# Appendix F - Silvicultural Systems and Their Applications

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# Appendix F - Silvicultural Systems and Their Application

## Introduction

This appendix describes the major silvicultural systems used in land management planning on the Klamath National Forest. It discusses the advantages and disadvantages of each silvicultural system and considers both biological and managerial perspectives. Most of the information in this appendix 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 the stand.

A stand is a community of trees sufficiently uniform to be distinguishable as a silvicultural or management unit. Typically, managed stand sizes vary from about 5 to 40 acres on NFS lands.

Management objectives for stands typically provide combinations of forest products and amenities. Some combinations are specific amounts of livestock forage, water runoff and wood products, kinds of wildlife habitat or 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. 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 forest level and project level. The Forests' 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, riparian areas and special habitat areas. At the project level, a certified silviculturist typically makes site-specific recommendations of silvicultural systems. Choices are based on matching the attributes of the silvicultural systems with specific management objectives (developed by the interdisciplinary team) and the ecological characteristics for specific stands.

The term "silvicultural prescription" describes the treatments developed for one or more of the steps specified in the silvicultural system. Examples of silvicultural prescriptions include recommended cutting practices, reforestation guidelines and/or release treatments.

## 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).

Silvicultural systems are not the creation of professional foresters. Rather, they are adaptations of natural occurrences. Nature makes "regeneration cuttings" by fire, insects, disease or wind. These can remove a single tree, a small group of trees, a stand or sometimes a whole forest. Vegetation within forest stands changes over time as trees grow, die and are replaced by other vegetation. These characteristic patterns of vegetation change, or successional trends, are specific to each forest type. They are further influenced by site conditions such as soil type, aspect and elevation.

Regeneration cuttings strongly influence stand characteristics and management options. Therefore, the five major silvicultural cutting methods are named after them: clearcutting, seed-tree, shelterwood, single-tree selection and group selection. In addition to these traditional cutting methods, the Forest has prescribed an additional method called green tree retention (GTR). Each of these methods includes regeneration cuttings to establish new tree seedlings or sprouts and intermediate cuttings to develop desired stand characteristics, such as species composition and spatial distribution.

There are 2 basic types of silvicultural systems. In even-aged systems, all the trees in the stand are about the same age throughout the life of the stand. In uneven-aged systems, the trees in the stand differ markedly in age, with at least three major age classes present.

For modeling and planning purposes, the Forest Plan EIS considered 6 methods. These methods are clearcut, GTR, seed tree shelterwood, removal step shelterwood, group selection and stand maintenance. These broad categories are used for planning and display purposes. The categories describe the methods expected to be used most often for the alternatives. Actual implementation of any alternative would include a full array of silvicultural prescriptions depending on the site-specific objectives.

## Even-aged Systems

Clearcutting, seed-tree and shelterwood are even-aged systems. GTR is a modified even-aged system which retains portions of the existing stand, creating a multiple-storied structure with 2 or more age classes present.

In even-aged systems, all or most of the trees are planted and/or regenerated naturally. As the stand grows, thinnings are sometimes conducted, harvesting trees that would die due to overcrowding.

Even-aged systems are managed on a rotation. The rotation age, or time period between stand regeneration and harvest, can be determined by desired age, size of trees, economics or stand growth. Even-aged silvicultural systems create site conditions similar to those following large-scale disturbances, such as a high intensity fire, insect epidemic or massive wind storm. Intermediate cuttings, like commercial thinning, mimic a recurring cycle of low intensity fires occurring within the stand.

Clearcutting is the harvesting, in 1 operation, of all merchantable trees in a stand with the intention of establishing 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. New stands also are created artificially through broadcast scattering of seeds or by planting seeds or seedlings. On the Forest, clearcut stands are usually regenerated by planting seedlings. In the past few decades, clearcutting has been the most commonly prescribed silvicultural cutting method on the Forest. (Refer to Simulation No. 8 in the map packet accompanying this EIS for an illustration of this method.)

The seed-tree cutting method requires leaving a few good seed-producing trees per acre (typically 2 to 5) during the regeneration cutting. These trees produce the seed needed to establish a new even-aged stand. Because natural regeneration within the desired time frames is unreliable on the Forest, these stands are usually planted. Following seedling establishment, the seed trees are harvested, leaving only those overstory trees needed to meet snag and other structural requirements. (Refer to Simulation No. 7 in the map packet accompanying this EIS for an illustration of this method.)

The shelterwood cutting method requires leaving sufficient trees per acre (typically 8 to 20) during the regeneration cutting. This provides an environment that protects (shelters) the seedlings of a new even-aged stand.

Protection may be needed from excessive moisture stress or frost in some forest areas. These stands are also commonly planted on the Forest. It is expected that after the new conifer seedlings become established, the shelterwood trees are harvested leaving only those overstory trees needed to meet snag and all other structural requirements. However, on the Forest, these shelterwood trees are often retained to ameliorate visual impacts and avoid below-cost timber sale returns. (Refer to Simulation Nos. 5 and 6 in the map packet accompanying this EIS for illustrations of this method.)

