Appendix E

Major Silvicultural Systems and their Application

APPENDIX E. MAJOR SILVICULTURAL SYSTEMS AND THEIR APPLICATION

INTRODUCTION

The purpose of this paper is to describe the major silvicultural systems used in land management planning for National Forests, and the advantages and disadvantages of each, considering both biological and managerial perspectives. *However, almost all of the information in this paper also* applies to selecting an appropriate silvicultural system for a particular stand.

Silvicultural systems are used to manage forest stands. A silvicultural system is a planned sequence of treatments for controlling the species composition and structure of the vegetation during the life of a stand. A stand is a community of trees sufficiently uniform to be distinguishable as a silvicultural or management unit. Typically, stand sizes vary from about 5 to over 30 acres on National Forest lands.

Management objectives for stands typically are combinations of forest products and amenities. An example is: specific amounts of livestock forage, water runoff, and wood products; kinds of wildlife habitat; and specific scenic view qualities. No single silvicultural system can produce all desired combinations of products and amenities from a particular stand, or from a National Forest.

Forests are managed by using combinations of silvicultural systems to achieve the forest management objectives. All of the silvicultural systems discussed here are used in the National Forests in California. The combinations vary greatly, depending on the characteristics of local forest ecosystems and differing management objectives.

Selection of the appropriate silvicultural systems occurs at both the National Forest land management planning level and Ranger District project level. The Forest's selection is based on a broad match of silvicultural systems with the overall planning objectives and ecological characteristics of broadly-defined land classes. Examples of land classes are: areas capable, available and suitable for growing commercial wood products; streamside management zones; and spotted owl management areas. At the Ranger District, project level selection of silvicultural systems is typically made by a certified silviculturist. Choices are based on matching the attributes of the silvicultural systems with specific management objectives and the ecological characteristics for specific stands.

DESCRIPTIONS OF THE SILVICULTURAL SYSTEMS

A silvicultural system typically includes cutting trees, growing new trees, and controlling competing plants. *Cuttings are classified as* regeneration cuttings (those that help to replace stands), and intermediate cuttings (those that maintain or improve the character of existing stands.

-- Occurrence of shade-tolerant and intolerant plants. Even-aged and group selection systems favor plants that can be readily established and which grow well in full sunlight (shade-intolerant plants). These include grasses, most forbs and shrubs, and many of the most valuable commercial tree species, such as ponderosa pine and Douglas-fir. The single-tree selection system favors plants that can be readily established and grow well at low light levels (shade-tolerant plants). Examples in California forests are many ferns; few grasses, forbs, and shrubs; many non-commercial hardwood tree species; and a few commercial conifer tree species, such as white fir and incense-cedar.

However, on low-quality forest lands where lack of soil moisture or other soil conditions cause low plant densities, shading by trees is greatly reduced. There, shade-intolerant plants will persist if the single-tree selection system is used.

-- Diversity of plant species. Species diversity depends on the biological and physical environments, how diversity is evaluated, and on how the stands are managed under the different silvicultural systems.

On moderate-to high-quality lands, stands managed by the single-tree selection system shift toward shade-tolerant species. In California, many stands and forests which were previously dominated by commercially more valuable pine and Douglas-fir now have large components of less valuable tanoak, madrone, or white fir. This process could reduce tree species diversity in such stands, compared with management by other silvicultural systems. The shift toward more shade-tolerant species also means that the species diversity of plants near the ground would eventually be lower in stands managed by the single-tree selection system.

The species composition of commercial tree species may be significantly increased or decreased during stand regeneration; depending on the environmental conditions, availability of natural seed, selection of species to be planted, and the success of the plantings. If artificial regeneration fails in stands with mixed species, the diversity in the naturally-regenerated stand may be reduced significantly. Potential seed trees of some species could have been harvested, or only certain species (for example, white fir) could regenerate naturally under the brush that rapidly occupies newly harvested areas.

If both artificial and natural regeneration fail, the species diversity of commercial trees has been significantly reduced. The risk of a complete regeneration failure is least for the single-tree selection system. There is high probability of successful natural regeneration of all species where openings are small, seed sources are present, and ground environmental conditions are suitable for tree seedling establishment. The risk of loss of diversity in large openings can be reduced by planting all appropriate species, or by designating appropriate seed trees or shelterwood trees of mixed species.

-- Vertical diversity. The vertical diversity in stands managed by the even-aged or group selection systems can be quite limited. Typically there is a single dominant layer of seedlings, saplings, or larger trees. However, usually there is considerable diversity in stands with the larger trees because some trees are significantly taller and have fuller crowns than others. Full vertical diversity still occurs over the forest, but not in each stand or group. By contrast, in the single-tree selection system, the vertical diversity within each stand should be much greater. Seedlings, saplings and trees in larger tree classes should be seen from any point in the stand.

-- Tree vigor. If the stands are well managed, tree and stand vigor should be independent of silvicultural systems, with three exceptions. First, new seedlings in openings (particularly shade-tolerant species such as red fir and white fir) are heavily stressed by heat and lack of adequate water, until they develop good root systems. These stresses often cause heavy mortality (especially of natural seedlings, or of low-quality or mishandled or poorly planted seedlings from nurseries). Second, seedlings in openings are more susceptible to damage or mortality from frosts, particularly at high-elevation sites. Where seedling mortality (even of high-quality of properly handled and planted nursery seedlings) is expected to be excessive, use of the single-tree selection, shelterwood, and group selection (where groups are small) systems are favored. Third, maintaining good vigor of small shade-intolerant species, such as ponderosa pine, can be very difficult in stands managed by the single-tree selection system. To promote vigor and growth of these trees, tree density may have to be reduced, which can significantly reduce timber yields.

Many stands on National Forest lands are severely infected with certain root diseases or dwarf mistletoes. It is very difficult and costly to maintain or improve tree vigor and productivity there if the single-tree selection system were used. These root diseases and dwarf mistletoes infect other trees more easily when this system is used.

