

## *V. SYNTHESIS*



# **17** *Reforestation Knowledge: Perspectives and Synthesis for Managers*

*Steven D. Tesch*

*Robert A. Lewis*

*David H. Lysne*

*Charles J. Brown*

**Introduction 423**

Applying reforestation information to  
different objectives **423**

Evaluating options within an ecological  
framework **424**

**Key Knowledge for Reforestation**

Success **424**

Understanding existing forests and  
ecological processes **424**

Long-term site productivity **424**

Regeneration methods **425**

Harvesting methods **426**

Site preparation **427**

Artificial and natural regeneration **428**

Ecology and management of non-conifer  
vegetation **428**

**Interpreting Research Results 430**

Hot, droughty sites **430**

Frost-prone sites **430**

Steep, rocky sites **431**

**Ecological and Economic Analysis**

Capabilities **431**

**Implementing the Knowledge 432**

Information Needs **433**

Summary **434**

## INTRODUCTION

Fifteen years ago, there was serious doubt about the ability of foresters to reestablish forests after harvest or wildfire in southwestern Oregon and northern California, or to convert existing brushfields and hardwood stands to conifers. That important issue has largely been resolved; reforestation success can be achieved on most sites if certain measures, described in this book, are followed. Concurrently, fundamental and applied information on forest ecosystems, vegetation ecology, and timber harvesting has been developed, along with some key analytical tools. This information provides a solid basis for multiple-resource management.

Most applied research has been oriented toward even-aged management, and, particularly in the last decade, toward intensive management. Research on uneven-aged management remains limited, but substantial information can be gleaned from observations of the many stands that have been selectively harvested over the last 50 years. Although there are always new questions to be addressed, and although more operational experience will be helpful, current knowledge indicates that most forest ecosystems in this region can be managed to meet a variety of objectives.

Much of the technical information directed at operational practices has been presented in the preceding chapters; this chapter synthesizes our knowledge about reforestation, particularly that which is most useful to upper-level resource managers. The chapter should also be of interest to regulatory officials, members of the judicial and legislative branches of government, the public, and foresters seeking a broad perspective on reforestation.

## *Applying Reforestation Information to Different Objectives*

The forests of southwestern Oregon and northern California are, and will continue to be, managed for a variety of purposes. Some are intensively managed to maximize wood fiber production, some are managed over longer rotations with emphasis on multiple-use objectives, some are inactively managed for timber production with minimal investment, and others, such as parks and wilderness areas, are managed exclusively for recreation and to preserve ecosystems. Regardless of management objectives, sustainability of forest productivity must be a primary concern, with a major component of sustainability being reforestation after natural disturbance or harvest. An understanding of (1) ecological principles, (2) management practices, and (3) analysis capabilities pertinent to the reforestation process is relevant to managing lands for all of the listed purposes. Application of these three categories to two different objectives is illustrated in the following examples:

Industrial tree-farm foresters must determine the productive potential of a site and project the effect that competing vegetation can have on seedling survival and growth; they may use computer-based growth models to compare different species composition mixes and rotation lengths relative to reforestation costs; and finally, they may implement different site-preparation techniques depending on the cost effectiveness or environmental impacts of each. Alternatively, a wilderness or park resource manager must evaluate the dynamics of forests being protected to determine if undesirable species shifts are occurring, if insect epidemics are likely, or if unacceptable fuel levels

are accumulating; growth models enable the manager to project future trends in ecosystem structure in order to evaluate wildlife habitat; and finally, if unacceptable trends are identified, the manager may need to implement appropriate actions such as prescribed burning to create desired conditions for natural regeneration or to reduce fire hazard.

### *Evaluating Options Within an Ecological Framework*

As land management objectives become increasingly complex, broader knowledge of ecological processes can help ensure successful reforestation. This is particularly true for forests managed on the basis of an ecological paradigm, where management is based on redirection of natural processes, rather than an agricultural paradigm, which focuses on their suppression. Answering the following questions will assist in making ecologically sound decisions:

- What are the species—both plant and animal—and structural characteristics of the existing stand?
- What events led to the establishment of the existing stand?
- What are the dynamics of the existing stand? Is it stable or in a state of rapid change?
- How will the stand react to various kinds of disturbance—either human-caused or natural?
- Given management objectives, what tools are available to manage the plants and animals to create the appropriate level of disturbance, or alternatively, to avoid undesirable disturbances?
- What are the landscape-level impacts of various levels of disturbance?

Answers require a mix of all three categories of basic reforestation information—ecological, management, and analytical. Such information provides a framework for evaluating alternative treatments on both a short-term and a long-term basis. It is important for managers to understand the breadth of options available with respect to both ecological and operational considerations. Some forest ecosystems are more resilient than others; limits must be recognized along with opportunities.

## **KEY KNOWLEDGE FOR REFORESTATION SUCCESS**

### *Understanding Existing Forests and Ecological Processes*

Tremendous diversity in soils, climate, topography, vegetation, and disturbance patterns characterize the southwestern Oregon and northern California area. Such environmental complexity supports substantial biodiversity across landscapes, perhaps increasing ecosystem stability as well as resiliency with respect to events such as insect and disease outbreaks. Managers must be aware of the area's diversity when evaluating reforestation options. Environments within short distances of one another may be very different; therefore, blanket reforestation prescriptions are not appropriate throughout the region.

It is also important to understand that forests are dynamic, not static. The current species composition, stand structure, and landscape pattern found in most forests have been strongly influenced by past disturbance. Fire has been a dominant factor, but livestock grazing, mining, and past harvesting activities also have affected forest development. For stands that are a product of relatively frequent disturbance, such as low-intensity fires every 10-15 years, removal of the disturbance mechanism will cause shifts, sometimes dramatically, in species composition, stand structure, and, occasionally, the stability of desirable forest conditions. For example, low-elevation pine forests thrive with regular, low-intensity fires, which minimize competition from developing understory shrubs. Without the disturbance, encroaching shrubs impose severe competition for water, even in mature pine stands, and the resulting stress predisposes the large trees to bark-beetle-induced mortality during droughts. Protecting these stands from disturbance cannot maintain existing conditions over long periods of time.

### *Long-term Site Productivity*

Sustainable forestry and the health of forest ecosystems both depend on maintaining site pro-

ductivity. In southwestern Oregon and northern California, management practices can significantly affect long-term productivity by changing the physical, chemical, and ecological properties of the soil. Practices that alter or remove the top layer of soil have the greatest potential to degrade a site.

The most typical impact on soil physical properties may be reduction in soil porosity from compaction during harvesting and site preparation. Compaction is a particular problem on flatter terrain where heavy machinery is operated. Loss of nitrogen and other nutrients through intense burning, topsoil removal during mechanical site preparation, whole-tree yarding, or yarding of large, unmerchantable logs (YUM) can be severe, although nutrients can be replaced to some extent through fertilization. The potential for problems still exists, but the information base available to managers is now generally adequate for planning road building, timber harvest, and site-preparation activities that limit damage to physical and chemical properties of the soil.

Recent findings have enhanced our appreciation of the complex role soil ecology plays in maintaining site productivity. For example, research in the last decade has improved knowledge of the symbiotic relationship between mycorrhizal fungi and conifer roots, which aids in water and nutrient uptake of seedlings. Most important timber species in the region cannot thrive without the presence of such fungi. Experiments suggest that seedlings inoculated with certain mycorrhizal fungi in the nursery may be better able to survive after planting, although this practice is not yet refined enough for large-scale application.