In the past, seed-tree and shelterwood cutting methods were the second-most commonly used systems on the Forest. These methods are commonly used in stands where red or white fir regeneration is desired. Seed-tree cuttings are also used where planting operations are more difficult due to adverse site conditions or desired species composition. Where red or white fir is a desired species, shelterwood cutting methods provide for more dependable re-establishment. On sites where excessive heat may be a problem for conifer survival, shelterwood cuttings are used. Because of the poor economics of harvesting the seed or shelterwood trees after seedlings are established, this cutting method has been used less than the clearcut method.

On NFS lands, traditional silvicultural systems are commonly modified to some extent to meet other non-timber resource objectives. GTR is an even-aged management system with some attributes of the uneven-aged system. GTR maintains a portion of the existing stand, creating a 2-storied structure with 2 or more age classes present to meet other resource concerns such as visual quality and habitat structural requirements.

Commonly, the trees are retained to provide stand structural components for wildlife habitat, visual enhancement or biological and structural diversity. Leave trees can provide future dead standing or down woody material (snags and logs) for wildlife. They can also enhance long-term site productivity or, in some cases when thrifty reproduction can be left, contribute to the future conifer growth and yields within a stand.

The size and number of trees retained depend on: (1) the specific site objectives, (2) the structure of the existing stand, and (3) the technical feasibility of retaining these reserve trees through harvest and site preparation activities. Trees commonly retained include conifer reproduction (saplings and poles), mature or overmature conifers, hardwood trees or a combination of these trees. These trees can be scattered uniformly throughout the stand or clumped together in the regeneration unit. Depending on the stand objectives and site conditions, there may be only a few residuals retained on site or the stand may be made up of large areas of residual trees. (Refer to Simulation Nos. 3 and 4 in the map packet accompanying this EIS for illustrations of this method.)

Other silvicultural prescriptions used in even-aged management systems include overstory removal, commercial thinning, salvage and sanitation. Overstory removal is a regeneration harvest. Commercial thinning, salvage and sanitation are intermediate harvests.

Overstory removal harvests an overstory layer of sparsely scattered conifers and retains a second layer of relatively well-stocked conifers. The overstory consists of significantly older and larger trees than the understory. The understory is now a combination of saplings and poles and is adequately stocked throughout most of the stand. Areas without adequate conifer stocking after harvest are commonly planted. The resulting stand is managed as an even-aged stand.

Commercial thinning is an intermediate harvest treatment applied to overstocked or potentially overstocked stands. Commercial thinnings typically harvest current mortality and slower growing conifers that may die before the next logical harvest entry. Thinnings are prescribed to control conifer stocking and maintain the vigor and growth of the existing trees. This is done to increase available moisture, nutrients and light to the remaining trees. The number of trees left after commercial thinning is determined by stand age, condition and management objectives.

Sanitation cutting is the removal of insect-infested, diseased and/or high risk trees within a stand. Salvage is the harvest of dead and/or dying trees. Sanitation is commonly prescribed to maintain stand vigor and growth. Both salvage and sanitation operations provide utilizable wood, while meeting snag and other structural guidelines. Removal of dead and dying trees also helps to reduce fire hazards within stands.

## Uneven-aged Systems

The single-tree and group selection cutting methods are uneven-aged systems. Trees in the stand differ markedly in age, with at least three major age classes present. The age class distribution in an uneven-aged stand is regulated to insure that adequate numbers of trees in all age classes are present and can be sustained through time. Since uneven-aged stands have no beginning or end points in time, these systems are managed through a series of cuttings at specified intervals, or cutting cycles. Uneven-aged systems approximate small-scale disturbances that remove individual trees or small groups of trees from within a stand. These naturally occurring disturbances might include periodic ground fires, insect kill or windthrow.

In the single-tree selection cutting method, 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. In the spaces created by harvesting individual trees, seedlings are planted, sprout or seed in naturally. Dense groups of young trees are thinned to provide for the growth of desired individual trees. (Refer to Simulation No. 1 in the map packet accompanying this EIS for an illustration of this method.)

The group selection cutting method requires harvesting trees in small groups (usually less than 2 acres) within a stand. The openings, resembling miniature clearcuts, provide the opportunity to regenerate a portion of the stand, and control age and species composition within the stand. Through time these small openings create a mosaic of even-aged groups. Thus, the group selection method uses the principles of even-aged systems described above to manage much smaller units of land. (Refer to Simulation No. 2 in the map packet accompanying this EIS for an illustration of this method.)

Salvage and sanitation operations, as described above, also can be applied to uneven-aged systems.

## Maintenance Cutting

Maintenance cutting is not a silvicultural system in itself. Maintenance cutting is included in the EIS to model very low levels of timber harvest on lands where timber production is expected to be minimal. The silvicultural cutting methods listed above can be utilized to achieve a maintenance cut. The silvicultural method used to achieve stand maintenance depends on management objectives and site-specific analysis.

## Timber Yield and Regulation of Forests and Stands

Timber yield is the amount of wood 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 (ASQ). By Federal law, the ASQ generally cannot exceed the long-term, sustained capacity of the forests to grow wood. Within each National Forest, stands are managed by silvicultural systems to achieve continuous production of the ASQ.

When this continuous production level is achieved, the forest and stands are said to be "regulated." Where single-tree or group selection cutting methods are used, each regulated stand would produce about the same yield from each harvest. This would occur about every 10 to 20 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 unmanaged stands to regulated stands on the Forest has been going on for several decades and 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

Table F-1 at the end of this appendix shows a summary of the key biological contrasts for various silvicultural systems.