Genetic Resources

-- Conservation of genes. Genetic diversity is basically unaffected when natural or artificial regeneration of commercial tree species is successful. (Successful artificial regeneration means that appropriate procedures are used during seed collection to ensure a large genetic diversity in the collected seed.) However, if regeneration of a particular species were to fail repeatedly over broad areas, genetic diversity would be reduced.

-- Quality of genes. Where improperly applied, the single-tree selection system can lead to "high-grading", which in turn reduces genetic quality for wood production. High grading is the selective removal of the best trees (most rapidly growing, largest, and most valuable for wood), so that most regeneration comes from seed produced by the lower-quality, remaining trees.

The average genetic quality may be significantly lowered in a stand managed by the single-tree selection system, because of higher rates of inbreeding. Some forest geneticists theorize that inbreeding should also increase under the shelterwood or seed-tree systems. Nearby trees of the same species usually are closely related, and they can pollinate each other. The natural seedlings should be even more inbred. By contract, artificial regeneration or natural regeneration from edges of large openings reduces the probability of significant inbreeding. Large openings facilitate pollen movement from more distant, less closely related trees.

Productivity. Scientific long-term comparisons of wood production using the different silvicultural systems have not been made anywhere in the world. This comparison will be possible many decades from now at Blodgett Forest, a

University of California research facility. Theoretically, the total biological productivity (biomass) may be greatest for stands managed by the single-tree selection system. This is because of more continuous tree cover, compared to the other systems. See Table 1 for a biological comparison of system attibutes. However, merchantable stand growth and timber yields may not be higher for the single-tree selection system. Merchantable yields are strongly influenced by managerial factors.

MANAGERIAL CONTRASTS AMONG FORESTS AND STANDS MANAGED BY DIFFERENT SILVICULTURAL SYSTEMS

The major managerial contrasts described in this section are summarized in Table 2.

Public Concerns. In the last two decades the clearcutting system and to a lesser extent the shelterwood and seed-tree systems, have generated controversy in the United States and Europe.

There are at least six major concerns in California:

- -- Clearcut areas are regarded as visually unattractive
- -- The risks of significant soil erosion and loss of soil productivity are thought to be much greater for the clearcutting system
- -- Regeneration of clearcut stands is thought to be unreliable
- -- The risks of significant genetic losses are thought to be much greater for the clearcutting system because new stands may be monocultures
- -- The use of chemical herbicides (strongly opposed by some groups and individuals) is thought to be much greater if even-aged systems are used, particularly the clearcutting system
- -- Artificial regeneration, particularly of even-aged stands, is thought to be too costly

All of these undesirable effects can occur under any silvicultural system. However, the risks of some are significantly different among certain systems. The concerns about genetic losses were addressed earlier in the sections on Diversity of plant species and Genetic Resources. The other five concerns are discussed in the following sections on Effects on Scenic Quality, Risks of Adverse Effects on Watersheds and Soils, Scientific Knowledge Base, Management Experience, Need for Control of Competing Vegetation (including the use of herbicides), and Treatment Costs.

Other managerial aspects of the silvicultural systems are also discussed in the sections below. They cover: risk of major wildfires; risk of damage by insect, disease, or wildlife pests; production of livestock forage; protection of archeological resources; administration of silvicultural projects; timber harvesting efficiency; genetic improvements in forests; and effects on fisheries and wildlife.

Effects on Scenic Quality. Uneven-aged silvicultural systems are usually better than even-aged systems for creating or maintaining naturally-appearing landscapes. Uneven-aged systems apply treatments on a small scale. The treatments are also more selective in nature, and are well distributed in the

Table 1. Ratings of the major silvicultural systems by principal biological attributes.

○ is Good, Excellent, or Many
◑ is Moderate or Few
● is Poor or None

BIOLOGICAL ATTRIBUTE	CLEAR CUTTING	SHELTERWOOD	SEED-TREE	GROUP SELECTION	SINGLE-TREE SELECTION
<u>Appearance</u>					
a. Diversity of tree sizes in a stand:					
(1) Vertical	●	●	●	◑	○
(2) Horizontal	●	●	●	◑	○
b. Number of openings in a forest[1]:					
(1) Larger than 2 acres	○	○	○	●	●
(2) 1/10th to 2 acres	●	●	●	○	●
(3) Smaller than 1/10th acre	●	●	●	●	○
c. Potential for conserving or improving plant species diversity in a stand	○	○	○	○	◑[3]
<u>Genetics</u>					
a. Resistance to inbreeding effects	○	○,◑	○,◑	○	●
b. Resistance to degradation by "high-grading"	○	○	◑	○	◑
c. Potential for conserving genes in a forest[2]	○	○	○	○	○
<u>Productivity</u> (potential for producing biomass)	○	○	○	○	○

1 Exclusive of roads and natural openings such as meadows or rock outcrops.
2 Assumes all harvested species are planted successfully, or will regenerate naturally; otherwise "Poor"
3 Assumes no major fires; otherwise "Poor"

Table 2. Ratings of the major silvicultural systems by key managerial attributes.

○ is Good, Excellent, or High
◑ is Moderate
● is Poor

MANAGERIAL ATTRIBUTE	CLEAR CUTTING	SHELTERWOOD	SEED-TREE	GROUP SELECTION	SINGLE-TREE SELECTION
<u>Overall Public Acceptance</u>	●	◑	◑	◑	○
<u>Natural Appearance</u>	●	◑	◑	◑	○
<u>Soil Protection in Stands</u>					
Soil stability where soils have high erosion potentials	●	◑	◑	●	○
<u>Scientific Knowledge Base and Management Experience</u>	○	◑	◑	◑	◑
<u>Wood Production</u>					
a. Cost efficiency of treatments:					
(1) General (based on treatment unit size)	○	○	○	●	●
(2) Regeneration	◑	◑	◑	◑	◑
(3) Feasibility of aerial application of herbicides	○	○	○	●	●
(4) Harvesting	○	◑	◑	◑	●
b. Potential for regulating the forest, while maintaining harvest levels	○	◑	○	●	●
c. Administrative efficiency (planning, contracting, and record keeping)	○	◑	◑	●	●
d. Need for control of competing vegetation	○	○	○	○	○
e. Potential for retaining vigor and value of residual trees[1]	○	○	○	◑	◑
f. Potential for genetic improvement of trees by planting	○	○	○	◑	◑

Table 2 (continued).