Currently, it appears the mycorrhizal populations in forest soils can be maintained after harvest by prompt reforestation. There is evidence, however, that some indigenous plant species, such as madrone and manzanita, may play an important role in the life cycle of certain soil organisms (including mycorrhizae) that depend on them for nutrients and as a substrate for growth. Therefore, eradication of competing vegetation probably should not be an objective; such complete control is virtually never accomplished anyway for more than very short periods even with the most intensive efforts. A balance must

be struck between the ecological benefits provided by these plants to the soil and their competitiveness for soil water on droughty sites.

There is increasing evidence that many important soil organisms can be affected by silvicultural practices that alter levels of soil organic matter, litter, and coarse woody debris (large logs). For most sites, as much organic matter as possible should be retained consistent with meeting site-preparation and reforestation objectives. Some uncertainty exists regarding coarse woody debris in fire-prone areas, where the presence of large quantities may predispose a stand to a catastrophic fire.

### *Regeneration Methods*

When timber harvests are designed to promote conditions conducive to reforestation, the harvests are called regeneration methods. The clearcut and shelterwood methods are commonly used to produce even-aged stands. Research has demonstrated that either method will work satisfactorily on most sites in the region. The choice of methods is often a function of logging feasibility and environmental impact assessment (e.g., number of acres disturbed), as well as other resource objectives or values. However, because of the fully exposed environment it creates, the clearcut method can pose problems on some extreme sites subject to summer frost, or on very hot aspects. On more moderate sites, the clearcut regeneration method has generally been favored in recent years because of operational efficiency in applying intensive artificial regeneration practices to create new even-aged stands. The method can also be important in controlling some diseases and in creating habitat for animal species requiring early-successional vegetation.

Variations of the shelterwood regeneration method offer opportunities to incorporate aesthetic objectives and provide habitat for animal species that need more-closed forest conditions. Both planted and natural seedlings benefit from some shade for a few years, but the costs of overstory removal and the associated damage to established regeneration have historically biased many foresters against the shelterwood method. However, guidelines are now available to assist

foresters in planning new timber sales using the shelterwood method, relating shelterwood overstory density and location to expected logging damage. This information can also be applied to existing stands that await overstory removal, making it possible to predict the probability of successful overstory removal given variables such as terrain, overstory volume, and established seedling height. Foresters may choose to initiate the clearcut method and establish new regeneration in areas with a low probability of adequate stocking after overstory removal, or they may choose to use more sophisticated equipment such as helicopters or cable yarders, which can provide necessary log control and minimize mortality to existing regeneration.

New research on the ability of Douglas-fir seedlings to recover from logging-related wounds also suggests that the problem of logging wounds may not be as great as it once appeared. More trees are damaged than are actually killed during overstory removal, and most wounds on trees up to 15 ft tall with reasonably healthy crowns heal within 5 years. Guidelines rating the potential of injured trees to become crop trees in the future are available and can be applied during post-harvest stocking surveys.

While many forms of "selective harvesting" have been used in the region, formal application of uneven-aged regeneration methods is rare and little studied. There is good reason to be interested in methods leading to uneven-aged stands, notably where minimizing site disturbance is important (e.g., riparian areas) and where complex stand structure is desired to promote certain wildlife species. Many ecological principles associated with uneven-aged stand dynamics are known, and growth models are available to project uneven-aged strategies. For any strategy involving long-term retention of overstory trees, reductions in understory growth are probable, but total stand growth may be satisfactory if overstory trees are vigorous. Most harvesting and operational considerations can be extrapolated reasonably well from experience with the shelterwood method. We have enough knowledge to try uneven-aged management on selected sites; however, these should be monitored closely to gain more information.

The ecology of forests in the region affords considerable flexibility in selecting regeneration meth-

ods to accommodate various land management objectives. Decision-makers must realize, however, that different methods involve different levels of complexity and can make a radical difference in stand yield and the cost of operations. Complex methods require considerable ecological and prescriptive expertise, as well as care in developing logging plans and contract stipulations and in sale layout and contract administration.

### *Harvesting Methods*

Public and private forests historically have been managed for a variety of resource purposes, but the primary objective for most lands not reserved for wilderness, parks, or other set-asides has been timber production. For industrial forest owners and timber purchasers, in particular, operational efficiency has been a major consideration in determining harvesting methods. Beyond ensuring that harvesting methods are consistent with requirements for successful reforestation and for resource protection, the single harvest entry associated with the clearcut regeneration method has been favored.

When other objectives besides timber production are top priority, active timber management, including harvesting, is one of the relatively few means by which foresters can manipulate forest dynamics to meet multiple-resource objectives. Changes effected by harvesting include preparation of appropriate conditions for reforestation of stands severely damaged by insects or disease and manipulation of stand structure for wildlife habitat. With careful planning and coordination between silviculturists and harvesting specialists, harvesting equipment and practices are available to accommodate many objectives.

Many analytical tools are now available to help develop harvesting strategies that will be operationally feasible and environmentally sound. Research and experience have fine-tuned such strategies as the use of designated skid trails, which reduce environmental impacts, maintain harvest productivity, and protect residual trees. There may be tradeoffs in costs and logistical feasibility, but by matching equipment to the task and considering the feasibility of all harvest entries before any harvest activity is started,

foresters can integrate harvesting productivity with silvicultural objectives. For example, helicopter logging is expensive, but in some cases the associated reduction in road construction costs can quickly offset the extra yarding expense, and using helicopters may also minimize the environmental impacts of road construction and logging. For regeneration methods that require multiple harvest entries, such as the shelterwood or single tree selection methods, avoiding incremental decision-making and insisting on early interaction between harvesting specialists and silviculturists will usually lead to greater flexibility in action plans and success in meeting reforestation goals.

### *Site Preparation*

Improved knowledge of the negative impacts that non-conifer vegetation can have on reforestation has led to greater focus on site preparation after harvest to reduce the vigor of potential competitors. Reducing the amounts of slash or scarifying the soil surface can also be important in improving access for tree planters or preparing seedbeds for natural regeneration. Prescribed burning, machines, and herbicides are the primary site-preparation methods.

While the benefits of all methods have been clearly demonstrated, each is capable of causing environmental damage or exacerbating vegetation management problems if not applied correctly. Careful, site-specific analyses must consider the susceptibility of the soil to damage as well as the likely immediate and longer-term effects on competing plants and other components of the forest ecosystem. In some cases, analyses may show that little or no site preparation is better over the long term.

Plants in the region have evolved different mechanisms to coexist with fire and other disturbances; thus, they often respond vigorously after site preparation. For example, deerbrush ceanothus seeds in the soil are scarified by the heat from prescribed fires. On exposed, warm sites, germinating ceanothus will develop into significant competition within 3-5 years, which can cause substantial conifer mortality. Therefore, stimulation of competing vegetation should be avoided, particularly when

resulting vegetation cannot be controlled during stand establishment.

Nevertheless, prescribed fire is a diverse tool that can be applied safely on varying terrain and tailored to both intensive and extensive management strategies. Current burning prescriptions are unlikely to cause site damage, but concerns about air quality are increasingly limiting the use of this tool for site preparation. This is unfortunate from a forestry standpoint, because, if anything, demand for use of prescribed fire is likely to increase as the role of natural disturbances in creating and maintaining the stability and diversity of the forest ecosystems in the region becomes better understood.