### Productivity

Scientific long-term comparisons of wood production using the different silvicultural systems has 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 higher for stands managed by the single-tree selection cutting method. This is because of more continuous tree cover, compared to the other systems. However,merchantable stand growth and timber yields may not be higher for the single-tree selection cutting method because merchantable yields are strongly influenced by managerial factors.

There is evidence from Europe (Assman, 1970) that yields are less with uneven-aged management compared to even-aged management. Additional factors, like species composition and the role of fire in the forest, can possibly affect the quantity and quality of timber yields from different silvicultural systems. These factors are further discussed in this appendix under Diversity of Plant Species and Risk of Major Wildfires.

Single-tree selection is operationally more complex than even-aged management systems. Repeated selection cuttings, part of single-tree selection, have been used frequently to manage NFS lands. This was done particularly in the Sierra Nevada and Cascade Mountain Ranges. There was a major shift to using the clearcutting or shelterwood cutting methods over the last two decades. In many instances, selection cuttings resulted in significant understocking in stands causing reduced productivity. Changes in species composition from shade intolerant species to shade tolerant species were undesirable from a commercial standpoint. (Refer to the section on Diversity of Plant Species.)

With single-tree selection, the inability to effectively treat flammable material increased fire hazards in stands. This creates an unacceptable fire risk. Genetic principles were often not understood and high quality, large trees were cut, leaving inferior, poorly growing smaller trees.

Repeated selection cuttings increase the chance of scarring trees during logging operations. This increases their vulnerability to insect attack and introduces them to disease. Thin-barked species, like true fir, are particularly susceptible to injury. On steeper slopes, repeated entries often results in understocked stands. In these situations, establishing a new even-aged stand typically is the most efficient way of regaining desired productivity levels and other stand qualities.

Wood production under even-aged management systems can vary depending on biological and managerial factors. For example, on a good mixed conifer site wood production is usually highest with the clearcutting method. Numbers and species of trees can be controlled, adequate spacing between trees maintained and competing vegetation treated to allow for increased conifer growth.

Leaving trees within a stand (GTR, shelterwood or seed-tree cutting methods) can significantly decrease conifer growth rates and future timber yields. The magnitude of this effect is highly variable depending on the size, number, species, distribution and fate of residual trees retained.

### Forest and Stand Diversity

***Variation In Tree Age –*** A forest managed by even-aged silvicultural systems consists of a mosaic of even-aged stands. Equal acres or areas of equal productivity of every age class would be represented in a regulated forest. Group selection would resemble the even-aged system, although stands would be smaller and more numerous.

By contrast, stands managed by single-tree selection in a regulated forest would have trees of many ages. Variation in tree age for a regulated forest, using GTR, would have characteristics of both even and uneven-aged systems. The forest would be a mosaic of even-aged openings with smaller multiple aged patches within.

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 reduce timber yields than on the types of silvicultural systems used to manage stands.

***Variation in Developmental Stages*** -- Forests develop differently between species, sites, spacing, age distributions and external influences, such as natural or human-caused disturbances. Silvicultural treatments change how the forest develops. In the even-aged system and group selection cutting method, a variety of plants (grasses to trees) are present in the forest. Each stage is represented by entire stands or groups. By contrast, in the single-tree selection cutting method, areas of understory plants are commonly very small (less than one-hundredth of an acre), but 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.

***Vertical Diversity*** -- The vertical diversity in stands managed by the even-aged system or group selection cutting method can be quite limited. Typically, there is a single dominant layer of seedlings, saplings or larger trees. However, there is usually 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. With the GTR prescription, leaving existing green trees in stands increases the within-stand vertical diversity. By contrast, in the single-tree selection cutting method, 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.

***Diversity of Plant Species*** -- Species diversity changes with the biological and physical environment, natural disturbances (such as fire) and management activities. Over time, the species composition within a stand changes considerably. The presence and abundance of different forbs, grasses, shrub and trees species will vary depending on the age of the stand, the management prescriptions applied and the occurrence of other natural processes. Because silvicultural treatments can alter the environmental conditions within a stand and directly impact existing or future vegetation, these treatments can significantly affect the diversity of plant species.

Even-aged systems and group selection cutting methods favor plants that can be readily established and grow well in full sunlight (shade-intolerant plants). These include a variety of grasses, forbs and shrubs and many of the most valuable commercial tree species, such as ponderosa pine, sugar pine and Douglas-fir.

Single-tree selection favors plants that can be readily established and grow well at low light levels (shade-tolerant plants). Examples include ferns, few grasses and forbs, many non-commercial hardwoods and a few commercial conifers, such as white fir.

On moderate to high quality lands, stands managed by single-tree selection shift toward shade-tolerant species. On low quality forest lands, where lack of soil moisture or other soil conditions cause low plant densities, shading by trees is reduced. There, shade-intolerant plants will persist if single-tree selection is used. In California, many stands previously dominated by commercially valuable pine and Douglas-fir, now have large components of less valuable tanoak, madrone or white fir due to single-tree selection.

The species composition of commercial tree species may be significantly increased or decreased during stand regeneration. This depends on the environmental conditions, availability of natural seed, selection of species to be planted and the success of the plantings.

