressed, injured or suddenly-released trees all put forth significantly higher numbers of epicormics than do large dominant trees in undisturbed stands.

Ecologically, Pacific madrone, tanoak, and California black oak possess a host of collective and specific adaptations that serve them well in severe environments. All three species devote substantial amounts of energy to reproductive material. Huge numbers of seeds and sprouts insure that the species both remain in place and capture new area. Other adaptive phenomena discussed are the means taken to discourage competition beneath tree crowns, the role of seed disseminators, competitiveness of sprouts, the stretched-out germination period, root-shoot ratios, thickened rootstocks, need for multiple stems per clump, and others. One of the most meaningful findings resulted from the study of plant moisture stress. Remarkable photosynthesis, transpiration, and respiration control mechanisms constitute successful survival strategies that have kept these species vigorous and competitive for 20 million years.

LOGGING A ROADSIDE STAND TO ENHANCE SCENIC VALUES

Historically, the roadside zone has been a hands-off zone for foresters. Aesthetics and timber harvesting simply did not mix in this zone.

This case study demonstrates that this conflict need not be so. With careful planning and choice of technique, timber management can be practiced in the roadside zone, and at the same time the opening-up of the stand can extend and enhance the near view.

In this 1968 study, special marking, logging, and slash disposal specifications were employed. In all, 22 percent of the merchantable volume and 32 percent of the marketable stems over 12 inches d.b.h. were removed. An estimated 95 percent of the slash no longer remains.

Cost of the special marking, felling, yarding, and slash disposal operations was $30 per m.b.f. or about twice that of the single-tree selection cutting method on the Experimental Forest--the most comparable cutting method.

Before-and-after photos show that, indeed, the stand was opened up and the view of the roadside traveler extended. Furthermore, an additional increment of contrast, variability, and beauty is now present that wasn't there before.

The highly favorable reaction to this study has led to a much larger, more intensive study in the Sierra Nevada mixed-conifer forest type on this district. A Research memorandum covering the details of this study was signed September 1974.

BIBLIOGRAPHY

CHALLENGE EXPERIMENTAL FOREST

Schubert, G. H.
1950. Control of sprouting of tanoak and madrone stumps. USDA For. Serv., Calif. For. and Range Exp. Stn. For. Res. Note 74, 2 p.

Paul, Benson H.
1956. Changes in spiral grain direction in ponderosa pine. USDA For. Serv., For. Prod. Lab. Rep. 2058, 8 p., illus.

Davis, E. M.
1960. Machining ponderosa pine and Douglas-fir...effect of growth rate and density. For. Prod. J. 10(1):1-3, illus.

Jackson, Willard L.
1960. A trial of direct control of pine engraver beetles on a small logging unit. USDA For. Serv. Misc. Paper 44, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 7 p., illus.

Jackson, Willard L.
1961. Board foot volumes of young growth mixed conifer timber. USDA For. Serv. Res. Note PSW-182, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 1 p.

Lanner, Ronald M.
1961. Living stumps in the Sierra Nevada. Ecol. 42(1):170-173, illus.

Newport, Carl A. and Elliot L. Amidon.
1961. Lumber grade and value performance of young-growth ponderosa pine logs at the Challenge Experimental Forest. USDA For. Serv. Tech. Pap. 55, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 14 p., illus.

Corbett, Edward S.
1962. Ponderosa pine reproduction in relation to seed supply at Challenge Experimental Forest. USDA For. Serv. Res. Note PSW-195, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 3 p.

Atkinson, William A., and Dale O. Hall.
1963. Comparative seed-tree and selection harvesting costs in young-growth mixed-conifer stands. USDA For. Serv. Res. Note PSW-19, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 3 p.

Hall, Dale O.
1963. The effect of advance growth on ponderosa pine seedling mortality at Challenge Experimental Forest. USDA For. Serv. Res. Note PSW-8, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 7 p.

Hall, Dale O., and Robert L. Neal.
1963. Reproduction losses from slash disposal at the Challenge Experimental Forest. USDA For. Serv. Res. Note PSW-N15, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 4 p.

Hall, Dale O.
1964. Hog-ringer speeds seedtrap construction. J. For. 62(1):39, illus.

McDonald, Philip M.
1965. Logging costs and production rates for the group-selection cutting method. USDA For. Serv. Res. Note PSW-59, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 4 p.