Careful use of large machines for site preparation can be effective on many soil types for controlling competing vegetation without causing excessive soil compaction. Studies have helped identify soils that are most subject to compaction, and guidelines are available for protecting sites with such soils. Machine site preparation typically stimulates the germination of seeds stored in soil, particularly in clearcuts, and creates a seedbed for windblown grass and forb seeds, often leading to abundant post-harvest vegetation that may threaten survival of seedlings if it is not controlled.

Herbicides are an efficient tool for eliminating competition for water and, if selected and applied properly, probably pose the least risk for damaging soil productivity because the soil surface is not disturbed. In addition to reducing water use, shade from injured or dead plants can protect developing conifer seedlings on some sites. However, because slash and vegetation are not removed or consumed, as in the case of prescribed fire, habitat for potential animal pests is left in place, and no planting spots and seedbeds are created unless herbicides are used in combination with another method.

Despite these caveats, foresters should consider the merits of site preparation after every regeneration-related harvest. Properly conducted site preparation can be important in creating an operational environment conducive to the establishment of conifer seedlings. Sometimes methods must be used in combination to obtain the desired results. Insofar as possible, site-preparation activities should be timed to immediately precede planting or

seeding in order to capture the temporary benefits associated with control of competing vegetation.

### *Artificial and Natural Regeneration*

Regardless of the regeneration and harvest methods used, most managers of public or industrial lands—especially those managing even-aged forests—currently rely primarily on artificial regeneration by planting seedlings to promptly establish new stands. Tremendous improvements in nursery technology within the last decade provide the capabilities to produce high-quality seedlings that are well adapted to planting sites. With careful handling during storage and transportation, and with careful planting, these seedlings offer the potential for excellent reforestation success. However, despite the improved technological base, large-scale production of quality seedlings remains somewhat inconsistent, and availability of desired seedlings should not be taken for granted. Diligence in working with nursery managers is important to ensure that high-quality seedlings are available for planting.

Most resource managers do not favor natural regeneration for even-aged stands. The method is imprecise; foresters cannot depend on obtaining an adequate number of newly germinated seedlings, and it is difficult to predict growth of advance regeneration after release. Despite its inherent uncertainties, however, natural regeneration can be successful when seed is available and seedbed and environmental conditions are appropriate. Natural regeneration has the greatest success when a disturbed seedbed and some canopy protection are available. Under those conditions, regeneration may be adequate even without heavy seed crops. For example, substantial numbers of natural seedlings have been observed on areas burned in the 1987 wildfires, particularly where a mosaic of surviving overstory trees exists. There is also evidence that natural regeneration will continue slowly over prolonged periods—areas classified as reforestation failures after 5 years have been acceptably stocked after 20.

Natural regeneration offers the advantages of reduced capital input and adaptation of seedlings to the site, as well as providing a means to regen-

erate sites that are too rocky to plant. These attributes must be balanced against the disadvantages of this type of regeneration: lack of predictability, lack of control over seedling density, and potential for a shift to more shade-tolerant species beneath dense canopies.

Where advance regeneration is already established, information is now available to analyze growth potential after release. Substantial improvement in height growth has been documented, even on poor sites in southwestern Oregon. Simulated comparisons with planted seedlings indicate advance regeneration is seldom surpassed by planted seedlings within at least the first 20 years after release. Density and distribution of advance regeneration after overstory removal are additional key factors to consider in evaluating this reforestation option.

### *Ecology and Management of Non-conifer Vegetation*

One of the major improvements in the scientific information base over the last decade has been an increased understanding of the role grasses, forbs, shrubs, and hardwoods play in forest ecosystem dynamics and particularly in the conifer reforestation process. Much has been learned about the reproductive ecology of various shrubs and hardwoods, particularly with respect to their response to different kinds of disturbance. For example, when manzanita is present in the mature stand, we know mechanical site preparation will scarify seeds stored in the soil and result in an explosion of manzanita seedlings to contend with in the next stand. Prescribed burning will scarify ceanothus seeds in the soil, resulting in potentially serious competition within several years. Retaining a fairly dense overstory canopy on warmer sites can minimize development of some sun-loving shrubs such as deerbrush ceanothus, and on frost-prone sites it can help control grasses and forbs, with the potential synergistic benefit of minimizing build-ups of gopher populations. Alternatively, shade-tolerant species such as tanoak can increase in dominance over time in stands subjected to commercial thinning or other intermediate entries that do not include adequate



forest-floor disturbance to minimize development of such species.

The effects of shrubs and hardwoods on conifers can be both direct and indirect. On droughty sites, competition for water is probably the key factor limiting conifer survival and growth. Non-conifer vegetation is typically well adapted to compete with conifer seedlings for the limited water supply. Indirectly, such vegetation creates habitat for mammals, birds, and insects that may harm the new trees. The vegetation itself may hamper reforestation through competition, and may serve as an alternate host for some diseases. However, it may also benefit forest ecosystems through nitrogen fixation, prevention of erosion, and production of browse.

Because different competitor plant groups behave differently, understanding their ecology is critical to meeting vegetation management objectives. On dry sites, for example, competition from grasses, forbs, and deciduous shrubs can cause substantial mortality to both planted and natural seedlings during the first year and can continue to contribute to mortality over the next several years if this vegetation not controlled. Competition from sclerophyll shrubs and hardwoods typically causes less mortality during the first several years, and in fact it may initially enhance survival through both shading and certain soil-biology interactions that are still poorly understood. However, over longer periods some conifer mortality is likely as a result of competing hardwoods and shrubs, especially on xeric sites or during years of drought. In any case, very substantial growth losses will occur as a result of this competition.

We are now able to predict the probable response of many species to various harvesting and silvicultural treatments or to natural disturbances. For example, by measuring the diameter of hardwoods such as tanoak before harvest, we can predict the amount of tanoak cover likely to be present from sprouting burls for up to a decade after harvest. Such quantitative relationships have been incorporated into computerized growth models such as SYSTUM-1 that enable evaluation and comparison of vegetation management strategies; output from these models can be applied to economic analyses. Because these vegetation management models are a rela-

tively new development, and because some are based on limited data, results must be extrapolated carefully. Continued research is needed to increase the reliability of these models and the range of treatments they are able to evaluate.

A key question, then, is how much vegetation management is enough? As we have seen, too much non-conifer vegetation can hinder the reforestation process, but eliminating all of it is neither practical nor desirable. Therefore, foresters must seek a balance in maintaining acceptable levels of non-conifer vegetation over the life of a stand. The best way to do this depends on management objectives, site, ecology of the desirable and undesirable plants and animals, and perhaps economics and operational practicality. Treatment strategies directed at ensuring survival of 200 saplings per acre at age 10 will likely be different from those attempting to maximize fiber growth over a relatively short rotation or those fostering habitat diversity for wildlife. Establishing clear objectives is an important first step. Knowledge of the ecology of non-conifer vegetation may enable managers to select harvest and site-preparation strategies that minimize vegetation management problems while accomplishing management objectives. Such avoidance strategies become increasingly important when the tools available for direct control of competition are limited.