If both artificial and natural regeneration fail, species diversity of trees is reduced. Overall, artificial regeneration has been very reliable in ponderosa pine, Douglas-fir and mixed conifer stands. The risk of a complete regeneration failure is least for single-tree selection. Successful natural regeneration of all species is best where openings are small, seed sources are present and ground environmental conditions are suitable for tree seedling establishment. 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.

Species diversity is usually less in stands managed by single-tree selection, compared to even-aged systems or group selection cutting methods. Full sunlight encourages understory development. However, plantation treatments that remove competing plants from stands and increase conifer growth rates alter the current and future species composition within a stand. Selection of conifer species and other vegetation to be maintained through these operations will affect future stand species composition.

## Diversity of Genetic Resources

***Conservation and Diversity 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 were used during seed collection to assure a large genetic diversity in the collected seed. If regeneration of a particular species failed repeatedly over broad areas, genetic diversity would be reduced. Similarly, with natural regeneration, potential losses in genetic diversity could occur when available seed sources are limited for years. Potentially, the forest genetics program could increase genetic variability within regenerated stands since parent trees are selected across a large geographical area (called a seed zone). With natural regeneration, a large portion of the parent trees are likely to be from within and near to the regenerated area.

***Quality of Genes*** -- The quality of genes can be maintained regardless of silvicultural system. However, where improperly applied, single-tree selection can potentially lead to "high-grading." High-grading is the selective removal of the best trees, so that most regeneration comes from seed produced by the remaining lower quality trees. This then reduces the genetic quality for wood production. This high-grading potential also exists in GTR prescriptions, although the potential loss in quality is probably less than with single-tree selection.

The average genetic quality may be significantly lowered in a stand managed by single-tree selection because of higher rates of inbreeding. Some geneticists suggest that inbreeding also may increase under the shelterwood, seed-tree or GTR cutting methods. Nearby trees of the same species usually are closely related and can pollinate each other. The natural seedlings can become even more inbred. By contrast, artificial regeneration or natural regeneration from edges of large openings reduces the probability of significant inbreeding. Large openings help pollen movement from more distant, less closely related trees, thus promoting genetic quality.

***Genetic Improvements in Forests*** -- Genetic improvements in stands help to increase timber growth, improve tree form and wood quality or increase resistance to disease and insect pests. This depends primarily on planting trees with desirable genetic characteristics. Therefore, the potential for genetic improvement is better for silvicultural systems that use artificial regeneration. Clearcutting, group selection and shelterwood cutting methods (if artificial regeneration is used) have the best potential for improving the genetic quality of forest trees. Single-tree selection, with its natural regeneration and higher rates of inbreeding, has the least potential.

## Forest Health

There are many factors that influence the health of individual trees and forest stands. Forest health depends on a complex interaction between individual trees, the environment, the presence of forest pests and diseases and natural- or human-caused activities that affect tree vigor and survival.

The health of forest stands depends on the collective vigor and growth of individual trees within a stand. Reductions in stand growth and increases in tree mortality are commonly the result of a combination of biotic and/or abiotic factors. These factors together affect the ability of individual trees to withstand adverse environmental conditions.

The risk of increased stand mortality and growth loss can be significantly reduced by activities (natural or through management) that maintain or increase the health of individual trees, reduce the risk of attack by pests and diseases and protect the stand from catastrophic fire losses. Although many natural processes cannot be controlled (fire, wind, lightning, etc.), silvicultural treatments can be prescribed to enhance forest health conditions and increase the likelihood that individual trees can withstand adverse conditions.

***Tree Vigor*** -- The vigor of an individual tree depends on several factors, including the availability of adequate light, water and nutrients for growth, the lack of injury or disease and adaptability (both species and genetic) to the site.

The availability of light, water and nutrients for conifers can be severely restricted by the amount of vegetation in the stand. Conifers under such stress are less likely to survive additional adverse conditions, such as drought or attack from forest pests and diseases. By suppressing the repeated low intensity fires historically common on the Forest, trees and understory vegetation that would have been removed by fire now occupy many forest stands. With this increase in vegetation, available resources became limited within the stand and forest health problems are common.

In uneven-aged stands, where trees of all sizes and ages are maintained, sustaining the vigor of smaller trees (especially the shade-intolerant species like ponderosa pine) can be very difficult. To promote vigor and growth of these trees, tree density may have to be reduced, which can significantly reduce timber yields. In even-aged systems where trees of similar age and size are well spaced from one another, individual tree vigor is more easily maintained. Periodic commercial thinning operations remove smaller, less vigorously growing trees and increase the vigor and growth of residual trees left within a stand.

The health and vigor of 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 of natural seedlings and of low-quality, mishandled or poorly planted seedlings from nurseries. Seedlings in openings are also more susceptible to damage or mortality from frosts, particularly at high elevation sites. Where seedling mortality is expected to be excessive, the use of single-tree selection, shelterwood or group selection (where groups are small) cutting methods is favored.

The presence of grasses, forbs, shrubs and competing trees can severely restrict the amount of light, water and nutrients for adequate conifer growth. 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, which can physically damage young conifer trees.

***Species Composition*** -- Species composition also can contribute to stand vigor and the occurrence of pests and diseases within a stand. The invasion and persistence of white fir into stands once dominated by ponderosa pine or Douglas-fir has resulted in excessive losses from insect attack and spread of disease. In other areas, where seedlings from other geographical areas were planted or the site was converted from one conifer species to another, the occurrence of disease, insect attack and physical unsuitability problems can be common. Silvicultural treatments can reduce forest health risks by selecting and managing for the appropriate mix of tree species for any given site and diversifying the species mix within and among stands. Diversification within stands is increased through planting and retaining multiple species with silvicultural methods.