Sundahl, William E.
1965. Cruising timber with portable tape recorder cuts costs. J. For. 63(4):284-285.

Atkinson, William A., and Dale O. Hall.
1966. Clearcut harvesting costs and production rates for young-growth, mixed-conifer stands. USDA For. Serv. Res. Note PSW-114, 2 p.

McDonald, Philip M. and Harry E. Schimke.
1966. A broadcast burn in second-growth clearcuttings in the north central Sierra Nevada. USDA For. Serv. Res. Note PSW-99, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 6 p., illus.

McDonald, Philip M.
1966. Seed fall and regeneration from a group selection cut...first year results. USDA For. Serv. Res. Note PSW-113, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 6 p., illus.

Sundahl, William E.
1966. Crown and tree weights of madrone, black oak, and tanoak. USDA For. Serv. Res. Note PSW-101, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 4 p., illus.

Sundahl, William E.
1966. Slash and litter weight after clearcut logging in two young-growth timber stands. USDA For. Serv. Res. Note-124, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 5 p., illus.

Hall, Dale O.
1967. Broadcast seeding ponderosa pine on the Challenge Experimental Forest...a progress report. USDA For. Serv. Res. Note PSW-144, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 4 p., illus.

Hall, Dale O.
1967. Slash disposal burns in pine patch-cuttings...a dialogue. USDA For. Serv. Res. Note PSW-148, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 6 p., illus.

Ziemer, Robert R.
1968. Soil moisture depletion patterns around scattered trees. USDA For. Serv. Res. Note PSW-166, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 13 p., illus.

Hall, Dale O.
1969. Prescriptions vary in ponderosa regeneration. For. Ind. 96(13):60-61.

McDonald, Philip M.
1969. Harvesting costs and production rates for seed-tree removal in young-growth, mixed-conifer stands. J. For. 67(9):628-630, illus.

The small forest landowner generally needs to know his costs accurately to turn a profit. One cost not readily available is the cost of harvesting seed trees after the desired reproduction has become established. Logging production rates also are valuable for planning purposes.

When 2 to 13 seed trees per acre were removed, felling production averaged 3,500 board feet per hour and cost $3.86 per thousand board feet. Skidding production was 4,500 board feet per hour and cost $3.59 per thousand board feet.

Compared to the original cut, skidding production from seed trees alone was much greater, mainly because the average log size was larger and the main skid trails already established were reused. Special care in logging to protect the regeneration (marking the felling direction of each tree, flagging skid trails, and carrying the winch line to the tree) tended to decrease production; but skidding production during seed-tree removal was still 38 percent higher than from the original cut. Seed-tree removal proved to be both economically profitable and silviculturally feasible.

McDonald, Philip M.
1969. Ponderosa pine seed-tree removal reduces stocking only slightly. J. For. 67(4):226-228, illus.

The seed-tree cutting method removes the mature timber in one cut except for a small number of trees left to produce seeds for establishing a new timber crop. This method can be used by California's many small forest land owners who often depend on natural forest regeneration rather than planting or seeding which often requires large capital outlays.

A potential trouble spot with seed-tree cutting is the loss of seedlings when the seed trees are logged. Losses of ponderosa pine seedlings during seed-tree removal have not been previously measured.

Seed trees were logged on 11 small units totaling 65 acres. Before logging, milacre stocking of 2-year-old seedlings ranged from 50 to 83 percent and number of seedlings from 1,300 to 7,000 per acre. Seedling losses from logging reduced the number of stocked milacres by only 3.8 percent and the number of seedlings per acre by only 212. The greatest losses took place where regeneration probably was too dense and in a compartment located on the steepest slope (25%). Overall, seedling losses from seed-tree removal were minor, showing that landowners can speedily harvest capital investment in seed trees without injuring their new crops.

McDonald, Philip M., William A. Atkinson, and Dale O. Hall.
1969. Logging costs and cutting methods in young-growth ponderosa pine in California. J. For. 67(2):109-112., illus.

Tucker, John M., William E. Sundahl, and Dale O. Hall.
1969. A mutant of Lithocarpus densiflorus. Madroño 20(4):221-225, illus.

An odd form of tanoak, a sublethal recessive mutation found one mile north of Challenge, Yuba County, California, is described. This distinctive mutant which is so different from typical Lithocarpus densiflorus justifies the formal taxonomic designation and is accorded the status of forma.