When direct control is desired or necessary to meet established land management objectives, however, a variety of vegetation management tools can be used successfully, including herbicides, prescribed burning, mulching, scalping, grubbing, cutting, and perhaps grazing by domestic livestock. For such tools to be used successfully, they must be operationally feasible, affordable, and appropriate to the vegetation and the site, and they must be in keeping with community values and attitudes. While some techniques such as grubbing, mulching, or grazing will probably require several treatments to ensure that objectives are met, in most cases reforestation is possible without herbicides after a carefully planned harvest of the existing stand of timber. Difficulties do increase when foresters attempt to reforest areas dominated by well-established grass or shrubs without herbicides.

## INTERPRETING RESEARCH RESULTS

Over the last 15 years a substantial amount of research has been conducted on many aspects of reforestation in southwestern Oregon and northern California. Many trial plantings have been established and monitored for 5 or more years. Results from these trials and observations from operational plantings have improved our understanding of the potential for reestablishing forests on cut-over or naturally disturbed sites across the range of environments common to the region and have illustrated the practices necessary to do so.

### *Hot, Droughty Sites*

Research results from hot, dry sites—much studied in the last decade—show that initial reforestation success is likely on many such forest lands with intensive reforestation practices. Across the range of harsh conditions common to the interior Siskiyou Mountains and the foothills of the southern Cascades and northern Sierra Nevada, properly timed site preparation, planting of quality seedlings, and subsequent vegetation control have led to high survival and good growth. Such successes have occurred on harvested areas reforested by the clearcut and shelterwood regeneration methods, as well as on areas where brushfields and hardwood stands were converted to conifer plantations. While some additional attention to detail is usually associated with preparing, planting, and tending of research plots, standard seedlings were planted and common site-preparation and vegetation management practices were used in most trials. Sites were typically not fertilized or irrigated. Many acres of young plantations have been established outside of research plots where foresters have had the opportunity and commitment to follow recommended practices.

Careful analyses are required to identify the ecological potential of these sites, to select the best-suited tree species, and to project requirements for vegetation management necessary to ensure continued conifer survival and growth. For example, on some low-elevation droughty sites converted from brush or hardwoods to conifers with the use

of intensive site preparation, 5-year-old mixed ponderosa pine and Douglas-fir plantations that were apparently established have suffered substantial mortality in the following decade without competition control. Three explanations for this are possible. First, on some sites, the more drought-tolerant ponderosa pine may thrive where Douglas-fir cannot survive to maturity. Second, even the best conifer species may grow to maturity only if low-intensity fire or other disturbance is frequent enough to eliminate competition and provide conifers with most of the site resources. Finally, the ecological potential of the site may simply be insufficient to support a conifer stand over the long run despite intensive site preparation and continual vegetation management.

Little research information is available regarding reforestation of hot, droughty sites by less intensive methods. However, observations of natural stands suggest that opportunities exist for foresters to carefully tailor silvicultural strategies to complement natural ecological processes. For example, many acres of mature forest exist on soils that are considered too rocky to plant by conventional means, but in which the moisture regime and other factors are conducive to natural regeneration over time. While direct reforestation costs may be reduced in this manner, the ecological skills required of foresters are probably greater. Meeting reforestation objectives in the long run requires a well-thought-out management strategy, especially where vegetation management troubles likely exist. Without more knowledge and operational experience, reforestation success with less intensive methods is likely to be sporadic and unpredictable.

### *Frost-prone Sites*

Reforestation challenges are also found on mid- to high-elevation sites subject to frost during the growing season. After disturbance, the development of both a competitive grass understory and a high pocket-gopher population often compounds the frost problem. The interaction of those three factors has frustrated foresters attempting to reforest mixed conifer stands through conventional intensive management practices. The clearcut or seed tree regeneration methods usually fail if

Douglas-fir and white fir are planted, because these species are sensitive to frost. Reforestation of exposed areas with more frost-tolerant pine species can be successful, provided that gopher control and vegetation management are aggressive; however, growth models project that yields from such stands are likely to be substantially lower than those from even-aged mixed conifer stands. For unstocked, frost-prone areas, initial use of pine species is probably the only reasonable choice. The more shade-tolerant Douglas-fir and white fir can be established later, after pines provide frost protection. If a seed source is available in adjacent stands, this will probably happen naturally; if not, foresters can artificially regenerate these species to promote diversity and, over longer rotations, higher yields. In the short term, however, developing understory conifers will compete with the larger pines and probably slow their growth.

Research and practical experience have demonstrated that mixtures of conifer species can be regenerated on frost-prone sites when adequate overstory canopy is maintained. However, the traditional practice of removing an entire shelterwood overstory within about 5 years in order to minimize logging damage to new seedlings may not be appropriate in the most severe frost areas. Even saplings 5-10 ft tall have been killed by a single frost.

Management strategies calling for longer-term retention of overstory trees, or perhaps uneven-aged management, have not been validated by research or operational experience. Nonetheless, ecological theory, computer projections, and observations of natural stands suggest that such strategies are biologically feasible. These reforestation strategies do require multiple harvest entries, with commensurate protection of residual trees, established regeneration, and site resources; and thus they can be costly and complex to manage. However, because the relatively flat terrain offers easy access, such strategies should be operationally feasible.

### *Steep, Rocky Sites*

Steep, rocky sites also may pose reforestation problems, even though large volumes of mature trees may be present. Two types of problems exist.

First, planting trees can be nearly impossible on sites with large rocks near the surface, and little soil may exist between the rocks to hold moisture and nutrients. Research shows that the soil may be unevenly distributed across such sites, and thus full stocking may not be possible. On less rocky sites, some plantings may be successful near stumps from the previous stand; on more extreme sites, only natural regeneration is a realistic alternative. Second, on some steep sites (usually slopes of more than 65 percent), gravel, rocks, and organic debris (ravel) sliding downhill during and after harvesting may bury small seedlings. However, research has shown that ravel actually kills few seedlings, and the risk declines rapidly as seedlings develop more rigid stems. Planting larger seedlings is an easy solution if the larger root system can be properly planted. Measures to protect seedlings from ravel do not appear to be economically feasible or necessary. Many of these steep, rocky sites seem to be manageable, particularly where moisture is not limiting. Yields and rotation lengths vary with site quality, but for sites where productivity is relatively low, extensive reforestation strategies utilizing natural regeneration, alone or in combination with planted stock, seem warranted.

## *ECOLOGICAL AND ECONOMIC ANALYSIS CAPABILITIES*

As the ecological and operational information bases have grown, various analytical tools have been developed that enable managers to better organize information and project trends over time. These new tools strengthen opportunities to compare management strategies on the basis of their short-term and long-term ecological and economic benefits and costs.

Plant association guides and various environmental classifications have been developed for portions of the region and serve as a framework for evaluating management practices. The plant association for a site can be determined by identifying key "indicator plants" and sometimes by estimating their abundance. Descriptions of the respective associations provide information on ecosystem characteristics and likely trends in species com-

position and stand dynamics over time, all significant factors in developing feasible silvicultural regimes. For example, a description of the tanoak series on the Siskiyou National Forest tells foresters that such sites will eventually become dominated by tanoak if they are not disturbed adequately to provide conditions that favor conifers rather than the more shade-tolerant hardwoods. Unfortunately, plant association guides or their equivalent have not been developed for all areas.