***Physical Damage*** -- Risk of significant insect or disease damage to trees increases if the trees have been wounded. Wounds can 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. Since cutting frequency is much higher for the single-tree selection method than for others, the risk of significant insect and disease damage is highest.

***Diseases and Pests*** -- Many stands on the Forests are severely infected with certain root diseases and/or dwarf mistletoe. Silvicultural treatments are commonly prescribed to either remove the infected trees and/or minimize the effects of the presence of these diseases. Under the even-aged system or group selection, these disease areas can be removed and regenerated with the appropriate species to maintain stand vigor. With the single tree selection method, it would be both difficult and costly to maintain tree vigor, since these root diseases and dwarf mistletoes can continually infect other residual trees.

Two serious diseases, dwarf mistletoe 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 the entire stand. Dwarf mistletoe plants can project seeds down on trees within about 100 feet horizontally, 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 cutting method, 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 system or group selection can create large areas temporarily dominated by this kind of vegetation. This can cause higher densities of potential pests, which increase the risk of damage to potential crop trees.

***Risk of Major Wildfires*** -- Risk of wildfire is greatest where accumulations of down and standing dead material exist. With the suppression of recurring low intensity fires throughout the Forest, an increase in understory vegetation and dead flammable materials has occurred. Increased understory vegetation adds both to the eventual dead fuel loading within forest stands and creates conditions for more erratic fire behavior.

Silvicultural systems that facilitate treatment of this dead flammable material help reduce the risk of a major wildfire occurring and/or spreading. Treatment also can reduce fire intensity. Reduction of this material has most commonly been accomplished by mechanical piling and burning (on slopes less than 35%) or by prescribed burning (on slopes greater than 35%). Fuel reduction is easier to achieve in even-aged systems where opening sizes allow for efficient use of mechanical equipment and prescribed burning. Fuel accumulations are more difficult and/or costly to treat when residual trees (shelterwood, seed or reserve trees) are left within harvest units. The use of prescribed fire or large mechanical equipment to treat fuels is severely limited with single-tree selection.

In addition to the difficulties treating flammable material under the single-tree selection cutting method, fires in these stands burn intensely and are more difficult to control. Openings that can serve as fuel breaks occur less frequently in forests or stands managed by this 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.

## Managerial Contrasts Among Forests and Stands Managed by Different Silvicultural Systems

Table F-2 at the end of this appendix shows a summary of the major managerial contrasts described in this section.

### Scientific Knowledge Base

The knowledge base for the single-tree selection cutting method is the least known, with regard to other silvicultural methods for NFS lands in California.

***Biological*** – Considerable research has been completed on the biological foundations for silvicultural systems. Planting, natural regeneration and genetic principles have been extensively studied. Research is more complete on early growth of young potential crop trees and control of competing plants for the even-aged systems and group selection cutting methods. Similarly, stand growth model research is more complete for the even-aged systems and group selection methods. There are no major differences in the knowledge base about intermediate cuttings or 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 system and group selection method. Only in the last decade have concerted efforts been made to research the long-term practicality of the single-tree selection cutting method. 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 single-tree selection 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, with associated monitoring, will be required before analyses of overall effectiveness can be made.

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

### Management Experience

***Public Concerns*** -- In the last 2 decades clearcutting and, to a lesser extent, the shelterwood and seed-tree cutting methods, have generated controversy in the United States and Europe.

There are at least 6 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 clearcutting.
- Regeneration of clearcut stands is thought to be unreliable.
- The risks of significant genetic losses are thought to be much greater for clearcutting 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 clearcutting.

– Artificial regeneration, particularly of even-aged stands, is thought to be too costly.

These undesirable effects can occur under any silvicultural system. However, the risks of some are significantly different among certain harvest methods. The concerns about genetic losses were addressed earlier in the sections on Diversity of Plant Species and Genetic Diversity of Resources. The other 5 concerns are discussed in this appendix under sections labelled Effects on Scenic Quality, Risks of Adverse Effects on Watersheds and Soils, Scientific Knowledge Base, Management Experience and Wood Production.

Other managerial aspects of the silvicultural systems are also discussed in the sections below. They cover production of livestock forage, protection of archaeological resources, administration of silvicultural projects, timber harvesting efficiency and effects on fisheries and wildlife.

***Effects on Scenic Quality*** – It usually is easier to create or maintain naturally appearing landscapes with the uneven-aged system rather than the even-aged system. The uneven-aged system is usually less noticeable because it creates less contrast and is more flexible in design. However, long-term maintenance of naturally appearing landscapes can be more difficult under the uneven-aged system. This is particularly true for the single-tree selection cutting method, because the inevitable natural wildfires are more difficult to control. Refer to the section on Risk of Major Wildfires.

Depending on circumstances, all silvicultural cutting methods may achieve visual quality objectives, whether the emphasis is on wood production or natural appearing landscapes. Regeneration cutting in some situations can meet retention or partial retention objectives (for example, partial cuttings, such as shelterwood, single-tree selection or openings that emulate and blend with natural conditions). Those alternatives that are optimal, or even feasible, depend on factors like location relative to the viewer, slope steepness and available topographic or vegetative screening.