○ is Good or Excellent
◑ is Moderate
● is Poor

MANAGERIAL ATTRIBUTE	CLEAR CUTTING	SHELTERWOOD	SEED-TREE	GROUP SELECTION	SINGLE-TREE SELECTION
Controlling Wildfires in a Forest					
a. Potential for controlling major wildfires	○	○	○	○[2]	●[3]
b. Potential for using controlled fires to manage fuels	○	○	○	◑[2]	●[3]
Risk of Significant Pest Damage					
Potential for controlling damage from dwarf mistletoes and certain tree root diseases	○	○	○	○[2]	●
Livestock Production Potential in a Forest	○	○	○	◑[2]	●
Streamside Management Zones					
Potential for protecting fish habitat	●	◑	●	◑	○
Wildlife Habitat in a Forest					
a. Potential for deer, rabbits, and quail	○	○	○	○	●[3]
b. Potential for spotted owls and tree squirrels	◑	◑	◑	○	○
c. Potential for soaring hawks and eagles	○	○	○	◑[2]	●[3]

1 Assumes gentle slopes; otherwise "Moderate", but "Poor" for the Group and Single-tree selection systems.
2 Assumes openings of about 1-2 acres; "Poor" if smaller
3 Assumes highly productive land; otherwise "Moderate" or "Good"

forest. However, long-term maintenance of naturally-appearing landscapes can be more difficult under the uneven-aged systems because natural wildfires are more difficult to control. (See the section on Risk of Major Wildfires.)

Where timber management activities are not permitted to be visually evident, the single-tree selection system may be the only feasible alternative. All silvicultural systems may be feasible where the management objective is to maintain the desired landscape character, depending on the circumstances. However, the uneven-aged systems would generally be better than the even-aged systems. All silvicultural systems may also be feasible where timber management objectives are dominant over visual quality objectives. Similarly, if the landscape character needs to be improved, any silvicultural system could be appropriate. For example, small or large temporary openings that blend with the topography, which are created by group selection or clearcutting regeneration cuttings, can help to achieve a pleasing landscape.

Risks of Adverse Effects on Watersheds and Soils. These risks depend more on the characteristics of the watershed and soils, and on the care and quality of work, than on the kind of silvicultural system used. Adverse effects associated with any silvicultural treatment can usually be avoided or mitigated. The major possible adverse effects are erosion, sedimentation in waterways, soil compaction, and loss of soil productivity through soil or nutrient loss.

The risks of significant, cumulative erosion and sedimentation effects in watersheds usually depend more on road quality and location than on silvicultural treatments.

The risk of significant erosion within stands depends on how much protective vegetation and litter cover is removed, as well as on road quality and location. This risk is generally higher for the clearcutting system because more cover is temporarily removed by clearcutting and preparation for seedling establishment. The risk is least for the single-tree selection system.

Extensive and frequent use of heavy machines can cause significant soil compaction of some soils. The risk of this occurring should not be different among the silvicultural systems.

The risk of soil nutrient losses is increased where vegetation or litter is cleared or high-intensity fires occur. Again, the risk due to clearing vegetation or litter is greater for the even-aged silvicultural systems. High-intensity fires may occur in any stand if controlled fires are used improperly. However, the risk of high-intensity fires is greater for the single-tree selection system because crown wildfires are more likely. (See the section on Risk of Major Wildfires.)

Scientific Knowledge Base. Knowledge is least for the single-tree selection system for National Forest lands in California.

-- Biological. Considerable research has been completed on the biological foundations for all of the silvicultural systems. Planting, natural regeneration, and genetic principles have been extensively studied for all systems. Research is more complete on early growth of young potential crop trees and control of competing plants for the even-aged and group selection systems. Similarly, stand growth model research is more complete for the even-aged and group selection systems. There are no major differences in the knowledge base about intermediate cuttings or about insect and disease pest management, among the silvicultural systems.

-- Managerial aspects. Research on the managerial aspects of California's forests has focused on the even-aged and group selection systems. Only in the last decade have concerted efforts been made to research the long-term practicality of the single-tree selection system. Earlier studies were not completed because of difficulties with controlling regeneration of some desired species, controlling stocking, or sustaining the desired stand structures and merchantable yields. This resulted in strong recommendations against the system by many forest research scientists. New interest has been generated by demands for continuous forest cover, maintenance of an unmanaged appearance, and an alternative to management by the even-aged systems. However, several decades of management will be required before analyses of overall effectiveness can be made.

Research in the group selection system is also underway in California. It too will require several decades of treatments to achieve regulated stands.

Management experience. Timber harvesting has occurred in California for over 140 years. However, experience with managing forests with the goal of regulating potential yields, has been limited to the last several decades. Regulation of National Forest lands has only involved the even-aged silvicultural systems, particularly clearcutting. However, extensive experience has been gained with all of the silvicultural systems in managing certain stands.

-- Single-tree selection. Most of the harvesting from National Forest and many private timber lands in California has been selection cuttings of large trees. These cuttings were typically made with no long-term plan for managing the stands by the single-tree selection system. This system can require cutting trees in all size classes during each operation. Regeneration from natural seeding was usually counted on. Also, growth of the young trees and the uncut smaller merchantable trees was counted on to offset the reduction in the forest inventory due to harvesting the largest trees. Unfortunately, repeated harvests of the largest trees have often caused undesirable results: understocked residual stands with lower quality, lower value trees. These stands will have to be regenerated using one of the even-aged silvicultural systems or the group selection system, so as to re-establish full stocking of desired species.