Sundahl, William E.
1971. Seedfall from young-growth ponderosa pine. J. For 69(11):790-792, illus.

The seed-tree cutting method leaves selected trees to regenerate the timber stand for the next crop. This method is tailored for the forest land owner who wants to harvest timber and regenerate similar desirable stands of ponderosa pine. It reduces anxieties about additional capital outlays for seeding, planting, or other cultural work necessary after some other types of cutting.

This study answered several questions relevant to selecting seed trees and their performance. The basic criterion for selecting seed trees must be good form. But among trees of acceptable form primary emphasis in seed-tree selection should be placed on past cone production as evidenced by old cones near the base of each tree. Consideration of tree spacing should follow. In even-aged stands, the larger trees tend to be the cream of the crop and, therefore, are phenotypically best to regenerate progeny for the next generation. Furthermore, trees 30 inches in diameter and larger are the best seed producers.

At least moderate cone crops can be expected at intervals of one to three years. The study showed that three to nine seed trees per acre produce 5,000 to 35,000 sound seed per acre in years of moderate to heavy cone crops. On this basis a minimum of four seed trees per acre are recommended.

McDonald, Philip M.
1972. Logging production rates in young-growth, mixed-conifer stands in north central California. USDA For. Serv. Res. Pap. PSW-86. Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 12 p., illus.

Forest managers and loggers in California have asked for production-rate values for logging young-growth timber. Stopwatch studies showed that log-making production rates were poorer for smaller trees in all steps of the process. By species, incense-cedar ranked poorest in all components, followed by ponderosa pine, while production rates were best for the moderately tolerant conifers--Douglas-fir, white fir and sugar pine. Log size affected skidding costs, with the production rate for 22-inch logs two and a half times greater than for 12-inch logs. The study showed relatively large differences in tree size in young-growth timber, and that these differences play a major role in determining logging production rates and costs. Recognition of this fact and the data developed should help loggers, forest owners, timber appraisers, and tax assessors in their work.

McDonald, Philip M. and Raymond V. Whiteley.
1972. Logging a roadside stand to protect scenic values. J. For. 70(2):80-83., illus.

Our society today needs both forest commodities and amenities. Battle lines too often are drawn between proponents of each. But in the case of roadside logging this needn't be.

A case study on the Challenge Experimental Forest, north central California, demonstrated that logging along roadsides need not despoil roadside stands. The predominant tree species was ponderosa pine, with Douglas-fir, white fir, sugar pine, incense-cedar, and various hardwoods in lesser amounts. Although about one-third of the merchantable stems and one-fourth of the merchantable volume were removed, no travelers objected to the appearance of the residual stand. Indeed, some found the view into the less-dense forest more pleasing. Foresters see benefits too. Cutting caused the proportion of pines in the stand to increase over that of fir and incense-cedar. The least healthy trees have been removed and extra trees in the formerly too dense stand are gone. Those remaining now have more space around them and their growth should increase.

Exacting standards for felling, skidding, and slash disposal were followed and caused the combined logging and slash disposal cost (30 dollars per thousand board feet) to be about twice that of a single-tree selection cut--the most comparable of several cutting operations on the Experimental Forest.

Continued cutting in similar fashion at planned intervals of 25 years should greatly affect future stand development. Species composition will shift from ponderosa pine to the more tolerant species. The age class distribution of trees in the stand also will change from essentially one age to many ages.

An inescapable conclusion is that the benefits were worth the cost. Careful logging can enhance the growth and health of trees and the roadside view, thus simultaneously providing amenities and forest commodities.

McDonald, Philip M.
1973. Cutting a young-growth, mixed-conifer stand to California Forest Practice Act standards. USDA For. Serv. Res. Pap. PSW-89, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 16 p., illus.

Criticism of logging results on private lands in California has been increasing because residual timber stands often are left in poor condition and regeneration is deficient. In 1958 a high-site mixed-conifer stand on the Challenge Experimental Forest, central California, was logged to the minimum standard of the 1953 Forest Practice Rules of the North Sierra Pine Forest District of California. The heavy cut changed the species composition from primarily ponderosa pine to hardwoods and tolerant conifers (Douglas-fir, white fir, and incense-cedar). Mortality, mainly from windsnap, in the submerchantable trees was highest for ponderosa pine. Regeneration of ponderosa pine was less than that of hardwoods and tolerant conifers. The cutting produced an understocked stand of slow-growing, currently less valuable species which does not utilize the full site potential. Results provide evidence for strengthening minimum requirements for timber operations in California under the Z'Berg-Nejedly Forest Practice Act of 1973 (Effective January 1, 1974).