***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 type of silvicultural system used. Adverse effects associated with any silvicultural treatment can usually be avoided or mitigated. The major adverse effects possible 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 greater for clearcutting than for other silvicultural cuttings, because more cover is temporarily removed by clearcutting and preparation for seedling establishment. The risk is least for single-tree selection.

Extensive and frequent use of heavy machines can cause significant compaction of some soils. The risk of this occurring is usually greater for the uneven-aged system because of more frequent entries.

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 system. High-intensity fires may occur in any stand if controlled fires are used improperly. However, the risk of high-intensity fires is greater for single-tree selection because crown wildfires are more likely (refer to the section on Risk of Major Wildfires).

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 NFS lands has only involved the even-aged silvicultural systems, particularly clearcutting. However, extensive experience has been gained with both silvicultural systems in managing certain stands.

***Single-Tree Selection*** -- Most of the harvesting from the NFS 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. This cutting method 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 were counted on to offset the reduction in the forest inventory due to harvesting the largest trees. Unfortunately, repeated harvests of the largest trees has often caused undesirable results. These stands will have to be regenerated using one of the even-aged silvicultural system or group selection to re-establish full stocking levels of desired species.

***Group selection*** -- The group selection method was applied extensively on NFS land in Region 5 about 20 years ago. Small openings were made to encourage natural regeneration, particularly of sugar and ponderosa pines. Special cutting guidelines were developed for various types of naturally occurring groups of trees. This strategy, 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. Because necessary silvicultural 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. Saving small groups of trees on steep slopes from excessive damage during harvesting or preparation of the site for successful establishment of tree seedlings is particularly difficult.

***Even-Aged System*** -- The oldest plantations on NFS lands in Region 5 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 promotion of young tree growth, intermediate cutting and regeneration cutting treatments for the even-aged system 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 cutting method is now 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 cutting methods. This is necessary to insure establishment and good growth of tree seedlings or sprouts.

Successful reforestation (artificial or natural) requires that competing vegetation be reduced to provide young trees the resources (primarily soil moisture) to become established and to begin to grow. Greater than 25 to 30% crown cover of vegetation competing for limited soil moisture will preclude seedling survival on most sites in most years.

Herbicides are an effective and economical means of controlling vegetation for a year or two to permit reforestation. There are some cases where herbicides are the only method, if limits are placed on expenditures and/or site characteristics make alternative methods infeasible. Such a situation exists where competing vegetation is well-established before harvest, the land is too steep to permit operation of machinery, or the use of other more site-disturbing techniques is unacceptable.

Vegetation control also benefits established trees. Where competition for site resources is not so fierce, trees can grow faster, are healthier and will produce large trees that function and look like a forest sooner. On poorer sites, trees may actually stagnate (fail to grow) until some disturbance removes those trees and the stand can begin to grow again.

Some have theorized that less control is needed for single-tree selection. Under this method tree cover is more continuous, resulting in fewer competing grasses, forbs and shrubs. However, some competitors, even in small numbers, can cause significant moisture stress in the seedling and sapling potential crop trees. Major competing plants (such as manzanita, bear clover, tanoak, or madrone) can keep good vigor when shaded by most conifers. The use of single-tree selection would not reduce the need for controlling competition from these plants.

Frequency of control treatments varies by silvicultural system. Treatments under single-tree selection could be needed in some portion of every stand as often as every 5 to 10 years. The average control treatment frequencies in the other cutting methods are much lower. For example, in the even-aged system, up to three control treatments could be needed in the first ten years of a new stand. No additional control treatments may be needed until the stand is regenerated. The average period between control treatments in an even-aged system is generally greater than 20 years. Regardless of the silvicultural cutting method 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 single-tree selection. Depending on topography and vegetation structure, it also may be impractical in the group selection cutting method.

***Treatment Costs*** -- The size of a competing vegetation control 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. Entering small units over a large area can be economically inefficient and operationally difficult to achieve. For these reasons, the even-aged system is the most cost efficient. Group selection and single-tree selection (in that order) are the least cost-efficient.

Regeneration by clearcutting is the most cost-efficient among the even-aged system. Shelterwood and seed-tree methods 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 method. The cost of GTR prescriptions is greater than clearcuts. However, this prescription is highly variable depending on the amount and distribution of vegetation left in a stand.

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, unreliable seed production by many commercial tree species and poor survival of natural regeneration often delays successful natural reforestation. This reduces wood productivity and can reduce conifer diversity within stands.

When natural regeneration is delayed, the sites are occupied by competing plants, which can be costly to control. Overall, artificial regeneration insures prompt reforestation of preferred species at desirable densities. If natural regeneration is to be used, the shelterwood and seed-tree cutting methods are usually more cost-efficient than the uneven-aged system. The reason is the economic savings associated with larger scale treatment areas.

***Achieving Regulated Forests, While Maintaining Forest Timber Harvest Levels*** -- Regulation can be accomplished most easily with the even-aged system or group selection. There are two critical disadvantages of single-tree selection. First, there is a lack of 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 about ten thousand potential crop trees per stand. Currently, the degree of inventory data needed for the single-tree selection cutting method is 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 single-tree selection when large acreages of unplanned even-aged stands occur.