-- Group selection. The group selection system was tried extensively on National Forest land in the Region about 20 years ago. Small openings were made to encourage natural regeneration, particularly of sugar and ponderosa pines. Special cutting guidelines were developed for different kinds of naturally-occurring groups of trees. The system, called Unit Area Control, failed for three reasons. First, the many small groups of natural regeneration could not be managed efficiently. They could not be monitored. Needed subsequent treatments were not made. The young trees did not grow well or died. Some groups could not be treated due to the higher costs of treating small areas. Second, the cutting guidelines could not be used consistently. There was great difficulty in determining which kinds of groups were actually present in the stand, and the location of their boundaries. Third, many of the small groups were unavoidably destroyed when large trees in adjacent groups were felled, or when logs were moved out of the stand, in later harvesting projects. It is particularly difficult and costly to save small groups of trees on steep slopes from excessive damage during harvesting or preparation of the site for successful establishment of tree seedlings.

-- Even-aged systems. The oldest plantations on National Forest lands in the Region are about 60 years old. Some are soon to be harvested and replaced, thus completing the cycle of an even-aged silvicultural system. Extensive experience has been gained in the regeneration, promotion of young tree growth, intermediate cutting, and regeneration cutting treatments for even-aged systems in all major timber types in the Region. Overall, artificial regeneration following clearcutting has been very reliable in ponderosa pine, Douglas-fir, and Mixed Conifer stands. Artificial regeneration has been significantly less reliable in red or white fir stands. The primary causes of planting failures are: (1) difficulties with consistently producing high-quality seedlings in the nurseries, and (2) planting when the environmental conditions are inappropriate. The shelterwood system with natural or artificial regeneration is presently used in red or white fir stands where regeneration after clearcutting is expected to be unreliable.

Wood Production

-- Need for control of competing vegetation (including the use of herbicides). Control of competing vegetation is needed in all of the silvicultural systems to ensure establishment and good growth of tree seedlings or sprouts. Some have theorized that less control is needed in the single-tree selection system. Under this system tree cover is more continuous, resulting in fewer competing grasses, forbs, and shrubs. However, these competitors cause significant moisture stress in the seedling and sapling potential crop trees (in addition to the substantial moisture stress caused by the larger trees), thereby reducing their survival and growth. There is no compelling theoretical basis for concluding that the need for control of competing vegetation should be reduced if the single-tree selection system were used. Certain commonly occurring, major competing plants can retain good vigor when shaded by most conifers such as manzanita, bear clover, tanoak, or madrone). Using the single-tree selection system would definitely not reduce the need for controlling competition from such plants.

Frequency of control treatments varies by silvicultural system. Treatments under the single-tree selection system could be needed somewhere in every stand as often as every 5 to 10 years. The average treatment frequencies in the other systems are much lower. For example, in any of the even-aged systems, up to about three treatments could be needed in the first ten years of a new stand. No additional treatments may be needed until the stand is regenerated - a period that could exceed 50 years. Thus, the average period between treatments would be greater than 20 years. Regardless of the silvicultural system used, the total acres treated (and the total pounds of herbicide applied per acre, if herbicides were used) should be about the same over the long term.

The aerial application of herbicides (usually the most cost-effective, and frequently the most controversial, method of applying herbicides) could not be used in the single-tree selection system. Depending on topography and vegetation structure, it could also be impractical in the group selection system.

-- Treatment costs. The size of a treatment area is a major factor in determining treatment costs and managerial feasibility. Generally, costs per acre in intensively managed forests are higher when the treatment units are smaller. Therefore, the even-aged systems are the most cost efficient, and the group selection and the single-tree selection system in that order) are the least cost-effective.

Regeneration by clearcutting is the most cost-efficient among the even-aged systems. Shelterwood and seed tree systems are less so, in that order. The removal of shelterwood trees or seed-trees, after the seedlings are established, is a second cost not required in the clearcutting system.

In theory, the total cost of natural regeneration should be less than for artificial regeneration. The costs of seed collection, nursery operations, seedling handling, and planting are eliminated. However, these savings are often offset by increases in pre-commercial thinning costs. Natural regeneration often results in much greater densities of threes than would be planted, or are desirable. Also, unreliable seed production by many commercial tree species often delays natural regeneration. This reduces wood competing plants, the control of which can be costly. Overall, artificial regeneration insures prompt reforestation of preferred species at desirable densities. If natural regeneration is to be used, the shelterwood and seed-tree systems are usually more cost-efficient than the uneven-aged systems. The reason is the economies of scale associated with larger treatment areas. Where artificial regeneration is to be used, the clearcutting and shelterwood systems are more cost-efficient, for the same reason.

-- Achieving regulated forests, while maintaining Forest timber harvest levels. Regulation can be accomplished most easily with the even-aged or group selection silvicultural systems. There are two critical disadvantages of the single-tree selection system. First, foresters lack the detailed information about trees needed for cutting on a stand-by-stand basis. There are tens of thousands of stands on a typical National Forest in California, with up to about ten thousand potential crop trees per stand. Currently, inventory data needed for the single-tree selection system are lacking for about two-thirds of these stands. Second, in the Mediterranean climate in California, large forest wildfires are inevitable. Reforestation after these fires creates many, new, even-aged stands. It is very difficult to regulate a forest under a single-tree selection system when substantial acreages of unplanned even-aged stands occur.

-- Planning, contracting, and record keeping. The many small units used in the uneven-aged systems makes for ineffective and costly operation and administration. If stands in a typical Ranger District were managed by uneven-aged systems, in excess of 50,000 separate areas would have to be inventoried, planned for, treated, and monitored. Even with computers the management complexity would be excessive. Therefore, the extent to which uneven-aged management systems are used for intensive timber management will necessarily be very limited.

-- Timber harvesting. Five important aspects of timber harvesting are strongly influenced by the choice among silvicultural systems: (1) variability in sizes of harvested trees, (2) area to be harvested, (3) complexity of the harvesting treatment, (4) the probability of causing significant damage to trees to be left in the stand, and (5) the probability of causing long-term root disease problems. The first three influence harvesting efficiencies, and the other two affect the vigor, tree stocking, and value of the residual stand.

There is wide size variation in trees harvested in each operation under the single-tree selection system. This reduces harvesting efficiency because logging equipment is size-dependent. However, this disadvantage could be insignificant in young-growth stands.

Harvesting in the single-tree selection system is much less efficient than for the other systems because more land must be treated in each operation to harvest the desired yield from the forest.