Neal, Robert L., Jr.
1973. Remeasuring tree heights on permanent plots using rectangular coordinates and one angle per tree. For. Sci. 19(3):233-236, illus.

Usual methods of remeasuring tree heights on permanent sample plots become more difficult and expensive as the trees grow older. The method described applies surveying techniques and electronic data processing. Permanently recorded coordinates and elevations of tree locations are used with angles to calculate the instrument location and elevation, instrument-to-tree distances, and total tree heights. This method can reduce the costs of tree height remeasurements.

Neal, Robert L., Jr.
1975. Ponderosa pine seeding trials in west-side Sierra Nevada clearcuts: some early results. USDA For. Serv. Res. Note PSW-305. Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 8 p., illus.

Artificial seeding after timber harvesting in the Sierra Nevada of California has been unreliable for establishing new stands. Twenty-seven combinations of seeding rates, aspect, and site treatment were tested. Best results were obtained with high seeding rates on unburned mechanically disturbed seedbeds with a high proportion of exposed mineral soil on northerly aspects. Sowing at least 1 pound of seed per acre consistently resulted in 400 or more seedlings per acre (988 seedlings per ha). Recommended procedures to obtain a minimum of 400 seedlings per acre are: (1) prepare 100 percent of the site by piling and burning slash and residual vegetation; (2) use seed that has had the standard endrin-arasan-aluminum-dust pest repellent treatment, or equivalent; and

(3) apply at least 1.5 pounds of seed (10,000 to 12,000 viable seed) per acre. This prescription for artificial seeding has been successful consistently, and is a reliable management option which is cheaper than planting.

McDonald, Philip M.
1976. Forest regeneration and seedling growth from five major cutting methods in north central California. USDA For. Serv. Res. Pap. PSW-115, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 10 p., illus.

Sometimes the forest manager does not know the amount, distribution, and growth potential of desired conifer seedlings and competitive shrubs and hardwoods that result from his silvicultural prescriptions. A wrong choice of cutting method or site preparation could be costly as regeneration failures cost 150 to 200 dollars per acre. Of the five classical regeneration cutting methods (clearcutting, seedtree, shelterwood, group selection, and single-tree selection), shelterwood cutting was best for ponderosa pine, establishing 3,620 seedlings per acre, and stocking 61 percent of milacres nine years after cutting. Hardwood seedling and sprout competition was greatest under selection cuttings, but shrubs were most abundant and competitive in clearcuttings where disturbance was greatest. Regeneration and seedling growth results obtained by this study enable the forest manager to match his cutting prescriptions to timber type, site, and management objectives, and are applicable in important forests of California and Oregon.

McDonald, Philip M.
1976. Inhibiting effect of ponderosa pine seed trees on seedling growth. J. For. 74(4):220-224, illus.

If ponderosa pine seed trees are kept too long, they inhibit height growth of seedlings. This inhibition is costly, amounting to 10.6 feet of height growth lost in 13 years if seedlings are within 20 feet of a seed tree. Inhibition persists for 4 years after seed trees have been removed. This finding and the implied need to remove seed trees early, probably applies anywhere that timber is harvested by the seedtree method-of-cutting.

McDonald, Philip M.
1976. Shelterwood cutting in a young-growth, mixed-conifer stand in north central California. USDA For. Serv. Res. Pap. PSW-117, Pac. SW For. and Range Exp. Stn., Berkeley, Calif. 16 p., illus.

Many timber stands are still being harvested by cutting methods which do not meet today's social, environmental, and wood production needs. The shelterwood cutting method has been tested in young-growth, mixed-conifer stands and has proved to be successful. Under this system the soil is well-protected, yet harvest yields are high. Seedfall from 12 residual shelterwood trees produced 134,000 sound seed per acre during a

3-year period, and about 3,700 well-distributed ponderosa pine seedlings and 600 seedlings of Douglas-fir, white fir, and sugar pine per acre were established 4 years after cutting. Basal area of the residual trees increased 8.22 square feet per acre in 5 years. Increased seed production and seedling establishment, plus accelerated growth rates of residual trees, are gains in productivity that landowners may realize from applying the shelterwood cutting method in Oregon and California.