Several new computer-based growth models have been developed that provide a mechanism for comparing timber outputs of various management alternatives as well as a quantitative method of projecting stand dynamics over time for other resource considerations. These models include ORGANON, CACTOS, PROGNOSIS, and SYSTM-1, with the last specifically for use in younger stands. All are based on local data and utilize state-of-the-art simulation procedures; output from them can be used for economic analysis of operations. These models are very powerful tools and collectively permit resource managers to simulate competition regimes in young stands, impact of thinning and density management in natural and managed stands, and changes in species composition, growth, yield, and mortality of conifers and hardwoods over time. Indeed, substantial improvements have been made in resource managers' ability to project the likely outcomes of management alternatives—including the alternative of no action—on tree growth or other attributes. With increasing availability of geographic information systems (GIS) and remote-sensing technology, analysts are increasingly able to model the impact of various practices at the landscape level as well.

Many forest land managers conduct financial analyses of various reforestation approaches and silvicultural systems. The criteria used in conducting and interpreting analyses vary by organization, but all initially require the ability to predict the outputs or benefits of treatment alternatives. As a result of the silvicultural and biometric research over the last decade, much better economic analyses are now possible; our knowledge of the long-term forest growth response to various treatments is much improved, as is the quality of predictive tools. For example, analytical tools now enable evaluations of alternative silvicultural regimes on the basis of both volume production and wood

quality. Some traditional, volume-based analyses for public land in southwestern Oregon showed that managing stands at wider spacing produced the highest financial returns because of larger-diameter trees. However, when log value (as a function of wood quality) was added to the analysis, higher-density stands were favored because of better self-pruning of limbs, resulting in smaller knots in the wood.

How one interprets this example analysis undoubtedly depends on one's views of future lumber markets, but that is not the point. The information base and analytical tools are now available to enable rational, quantitative analyses of the economic attributes of alternatives. Because it is difficult to place dollar values on many timber and non-timber resources, economic analyses remain constrained in that regard.

## **IMPLEMENTING THE KNOWLEDGE**

Has the increased knowledge about the principles and the practice of reforestation been acted on, and has it led to improved reforestation success? Generally the answer to both those questions is "yes," but with the following caveats:

- Known reforestation principles are reasonably well applied, but environmental variability will always result in some inconsistency of results—especially over short periods that can be influenced by severe drought, insect epidemics, wildfire, or other unpredictable events.
- Human error has been reduced by intensive technology-transfer efforts over the last decade. Continuing education and technology transfer must receive high priority, however, as new employees arrive and others change job responsibilities. In the next few years, training challenges may arise if the workforce is reduced in public agencies, as is expected. In some situations, technicians may be given increased responsibility for interpreting field environments and for making treatment decisions—jobs that will require greater skill, particularly as prescriptions become more complex.
- Efforts must continue to ensure collaboration among researchers and practitioners so that

basic research information can be effectively applied to operational practices. Some fine-tuning of procedures or calibration of results should be anticipated in the transition from research laboratories or plots to field application, especially when new practices are implemented over many acres.

- Some research results and recommendations are difficult to implement because of a limited workforce, costs, or operational practicality. For example, hand weeding in plantations is an ecologically sound practice that can adequately control certain types of vegetation and provide necessary resources for developing seedlings. However, hand weeding large acreages is not only a logistical challenge, but is typically very expensive.
- Some research information has not been fully applied because of societal considerations or regulatory limitations. For example, information illustrating the important role of fire in ecosystem health and its relative ease of application is available, but air quality regulations increasingly restrict its use.
- Finally, lack of clear objectives can frustrate application of the best available information. Top-quality silvicultural plans result when managers attempt to identify longer-range perspectives. Those working hypotheses help minimize incremental decision-making.

## **INFORMATION NEEDS**

Currently, the greatest challenge facing forest managers is the development of strategies for managing forest ecosystems at the landscape level. Developing such guidelines requires improvements in landscape-level analysis techniques, better data on plant and animal habitat requirements and their relationships to various landscape patterns, and perhaps some agreement on the social acceptability of various patterns. There is a direct link between landscape-level management and stand-level reforestation practices; landscape-level strategies ultimately influence individual stand-structure and species-composition goals. These, in turn, ultimately affect flexibility in choosing regeneration methods.

Trends towards managing for more complex stand structure over time necessitate refinement of existing growth and yield models, for two reasons:

to better project reforestation success of various species under different canopy densities, and to project stand growth as a function of structural patterns. Existing growth models assume average, uniform structural patterns throughout a stand; they do not model patchy mosaics of structure very well. Growth models can also be improved by refinements that aid in predicting ecological stand dynamics, including perhaps snags and woody debris, as well as traditional timber yields.

Further efforts are needed to refine growth models that predict the effects of competing vegetation on young conifers. More biological data is needed for these models to broaden the list of manual treatments that can be evaluated across more vegetation types. Additional research trials should be conducted to follow various vegetation management strategies over longer periods. Given the significance of vegetation management to reforestation success and public opposition to the application of herbicides, vegetation management based on avoidance strategies rather than direct control may be a key to affordable reforestation success, particularly on public lands.

While we have adequate information for the reforestation of many hot, droughty sites, we need research on the reforestation of productive mixed conifer forests on high-elevation cold sites. Although frost damage to seedlings and saplings is a major concern on those sites, research must integrate the issues of pocket-gopher damage and vegetation management as well.

Many of the proposed alternative silvicultural strategies are untested. Trials and demonstrations are needed to document reforestation potential, ecological processes, yields, and management feasibility. For example, uncertainty exists about our ability both to regenerate shade-intolerant species in association with retained canopy cover and to manage other ecosystem components such as snags, woody debris, and wildlife. Another untested but important strategy is the use of active forest management to produce mature forest features within shorter rotations. We generally know how to practice intensive, high-yield forestry; we are less able to predict outcomes of extensive practices that rely on natural regeneration and the reintroduction of natural disturbance regimes. Such trials must consider the ecological, socioeconomic, management, and operational aspects of

these practices at the level of the landscape as well as of the individual stand.

## SUMMARY

Major advances in scientific information and operational experience have provided the knowledge to reforest most sites in the region following harvest or natural disturbance with a confidence of success that was not possible 15 years ago.

This book documents that such success is possible and outlines the considerations and actions necessary to achieve it. As described in earlier chapters, the region's environment and its well-adapted non-conifer vegetation interact to create often-hostile conditions for survival and growth of seedlings. Such conditions require careful and timely execution of well-thought-out plans for reforestation. In order to succeed, managers must work to identify long-term objectives. They must make monitoring of reforestation efforts by technically competent people a high priority so that potential problems can be identified and solved before they become serious. The feedback from monitoring is also an important resource for designing future action plans and for identifying information gaps that require additional research.

Resource managers, particularly those at the upper levels, face a complex challenge when formulating policy and making day-to-day decisions that incorporate the best technical information available on reforestation within a framework of a changing society and environment. Actions must be biologically sound, make economic sense, be socially acceptable, and be operationally feasible.

Given that society's views toward objectives for managing forests are changing, it is commonly asked if the current information is relevant to solving new challenges. It is true that much research and experience has been oriented toward development of even-aged stands for maximum timber production, typically with intensive methods. However, much basic knowledge has been developed about forest ecosystems, vegetation ecology, timber harvesting, and operational techniques that can be applied to creating other forest structures. There are gaps in knowledge that warrant further research, and alternative management strategies need to be tested, but we believe adequate knowl-

edge exists to be optimistic about our ability to reforest and actively manage lands in southwestern Oregon and northern California for a variety of objectives.