The complexity of harvesting treatments is also greatest in the single-tree selection system. Identifying which trees to cut, determining where they are to be felled, felling the trees in the designated areas, and removing the trees or logs out of the stand without damaging the residual trees can be very difficult and costly. In the single-tree selection system, cuttings occur as frequently as every five to ten years. In the other systems, only the intermediate cuttings are as complex. The regeneration cuttings in the other systems are more straightforward operations. Group selection and clearcutting are the most efficient.

Logging damage to trees left to grow in the stand is typically greatest for the single-tree selection system. It is very difficult to selectively harvest trees in dense stands without damaging many residual trees, particularly on steep slopes. Damaged trees are often infected by wood-decaying fungi that can persist in the soil for long periods, thus retaining the capacity to infect new trees. The fungi reduce the windfirmness, vigor, commercial value, and stocking of residual trees. This characteristic is a particular concern in developed recreation areas where selection systems are often applied. Stands with red or white fir have an especially high probability of being infected with wood-decaying fungi when damaged.

-- Genetic improvements in forests. Genetic improvements to increase timber growth, improve tree form and wood quality, or increase resistance to disease and insect pests, depend primarily on planting trees with desirable genetic characteristics. Therefore, the potential for genetic improvement is greater for silvicultural systems that use artificial regeneration. The clearcutting, group selection, and shelterwood systems (if artificial regeneration is used) have the greatest potential for improving the genetic quality of forest trees. The single-tree selection system, with its natural regeneration and higher rates of inbreeding, has the least potential.

Risk of Major Wildfires. The even-aged systems (clearcutting in particular) are best for reducing the risk of major wildfires because the greater control of fuel distribution makes wildfire prevention and suppression easier and less costly. The single-tree selection system is least desirable because fires burn intensely and are more difficult to control. Openings which can serve as fuel breaks occur less frequently in forests or stands managed by this system.

Silvicultural systems are not just the creation of foresters; rather, they are adaptations of natural occurrences. Nature makes "regeneration cuttings" by means of fire, insects, disease, wind, and other phenomena; by removing a single tree, a small group of trees, a stand, or sometimes a whole forest.

Regeneration cuttings strongly influence stand characteristics and management options. Therefore, the 5 major silvicultural systems are named after them: clearcutting, seed-tree, shelterwood, single-tree selection, and group selection. Each of these systems includes regeneration cuttings to establish new tree seedlings or sprouts, and intermediate cuttings to develop the desired stand characteristics, such as species composition, spatial distribution, and plant vigor.

The clearcutting, seed-tree, and shelterwood systems are even-aged systems; which means that all of the trees in the stand are approximately the same age for almost all the life of the stand. The single-tree and group selection systems are uneven-aged systems; the trees in the stand differ markedly in age, with at least three major age classes present. Uneven-aged stands have no beginning or end points in time.

Even-aged Systems

Clearcutting (shown in Figure 1) is the harvesting, in one operation, of all merchantable trees in a stand or a larger area to help establish a new even-aged stand. The new stand may be created by natural processes such as seeding from trees in adjacent stands, or by sprouting from the stumps or roots of the cut trees. The new stand can also be created by man through broadcast scattering of seed, or by planting seeds or seedlings. In California, clearcut stands are usually regenerated by planting seedlings.

Clearcutting does not necessarily mean that all unmerchantable trees are removed. Where feasible, high-quality unmerchantable trees are saved to become part of the new stand. A 1987 survey showed that on gentle terrain in the National Forests on the western slope of the Sierra Nevada mountains, high-quality unmerchantable trees are being retained on an average of about 10 and 20 percent of the acres being regenerated to ponderosa pine, and to red fir or white fir, respectively.

The seed-tree system (shown in Figure 2), each tree is evaluated for its contribution to the desired characteristics of the uneven-aged stand. Regeneration and intermediate cuttings are usually done in one operation. The desired seedlings or sprouts grow in the spaces created by harvesting of individual trees.

Repeated selection cuttings, part of the single-tree selection system, have been used frequently to manage National Forest lands, particularly in the Sierra Nevada and Cascade Mountain Ranges. There has been a major shift to using the clearcutting or shelterwood systems over the last two decades. The primary reason is that the selection cuttings caused significant understocking in many stands, thereby reducing productivity. There are many examples of poor selection cuttings in California, under the guise of the single-tree selection system. High quality, large trees were cut, leaving inferior, small trees. Genetic principles were ignored, and many stands were left understocked, with