***Planning, Contracting and Record Keeping*** -- The even-aged system is generally easier and more cost-efficient to manage than the uneven-aged system. The many small units used in the uneven-aged system makes for ineffective and costly operation and administration. If stands in a typical Ranger District were managed by the uneven-aged system, more than 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 the uneven-aged management system is used for intensive timber management will be limited.

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

Because logging equipment is piece-size-dependent, harvest efficiency is improved when harvested trees are uniform in size. With even-aged systems, harvested trees are fairly uniform in size. With single-tree selection, there is a wide size variation in trees harvested in each operation. However, this disadvantage could be insignificant in young-growth stands.

Harvest operations are also more efficient where higher yields per acre can be obtained. With the even-aged system, the amount of timber harvested per acre is greater and the number of acres harvested is less than with single-tree selection. More land must be treated in each operation to harvest the desired yield from the forest with single-tree selection.

The complexity of harvesting treatments is greatest for single-tree selection. 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. With single-tree selection, cuttings occur as frequently as every five to ten years. In the other cutting methods, only the intermediate cuttings are as complex. The regeneration cuttings are more straightforward operations. Group selection and clearcutting are the most efficient.

Controlling the amount of logging damage that occurs in a stand is easiest where fewer trees need to be protected. Logging damage is typically greatest for single-tree selection. It is very difficult to harvest trees selectively 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.

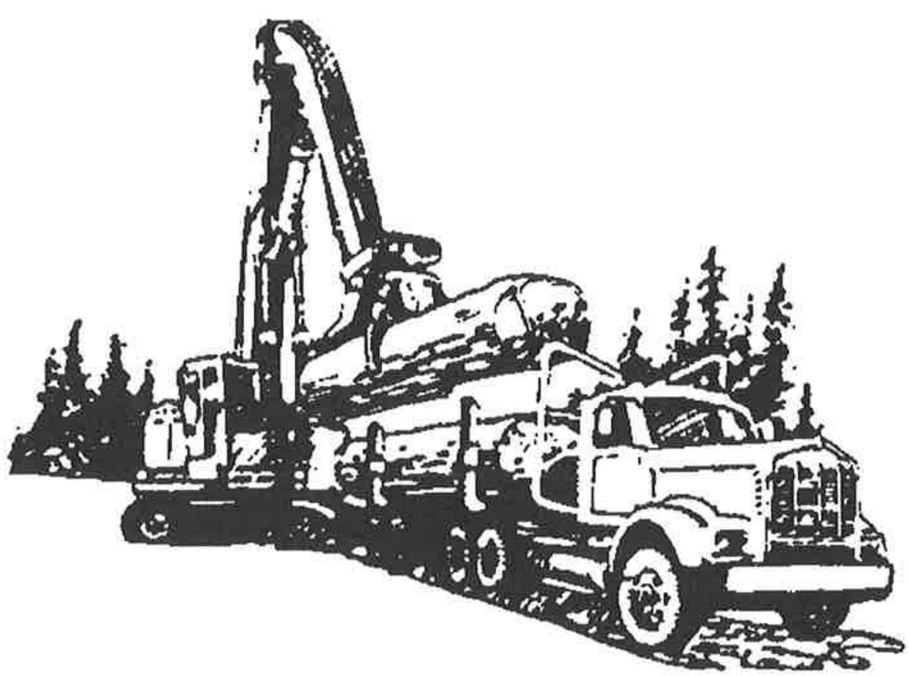
***Production of Livestock Forage and Browse*** -- The even-aged system and the group selection cutting method are best for livestock production. Grasses, forbs and shrubs used by livestock occur in the greatest quantity in openings. Management efficiency increases in large forage areas because livestock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

***Protection of Archaeological Resources*** -- There should be no significant differences among the silvicultural systems in their risk of damage to undetected archaeological resources. Damage depends more on the intensity and frequency of management treatments than on the type 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. Single-tree selection or group selection are usually more advantageous than the even-aged system for managing the vegetation in riparian areas. However, silvicultural cutting methods used outside these areas do influence the amount of sediment in the water. (Refer to the section titled Risks of Adverse Effects on Watersheds and Soils.)

The choice of silvicultural system 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 system or group selection favors deer, quail and rabbits that use herbaceous and shrubby vegetation most abundant in large openings in the forest. Single-tree selection may favor animals that need vertical diversity, such as spotted owls and tree squirrels.

Most forest wildlife species could use a particular young-growth stand sometime 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 type of silvicultural system used would influence the proportions of wildlife 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 cutting methods in the forest would probably best achieve most wildlife management objectives.



## Table F-1. Ratings of the Major Silvicultural Systems by Priniciple Biological Attributes

- ■ (solid black) is Good, Excellent or many
- ▩ (dark stipple) is Good to Moderate
- ░ (light stipple) is Moderate or Few
- □ (empty) is Poor or None