## GLOSSARY

**Abrams formation.** Metamorphosed clastic sedimentary rock, quartz-mica schist.

**acceptable tree.** A tree of suitable species, size, and condition so that it has potential for contributing to the desired future stand.

**accordant ridgetops.** Ridgetops of approximately the same elevation, indicating that what is now a terrain dissected by deep cut streams was once a flat, high peneplain.

**accuracy.** In a statistical sense, the success of estimating the true value of a quantity.

**advance regeneration.** Young trees that have become established naturally before timber harvest.

**agglomerate.** Angular, cemented pyroclastic fragments forming rock.

**alfisols.** Well-developed soil with an argillic B horizon, but still young enough to have good nutrient characteristics.

**allelopathy.** The influence of plants upon each other through products of metabolism.

**andesite.** Moderately basic, extrusive surface volcanic rock; viscous when molten, forming coarse breccia flows and cone-shaped volcanoes; usually dark gray.

**anion.** Negatively charged mineral ion (e.g.,  $\text{NO}_3^-$  or  $\text{OH}^-$ ).

**Applegate formation.** Similar to the Dothan, layers of tuffaceous, metamorphosed sediments and volcanics with some ultramafic, intrusive rock inclusions; tilted and faulted, unstable and prone to landsliding.

**argillic.** An increase in clay content in subsoil relative to overlying soil horizons caused by translocation of clay minerals during leaching.

**aspect.** The direction toward which a slope faces.

**autecology.** Relationship of individual organism to the environment.

**available soil water.** Soil water that is available to the plant; generally the water content between field capacity and the permanent wilting point.

**basal area.** The area of the cross section of a tree at 4.5 ft above the ground, usually expressed as the summation of all trees in a forest in  $\text{ft}^2/\text{acre}$ .

**basalt.** Basic, extrusive volcanic rock; very liquid when molten, forming wide, flat shields or flows; usually gray to black in color weathering to orange-red.

**bellygrinder.** A hand-operated hopper for applying such materials as seeds, granular fertilizer and pesticides by feeding them onto a spinning plate.

**bias.** In a sampling sense, a systematic distortion that may arise from many sources, such as a flaw

- in measurement, method of sample selection, or technique of estimating a parameter.
- breccia.** Angular, pyroclastic rock fragments in a matrix of fine-textured pyroclastic material.
- breeding zone.** A geographical area of defined boundaries and altitudinal limits, from which trees will be selected and bred as a genetically improved strain normally intended for planting in the same area.
- brush.** Hardwood shrubs and trees that often interfere with reforestation and afforestation.
- bulk density.** The mass or weight of oven-dry soil per unit of bulk volume.
- burl.** A woody swelling containing many preformed buds, found below ground in tanoak and green-leaf manzanita (lignotuber Bot.).
- carriage clearance.** The distance between the bottom of the carriage and the ground.
- cation.** Positively charged mineral ion (e.g.  $\text{NH}_4^+$  or  $\text{Ca}^{++}$ ).
- cinders.** Uncemented volcanic ejecta, 4 to 32 mm in diameter.
- clastic.** Sedimentary rock composed of cemented rock shards as opposed to chemical precipitates (e.g., sandstone; limestone, being composed of precipitated calcium carbonate, is non-clastic).
- co-dominant tree.** An individual with its crown in the upper layers of the overstory canopy.
- cohort.** A member of a group with like characteristics.
- cold hardness.** The level of a plant's resistance to damage from low temperatures.
- Colebrooke schist.** Quartz-mica phyllite and schist, well foliated sandstone and metavolcanics, highly contorted.
- colloids.** Gel-like mineral composites.
- confidence level.** The degree of certainty desired, or associated with the mean or another statistic; if calculated mathematically, generally called confidence limits.
- constancy.** The number of plots that a given species occurs in as a percent of the total.
- crop cycle.** In nursery practice, the period between stratifying or sowing seed of a particular seedlot and the lifting and packing of that seedlot for shipping to the field.
- cross-flying.** A technique for the aerial application of pesticides. Two flights are made at right angles over a given area.
- cut-surface treatment.** Herbicide treatment in which chemical is poured onto freshly cut stump.
- dacite.** Extrusive, volcanic rock, slightly more acidic than andesite with similar viscous properties.
- deflection.** The distance at mid-span from the skyline to the imaginary line that runs straight from the tower top to the skyline anchor.
- diluent.** The carrier used to dilute a pesticide for application.
- diorite.** Moderately basic, intrusive volcanic, chemically equivalent to andesite, but coarser textured.
- direct seeding.** The process of reforesting by applying seed to the site either by broadcasting it from the air or ground or by placing it in specific spots on the ground.
- dominant tree.** An individual with its crown in the uppermost layer of the overstory canopy.
- Dothan formation.** Well-cemented, graywacke sandstone, interbedded with thin layers of mudstone, shale or siltstone; largely sandstone, but ranges from conglomerate to mudstone.
- efficient.** (1) A statistic that has a variance smaller than any other estimate of the same population



- parameter; (2) an experimental design that secures a greater degree of precision than another or yields the same precision with less expenditure of time and money.
- endemic.** Native to a particular locality.
- entisols.** Very young soils, A horizon overlying C horizon.
- extensive survey.** Any survey effort that is primarily in the form of a reconnaissance; i.e., observational and informal in structure rather than systematic and formal.
- factorial combination.** In experimental design, two or more series of treatments tried in all possible combinations.
- felling to lead.** Felling the tree in a direction in line with the direction the logs will be pulled out.
- foliar-active.** A description for herbicides that enter plants through the foliage.
- Franciscan formation.** A graywacke and shale sedimentary formation from the Coast Ranges of California with correlatives in Oregon (Dothan and Otter Point formations).
- frequency.** In a biological sense, the percentage, or proportion of plots or areas on which a species or other entity was found relative to the total number examined—synonymous with stocking, occurrence.
- full stocking.** A uniform distribution of trees representing a specified density per acre.
- gabbro.** An intrusive, volcanic rock, more basic than basalt; very coarse textured, black.
- Galice formation.** Metasedimentary and metavolcanic, thick sequence of thinly layered, slaty to phyllitic mudstones interbedded with medium-grained, well-sorted sandstones; minor inclusions of greenstones, adjacent to serpentinitic areas.
- genetic markers.** Physical expression of variants of individual genes (e.g., chemical markers) which are often used in genetic analyses.
- genotype.** The genetic composition of an individual.
- gneissic rock.** Amphibole gneiss, believed metamorphosed from the Galice formation; usually with alternating stripes of minerals that have separated and reformed in bands during heat or pressure events.
- grading standards.** In nursery practice, specifications of factors such as size, form, health, and color that determine whether a seedling is to be accepted for planting.
- granitics.** Range from granite to coarse-textured basalt.
- greenstone.** Metamorphosed volcanic rock that takes on a bright green color.
- ground lead.** Log movement with no suspension, such that the leading edge of the log is in contact with the ground.
- grus.** Highly weathered granite, coarse and crumbling with mild pressure.
- herbicides.** Pesticides used to kill or control the growth of plants.
- Humbug Mountain conglomerate.** Thickly bedded, gravelly, cemented conglomerate; clasts of chert, schist, diorite and other extrusive volcanic rocks.
- hypocotyl.** Stem between the roots and the cotyledons of a newly germinated seedling.
- hypo hatchet.** A hatchet that injects a preset amount of herbicide into tree stems on impact.
- inceptisols.** Similar to entisols, except that enough development has occurred to form a cambic B horizon.
- intensive survey.** Any survey effort that requires sampling and data collection according to a pre-

designed plan for coverage of the area and observations to be made.