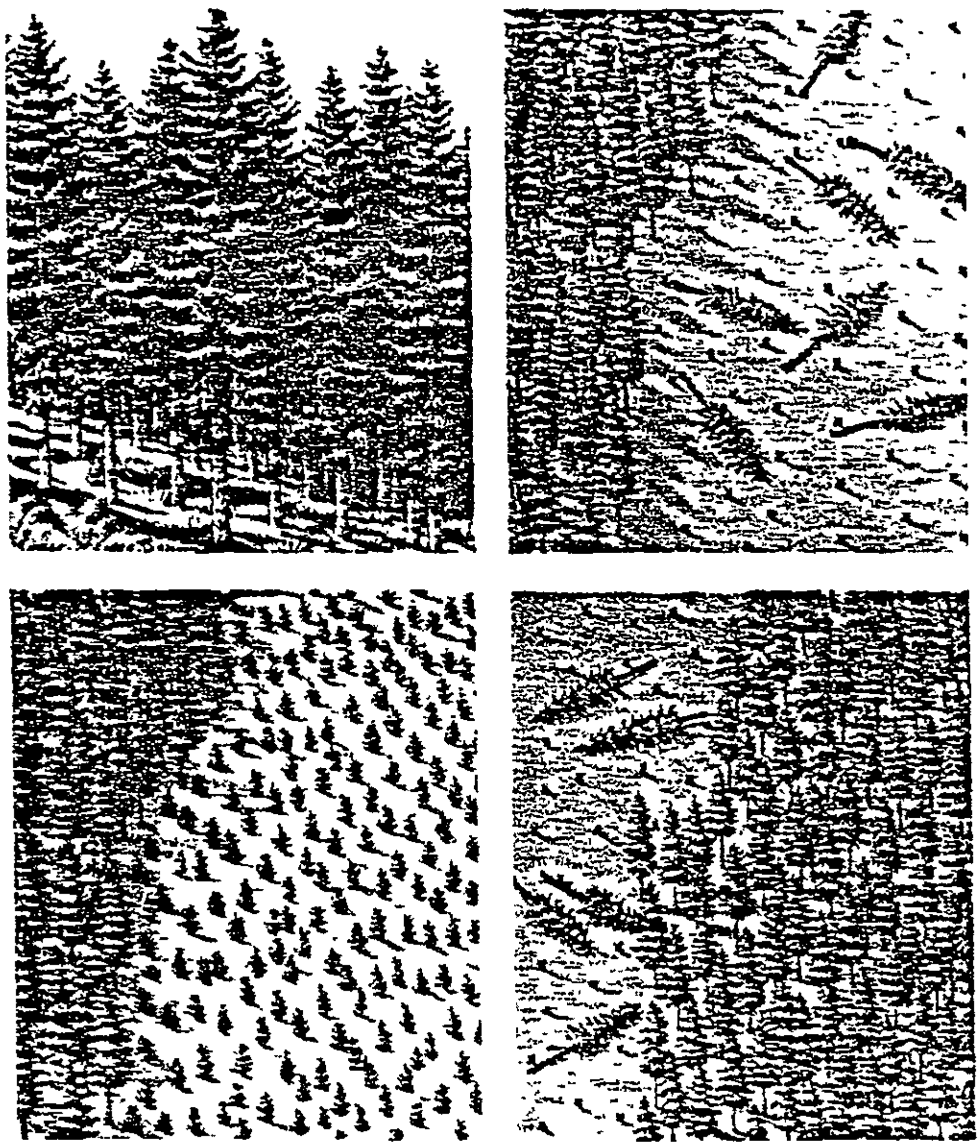

Figure 1. **Clearcutting.** *Part of a mature stand is cut, removing all trees. A new stand arises from seeds of surrounding trees or from sprouts sent up by roots or stumps. Seedlings may also be planted or seeds broadcast. When the new trees are well on their way in the unobstructed light of the clearing, a neighboring stand of mature trees is cut in turn. (The illustration is from* The Secret Life of the Forest *by Richard M. Ketchum, copyright 1970 by American Heritage Press, and is used with the permission of McGraw-Hill Book Company* and the Society of American Foresters.)

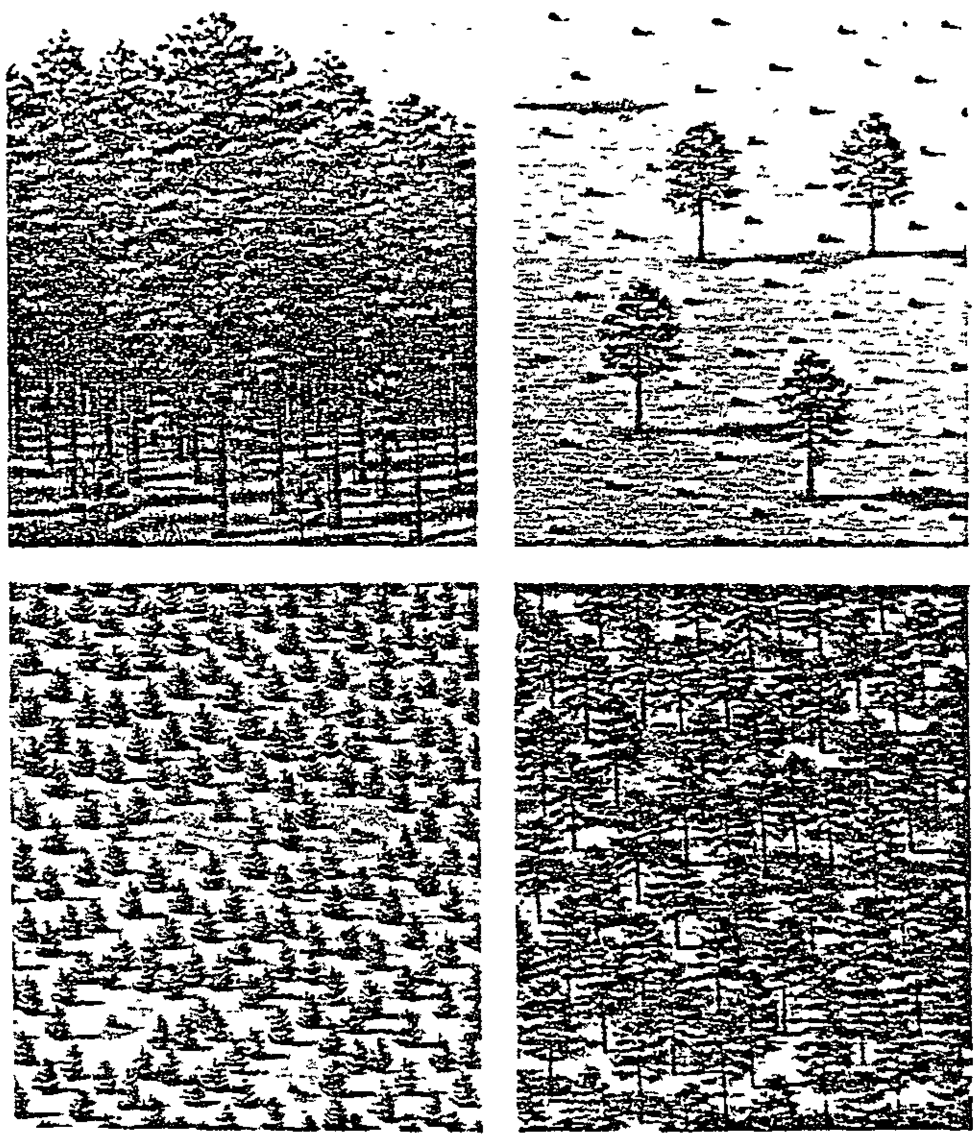

Figure 2. **Seed-tree System.** *The mature stand is logged, but enough trees are left to reseed the area. The seed trees usually are large and valuable, and may be harvested when they have fulfilled their purpose. Like clearcutting, the system favors light-demanding species. (The illustration is from* The Secret Life of the Forest *by Richard M. Ketchum, copyright 1970 by American Heritage Press, and is used with the permission of McGraw-Hill Book Company* and the Society of American Foresters.)