| Biological Attributes | Green Tree Reten- tion | Shelter- wood | Seed Tree | Group Selec- tion | Clear- cutting | Single- Tree Selec- tion |
|---|---|---|---|---|---|---|
| **Appearance** | | | | | | |
| a. Diversity of tree sizes in a stand: | | | | | | |
| (1) Vertical | Moderate or Few[1] | Poor or None | Poor or None | Moderate or Few | Poor or None | Good, Excellent or many |
| (2) Horizontal | Moderate or Few[1] | Poor or None | Poor or None | Moderate or Few | Poor or None | Good, Excellent or many |
| b. Number of openings in a forest[2]: | | | | | | |
| (1) Larger than 2 acres | Good, Excellent or many | Good, Excellent or many | Good, Excellent or many | Poor or None | Good, Excellent or many | Poor or None |
| (2) 1/10th to 2 acres | Poor or None | Poor or None | Poor or None | Good, Excellent or many | Poor or None | Poor or None |
| (3) Smaller than 1/10th acre | Poor or None | Poor or None | Poor or None | Poor or None | Poor or None | Good, Excellent or many |
| c. Potential for conserving or improving plant species diversity in a stand: | Good, Excellent or many | Good, Excellent or many | Good, Excellent or many | Good, Excellent or many | Good, Excellent or many | Moderate or Few[3] |
| **Genetics** | | | | | | |
| a. Resistence to inbreeding effects: | Good to Moderate | Good to Moderate | Good to Moderate | Good, Excellent or many | Good, Excellent or many | Poor or None |
| b. Resistance to degradation by "high-grading": | Good, Excellent or many | Good, Excellent or many | Moderate or Few | Good, Excellent or many | Good, Excellent or many | Moderate or Few |
| c. Potential for conserving genes in a forest[4]: | Good, Excellent or many | Good, Excellent or many | Good, Excellent or many | Good, Excellent or many | Good, Excellent or many | Good, Excellent or many |
| **Productivity** (potential for producing biomass) | Good to Moderate | Good, Excellent or many | Good, Excellent or many | Good, Excellent or many | Good, Excellent or many | Good, Excellent or many |

[1] Range of prescription would vary in vertical and horizontal diversity from "Poor" to "Good."

[2] Exclusive of roads and natural openings, such as meadows or rock outcrops.

[3] Assumes no major fires; otherwise "Poor."

[4] Assumes all harvested species are planted successfully, or will regenerate naturally; otherwise "Poor."

## Table F-2. Ratings of the Major Silvicultural Systems by Key Managerial Attributes

■ (solid) is Good, Excellent or many
▒ (shaded) is Moderate or Few
□ (empty) is Poor or None

| Managerial Attributes | Green Tree Retention | Shelterwood | Seed Tree | Group Selection | Clearcutting | Single-Tree Selection |
|---|---|---|---|---|---|---|
| **Overall Public Acceptance** | Moderate | Moderate | Poor | Good | Poor | Good |
| **Natural Appearance** | Moderate | Moderate | Poor | Good | Poor | Good |
| **Soil Protection in Stands** | | | | | | |
| Soil stability where soils have high erosion potentials | Moderate | Moderate | Moderate | Poor | Poor | Good |
| **Scientific Knowledge Base and Management Experience** | Poor | Moderate | Moderate | Moderate | Good | Moderate |
| **Wood Production** | | | | | | |
| a. Cost efficiency of treatments: | | | | | | |
| (1) General (based on treatment unit size) | Moderate | Good | Good | Poor | Good | Poor |
| (2) Regeneration | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate |
| (3) Feasibility of aerial application of herbicides | Moderate | Good | Good | Poor | Good | Poor |
| (4) Harvesting | Moderate | Moderate | Moderate | Moderate | Good | Poor |
| b. Potential for regulating the forest, while maintaining harvest levels: | Moderate | Moderate | Good | Poor | Good | Poor |
| c. Administrative efficiency (planning, contracting and record keeping): | Moderate | Moderate | Moderate | Poor | Good | Poor |
| d. Need for control of competing vegetation: | Good | Good | Good | Good | Good | Good |
| e. Potential for retaining vigor and value of residual trees[1]: | Good | Good | Good | Moderate | N/A | Moderate |
| f. Potential for genetic improvement of trees by planting: | Good | Good | Good | Moderate | Good | Moderate |

## Table F-2. Ratings of the Major Silvicultural Systems by Key Managerial Attributes (cont'd)

■ is Good, Excellent or many
▒ is Moderate or Few
□ is Poor or None

| Managerial Attributes | Green Tree Reten-tion | Shelter-wood | Seed Tree | Group Selec-tion | Clear-cutting | Single-Tree Selec-tion |
|---|---|---|---|---|---|---|
| **Controlling Wildfires in a Forest** | | | | | | |
| a. Potential for controlling major wildfires:[1] | Good | Good | Good | Good[2] | Good | Good[3] |
| b. Potential for using controlled fires to manage fuels: | Moderate | Good | Good | Poor[2] | Good | Poor[3] |
| **Risk of Significant Pest Damage** | | | | | | |
| Potential for controlling damage from dwarf mistletoe and certain tree root diseases: | Good | Good | Good | Good[2] | Good | Poor |
| **Livestock Production Potential in a Forest** | Good | Good | Good | Moderate[2] | Good | Poor |
| **Riparian Management** | | | | | | |
| Potential for protecting fish habitat: | Moderate | Moderate | Poor | Moderate | Poor | Good |
| **Wildlife Habitat in a Forest** | | | | | | |
| a. Potential for deer, rabbits and quail: | Good | Good | Good | Good | Good | Poor[3] |
| b. Potential for spotted owls and tree squirrels: | Moderate | Moderate | Moderate | Good | Moderate | Good |
| c. Potential for soaring hawks and eagles: | Moderate | Good | Good | Moderate[2] | Good | Poor[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."