**kaolinite clay.** A 1:1, nonexpanding, very stable, highly weathered clay mineral found in soils under conditions of extreme weathering; has a very low cation exchange capacity (CEC), and tends to act more like a silt or sand particle due to its large size and high stability.

**leader.** The terminal or topmost shoot.

**lifting.** In nursery practice, the process of digging or pulling tree seedlings from nursery seedbeds or planting beds prior to bareroot planting in the field or in a transplant bed.

**LSD.** Least significant difference; the smallest difference between two means that indicates the means differ because of some factor other than chance. The probability of accepting incorrect results is often stated as a subscript.

**macroenvironment.** The general environment of a broad area.

**mafic.** Basic rock types with relatively low silica content and higher units of Ca, Mg, etc.

**marble.** Metamorphosed limestone.

**mass wasting.** Land sliding.

**mean.** The arithmetic average of a set of numbers.

**mechanically assisted directional felling.** The use of mechanical devices such as cables or jacks to achieve the desired felling pattern.

**mesic.** Having moderate amount of moisture; neither hydric nor xeric.

**metagabbro.** Coarse-textured intrusion between metavolcanics and meta-sediments.

**metavolcanics.** Altered flows with tuff, breccia, stratified tuff plus intrusive andesites and basalts; generally hard on steep slopes and soft on flats.

**microenvironment.** The immediate environment of a specific habitat; often that surrounding individual seedlings.

**milacre.** One-thousandth (1/1000) of an acre.

**Miocene.** The fourth epoch of the Tertiary Period in the Cenozoic Era, 10 million years before the present; marked by the development of many modern mammals.

**montmorillonite clay.** A 2:1 expanding crystalline-lattice clay formed under conditions of slow weathering (e.g., in poorly drained, boggy soils); the mineral can expand to twice its dry volume under saturated conditions due to easy entrance of water molecules between clay lattice layers.

**morphology.** Form and size of organisms or parts of organisms.

**motor-manual.** Forest-tending operations conducted with gasoline-powered equipment, such as chain saws and circular saws.

**Mt. Mazama.** Andesite cone (Crater Lake) surrounded with extensive andesitic pyroclastic deposits that form a windward blanket extending for many miles northeast, exploded during eruption about 7,000 years ago.

**mycorrhizae.** A symbiotic association between tree roots and specialized soil fungi.

**natural selection.** An evolutionary process in which organisms with certain characteristics produce more offspring than those lacking such characteristics in a given environment.

**operable-sized opening.** The minimum size opening to be detected for additional silvicultural treatment.

**Otter Point formation.** An Oregon correlative of the Franciscan formation of northern California; graywacke and shale with volcanic and metamorphic inclusions.

**overstory.** The trees that form the uppermost canopy layer in a forest.

## Glossary

---

- parameter.** Any quantitative characteristic or attribute of an individual or population.
- peridotite.** Olivine plus pyroxene, partly altered to serpentinite, green to rust colored.
- permanent wilting point.** The soil water content at which plants remain permanently wilted unless water is added to the soil.
- phenotype.** The appearance of an individual for one or more traits, which is the product of the interaction of the individual's genes and its environment.
- photoperiod.** Duration of light, usually expressed in hours, within a 24-hour day.
- Pleistocene.** The first epoch of the Quaternary Period in the Cenozoic Era, marked by the recession of continental ice sheets and the appearance of modern humans.
- Pliocene.** The last epoch of the Tertiary Period in the Cenozoic Era, during which many modern plants and animals developed.
- population.** The entire collection of individuals that comprise a grouping of interest, such as those on a specified area or having specific attributes.
- precision.** In a statistical sense, the clustering of sample values about their own average; precision is not necessarily equivalent to accuracy.
- propagules.** Any part of a plant that may be used to propagate it, either sexually or vegetatively.
- puddling.** Loss of soil structure.
- pumice.** Coarse, volcanic-ash air or flow deposit; generally unconsolidated.
- quadrat.** A small, clearly demarcated sample area of known size.
- ravel.** The downslope movement of scree and woody material due to gravity.
- regeneration.** The young trees on an area representing early stages in the renewal of a forest stand.
- regeneration goal.** The silviculturally prescribed stocking percentage, density, and kind of tree to be established on an area in a specified period of time.
- regeneration period.** The time required for the establishment of a stand by natural or artificial regeneration. In broadest terms, it may include the time required for pre-harvest planning and harvest of the previous stand.
- relict.** A population living in isolation as a survivor from an earlier period or as a remnant of an almost extinct group.
- rhizome.** An underground stem that produces roots and supports above-ground stems.
- rhyolite.** Extrusive, acidic, volcanic rock; very viscous, even explosive, when molten.
- Rogue formation.** Mafic, volcanic rocks found interspersed with the Galice formation in southwestern Oregon.
- root collar.** The point of separation between the stem and root of a plant.
- root regeneration potential or capacity.** The number and/or total length of roots grown by a tree seedling under controlled test conditions.
- rotation.** The number of years between the regeneration of a stand and its final harvest.
- salmon formation.** Highly metamorphosed, basic volcanic rock; hornblende schist.
- sample.** The observed or measured part of a population.
- sampling intensity.** The number of observations or measurements required to sample a population with a prescribed degree of precision.
- scalping.** Removal of vegetation and other organic or inorganic material to prepare a planting spot.

- schist.** A slightly metamorphosed rock that forms in fine, shiny foliation layers.
- scoria.** Another name for pumice; lava containing numerous cavities caused by gases expanding while the lava cools.
- scree.** Loose rock and gravel on a steep slope.
- seed bank.** Seed stored in the soil litter layer that is capable of germinating.
- seedbed.** The soil or forest floor on which seed falls.
- seedbed density.** In nursery practice, the number of seedlings grown per area of seedbed. The density is usually expressed as number per ft<sup>2</sup> or per m<sup>2</sup>.
- seed crop.** The amount or number of seeds produced by a given species in a given year.
- seed zone.** Area having defined boundaries and altitudinal limits, within which soil and climate are sufficiently uniform that it is expected that seed can be freely moved without problems of maladaptation.
- self-shading.** Of a seedling, the ability to shade its base with its branches.
- seral.** An early stage in plant succession that follows natural or human-caused disturbance.
- serpentinite.** Greasy-looking, yellow to olive-green to black, along faults and geologic contacts; fractures into small chunks with polished surfaces, sometimes soft enough to carve with a knife.
- shade-intolerant.** Plant species adapted to reproduce and thrive in the open.
- shade-tolerant.** Plant species adapted to reproduce and thrive in shade.
- shoot:root ratio.** See top:root ratio.
- skeletal soils.** Soils with over 35 percent volume in coarse fragments.
- slash rakes.** Bulldozer blades with tines for dislodging and moving woody material.
- soft marine sediments.** Soft, finely bedded siltstones, mudstones and claystones.
- soil compaction.** An increase in soil bulk density from an undisturbed state.
- soil field capacity.** The soil water content after gravitational water drainage has become very slow and the water content becomes relatively stable.
- Southfork Mountain schist.** Northern California equivalent to the Colebrooke schist of Oregon; a narrow belt of schist that extends along the entire western edge of the Klamath Province.
- spatial arrangement or pattern.** The placement or distribution pattern of trees on an area, described as random, uniform, or clumped (aggregated).
- stand density.** A measure of the degree of crowding of trees within stocked areas; i.e., the number of trees per unit area.
- stem-injection treatment.** Herbicide treatment in which a mechanical implement is used to wound the bole of a tree and a solution containing a herbicide is injected into the wound.
- stockable plot.** A plot on which 50 percent or more of the area is biologically and physically suitable for seedling establishment.
- stocking.** A measure of the proportion of the area actually occupied by trees; i.e., the percentage of area stocked.
- stocking standard.** Agreed-upon classes of stocking with implications for what level is satisfactory; also, the legally prescribed minimum stocking required to comply with conservation laws.
- stomata.** Openings or pores in the leaf surface through which gas exchange occurs. Each stomate is surrounded by two guard cells that regulate the size of the opening.