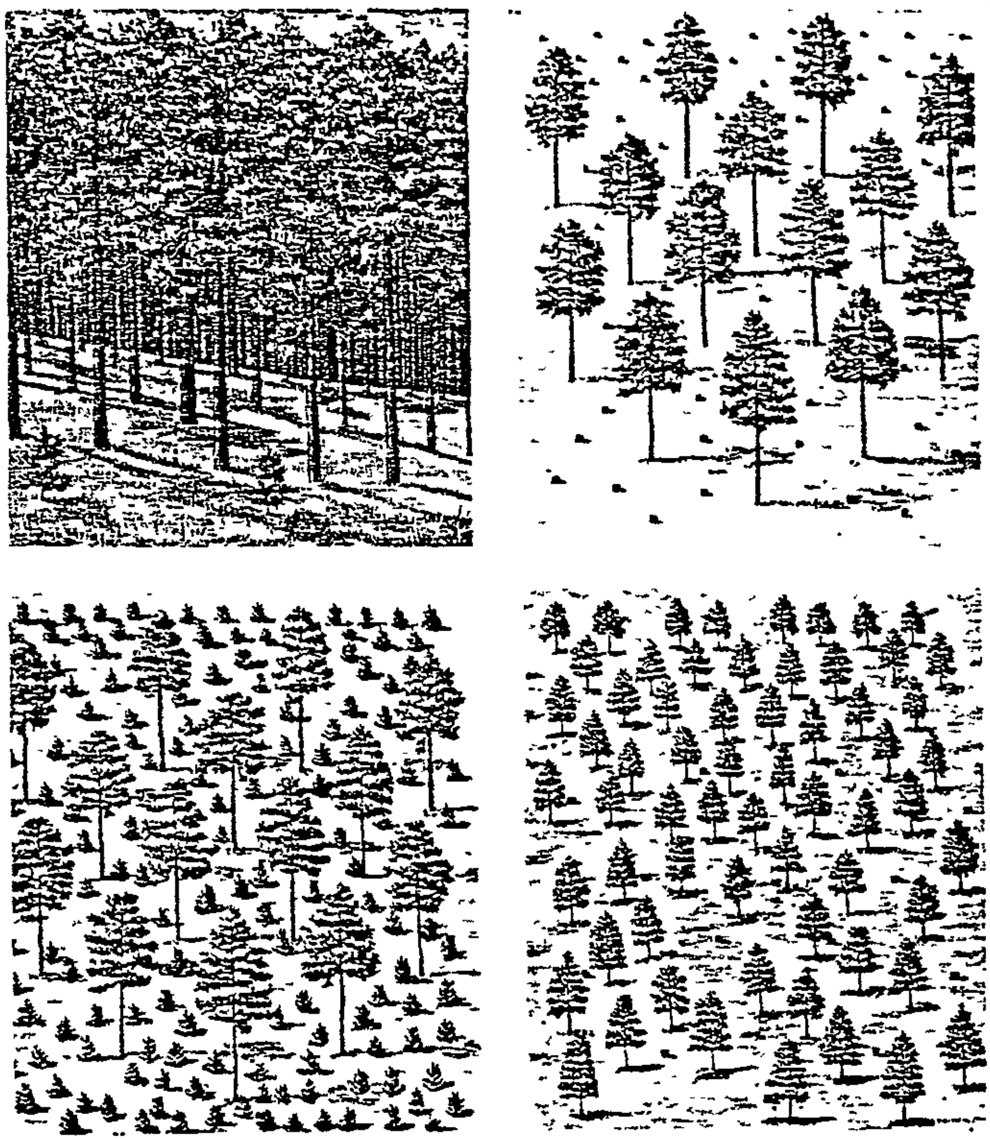

Figure 3. **Shelterwood System.** *A mature stand is partially cut, leaving some of the better trees of desired species to grow, cast seed, and provide shade and perhaps other shelter for the new stand. Usually more trees are left per acre than in the seed-tree system. These shelter trees will be harvested after seedlings have become established and no longer need protection.* (The figure and caption are used with the permission of the Society of American Foresters.)

slow-growing, small trees that are more susceptible to attacks by insects and diseases. In these situations, establishing a new even-aged stand typically is the most efficient way of regaining desired productivity levels and other stand qualities.

The shelterwood system (shown in Figure 3) requires leaving sufficient trees per acre (typically 10 to 20), during the regeneration cutting, to provide an environment that protects (shelters) the seedlings of a new even-aged stand. Protection may be needed from excessive moisture stress or frosts in some forest areas. The new stand can be created by the natural or artificial processes described above.

Regeneration under shelterwoods by planting seedlings is a common practice on national Forest lands in the Region. The shelterwood trees are harvested following establishment of the seedlings of the new even-aged stand. The shelterwood system is the second-most commonly used even-aged system on National Forest lands in Region 5, after the clearcutting system. The shelterwood system is most commonly used in stands where red or white fir are to be regenerated.

The group selection system requires harvesting trees in small groups (less than about 2 acres). The openings created in the stand resemble miniature clearcuts. The uneven-aged stand consists of a mosaic of even-aged groups. Thus, the group selection system uses the principles of even-aged systems described above to manage much smaller units of land. Currently, the group selection system is used less frequently than the single-tree selection system on the National Forest lands in Region 5.

Even-aged systems are more practical than uneven-aged systems for intensive management of wood products. The reasons are explained in the section below on "MANAGERIAL CONTRACTS..."

TIMBER YIELD AND REGULATION OF FORESTS AND STANDS

Timber yield is the amount of wood that is harvested periodically from a specified forest area. The maximum yield allowed from a National Forest for a planning period (typically one decade), is called the allowable sale quantity.

By Federal law, the allowable sale quantity generally cannot exceed the long-term, sustained capacity of that Forest to grow wood. Within each National Forest, stands are managed by silvicultural systems to achieve continuous production of the allowable sale quantity.

When this continuous production level is achieved, the Forest and stands are said to be "regulated". Where the single-tree selection or group selection silvicultural systems are used, each regulated stand would produce approximately the same yield from each harvest, which would occur about every 10 years. By contrast, where the even-aged systems are used, yields from each harvest in a regulated stand would not be equal, but the average yield for the Forest would be the same.

The conversion of wild stands to regulated stands in many of California's forests has just begun. The goal of regulation will take many decades to achieve. No major forest in California has yet been regulated.

BIOLOGICAL CONTRASTS AMONG FORESTS AND STANDS MANAGED BY DIFFERENT SILVICULTURAL SYSTEMS

Appearance

-- Variation in tree age. A forest managed by even-aged silvicultural systems consists of a mosaic of even-aged stands. Every age class would be represented in a regulated forest, and each age class would be represented by approximately the same number of stands. A regulated forest managed by the group selection system would resemble forests managed by the even-aged silvicultural systems; except that the even-aged components (groups) would be much smaller and more numerous. By contrast, each stand in a regulated forest managed by the single-tree selection system would have trees of many ages (perhaps all ages).

The oldest (or largest) trees in any managed forest depend primarily on the management objectives, not on the silvicultural systems. In particular, the amounts of large- or old-growth to be produced or maintained depend more on the willingness to forego yields than on the kinds of silvicultural systems used to manage stands.

-- Variation in developmental stages. In the even-aged and group selection systems, all stages of forest development are present in the forest; including grasses, forbs, shrubs, tree seedlings, and larger trees. Each stage is represented by entire stands or groups. By contrast, in the single-tree selection system the areas dominated by small plants such as grasses, forbs, or shrubs are commonly very small (for example, less than one-hundredth of an acre), but they typically occur somewhere in every stand. In a regulated forest, the total area occupied by each stage should be about the same, regardless of the silvicultural system.

Also, the multiple tree layers create "ladders", permitting ground fires to spread into the crowns of the large trees. Crown fires are more destructive and more difficult to control than ground fires. Finally, the use of controlled fires to reduce the risks of large wildfires is most difficult and costly in the single-tree selection system.

Risk of Significant Pest Damage. Silvicultural treatments reduce risks by selecting appropriate tree species, by diversifying within and among stands, and by maintaining tree vigor. Diversification within stands is increased through use of multiple species or uneven-aged silvicultural systems. Vigor is promoted by preventing the trees and other plants from becoming too dense. Competing plants also provide habitat for animal pests such as pocket gophers and rabbits. Well-managed stands in all systems reduce the risk of significant pest damage. However, there are significant exceptions.

Risk of significant insect or disease damage to trees increases if the trees have been wounded. Many wounds occur during silvicultural treatments. Accidental scarring of trees can be caused by felling nearby trees, or by bumping them with machines or logs moving through the forest. Risk increases with frequency of stand treatments, particularly cutting. Cutting frequency is much higher for the single-tree selection system than for others, so the risk of significant insect and disease damage is highest.

Two serious disease, dwarf mistletoes and some root rots, can be difficult, costly and, in some cases, impossible to control under selection systems. Damage from these diseases is most easily controlled by managing stands as wholes. Dwarf mistletoe plants can project seeds down on trees within abut 100 feet horizontally, thereby infecting nearby susceptible species. Even-aged systems allow the manager to control damage from this pest through cutting treatments.

Many root disease fungi infect susceptible trees by root-to-root contact. Some root diseases start at harvest time and spread to other trees in the stand. Control may require killing trees in a zone around the infected area. Uneven-aged management, particularly the single-tree selection system, can perpetuate root disease "centers" and spread infection.

Generalizations about wildlife pest damage and silvicultural systems are difficult. The major potential wildlife pests in the Region include pocket gophers, deer, porcupines and rabbits. These animals feed in vegetation dominated by grasses, forbs, shrubs, or tree seedlings. Use of the even-aged or group selection systems can create large areas temporarily dominated by this kind of vegetation. This can cause higher densities of potential pests, which increases the risk of significant damage to potential crop trees. However, often the actual damage levels are not increased where this occurs.

Production of Livestock Forage and Browse. Even-aged systems and the group selection system are best for livestock production. Grasses, forbs, and shrubs used by livestock occur in the greatest quantity in openings. Management efficiency increases in large forage areas because livestock control and access is easier and less costly.

Protection of Archeological Resources. There should be no significant differences among the silvicultural systems in their risk of damage to undetected archeological resources. Damage depends more on the intensity and frequency of management treatments than on the kind of silvicultural system, particularly when large machines are used.

Effects on Fisheries and Wildlife Habitat. Fisheries habitat is most easily protected where the water quality is high, stream temperatures are kept moderate through shading, and where the runoff quantity is sufficient to maintain spawning areas. The single-tree selection or group selection systems are usually more advantageous than the even-aged systems for managing the vegetation in streamside management zones and riparian areas. However, the silvicultural systems used outside these zones does influence the amount of sediment in the water (see the discussion in the section titled Risks of Adverse Effects on Watersheds and Soils.)

The choice of silvicultural systems to best manage wildlife habitat depends on which species are to be emphasized. Regardless of which treatment is used in a stand, some species will benefit and others will not. Most wildlife species are adapted to thrive in specific structures and species of forest vegetation. For example, the use of the even-aged or group selection systems favors deer, quail, and rabbits that use herbaceous and shrubby vegetation most abundant in large openings in the forest. The single-tree selection system may favor animals that need vertical diversity, such as spotted owls and tree squirrels.

Almost all forest wildlife species could use a particular young-growth stand at some time in its development regardless of the silvicultural system. (The exceptions are the few species that may be totally dependent on very large, decadent trees for habitat.) The kind of system would influence the proportions of species and when and how they could use the stand as habitat. A significant exception is single-tree selection management applied to large areas. The absence of large openings could prevent use by wildlife adapted to this kind of habitat, such as soaring hawks. Overall, a mix of the silvicultural systems in the forest would probably best achieve most wildlife management objectives.

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