- stratification.** The storing of seeds in a moistened medium to maintain viability and overcome dormancy.
- strobilus.** The “cone” of conifers in which seeds or pollen grains are produced.
- stump-jump.** Movement of the tree away from the stump as it falls.
- symbiosis.** The living together of two or more organisms of different species.
- target seedling.** A seedling that meets preestablished physiological and morphological specifications.
- tolerance.** The ability of an organism to live under a given set of conditions.
- toposhade.** Shade resulting from nearby landforms.
- top:root ratio.** The ratio of the length or weight (fresh or dry) of a tree seedling’s stem and foliage to the length or weight (fresh or dry) of its roots.
- traverse line.** A straight route of travel across an area for the purpose of locating sample plots at designated intervals.
- treatment efficacy.** How well a treatment achieves its goal.
- tree jacking.** A technique of mechanically assisted directional felling in which hydraulic tree jacks are placed in the back cut of the tree to push it against its natural lean.
- tree lining.** A technique of mechanically assisted directional felling in which a winch pulls a tree into the desired lay.
- tubing.** The practice of placing a plastic, wire, or paper tube over all or part of a tree seedling to reduce animal damage.
- tuff.** Consolidated or lithified deposit of volcanic ash.
- Tyee formation.** Thick, rhythmically-bedded sandstone with thin-bedded mudstone; most common rock type in the Oregon Coast Ranges.
- ultisols.** Very old, maximum-developed soil. Often dominated by iron and aluminum oxides and clays with very low nutrients content.
- ultra-basic (serpentine).** Soil parent material of low-fertility typified by a calcium-magnesium imbalance.
- Umpqua formation.** Bedded sandstones and siltstones near coast; greatest risk of landsliding on the Siskiyou National Forest.
- underburning.** Prescribed burning conducted within an existing stand of trees to remove slash or manage competing vegetation.
- underplanting.** Planting trees beneath an existing canopy of larger trees or shrubs.
- understory.** Plants growing under the canopy formed by other, taller plants in a forest.
- ungulates.** Deer and elk.
- VMD.** Volume median diameter; the diameter of a spray droplet possessing median volume.
- void.** An opening (gap) in a stand where one or more trees are missing in terms of a prescribed stocking or spacing.
- weeds.** Plants that are not wanted at a particular place or time.
- Xerothermic.** A hot, dry climatic period, such as one of the post glacial periods.
- xylem pressure potential.** A measure of xylem sap tension which is an indicator of plant water stress. Increasingly negative xylem pressure potential (e.g., -0.5 MPa to -1.5 MPa) reflect increasing plant water or moisture stress in the plant.

COMMON AND SCIENTIFIC NAMES

Birds and mammals

bald eagle	<i>Haliaeetus leucocephalus</i>
deer mouse	<i>Peromyscus maniculatus</i>
deer	<i>Odocoileus</i> spp.
elk	<i>Cervus</i> spp.
hare (showshoe rabbit)	<i>Lepus americana</i>
hawk	several orders
mountain beavers	<i>Aplodontia rufa</i>
owl	several orders
northern spotted	<i>Strix occidentalis</i>
pocket gopher	<i>Thomomys</i> spp., <i>Geomys</i> spp.
porcupine	<i>Erethizon dorsatum</i>
rabbit	<i>Sylvilagus</i> spp.
vole	<i>Microtus</i> spp.
wood rat	<i>Neotoma</i> spp.

black-stain root disease

blister rust  
damping-off

dwarf mistletoe  
Indian paint fungus  
(stem decay, heart rot)

laminated root rot  
Phytophthora root rot  
Port-Orford-Cedar root rot

seedling root rot  
shoestring root rot

white pine blister rust

*Leptographium (Verticicladiella) wagneri*  
var. *pseudotsuga*  
var. *ponderosum*  
*Cronartium ribicola*  
*Fusarium* spp.,  
*Pythium* spp.  
*Arceuthobium* spp.

*Echinodontium tinctorum*  
*Phellinus weirii*  
*Phytophthora* spp.  
*Phytophthora lateralis*  
*Phytophthora* spp.  
*Armillaria ostoyae*  
(*A. mellea*)  
*Cronartium ribicola*

Diseases

annosus root rot (butt rot)	<i>Heterobasidium annosum</i> ( <i>Fomes annosus</i> )
Armillaria root rot	<i>Armillaria</i> spp.

Grasses and Forbs

Alaska oniongrass  
American vetch  
annual ryegrass  
beargrass  
blue wildrye  
bracken fern  
  
brodiaea

*Melica subulata*  
*Vicia americana*  
*Lolium temulentum*  
*Xerophyllum tenax*  
*Elymus glaucus*  
*Pteridium aquilinum*  
*Brodiaea*

## Common and Scientific Names

---

<p>California brome catchweed bedstraw deer-fern dogtail, hedgehog</p>	<p><i>Bromus californicus</i> <i>Gallium aparine</i> <i>Blechnum spicant</i> <i>Cynosurus echinatus</i></p>	<p>grasshopper, locust millipede pine reproduction weevil  pine resin midge</p>	<p>Acrididae Diplopoda <i>Cylindrocopturus eatoni</i> <i>Cecidomyia piniopsis</i> <i>Hylastes macer</i> <i>Rhyacionia zozana</i> <i>Steremnius carinatus</i>, <i>Pissodes fasciatus</i> <i>Cylindrocoptera furnissii</i> <i>Oligonychus ununguis</i> <i>Eucosma sonomana</i> <i>Phyllophaga</i> spp., <i>Polyphylla</i> spp. <i>Pissodes strobi</i> Elateridae</p>
<p>fescue   Idaho   sheep long-stolon sedge</p>	<p><i>Festuca</i> spp. <i>F. idahoensis</i> <i>F. ovina</i> <i>Carex pennsylvanica</i> <i>Verbascum thapsis</i></p>	<p>pine root bark beetle ponderosa pine tip moth root-feeding weevils</p>	<p><i>Hylastes macer</i> <i>Rhyacionia zozana</i> <i>Steremnius carinatus</i>, <i>Pissodes fasciatus</i> <i>Cylindrocoptera furnissii</i> <i>Oligonychus ununguis</i> <i>Eucosma sonomana</i> <i>Phyllophaga</i> spp., <i>Polyphylla</i> spp. <i>Pissodes strobi</i> Elateridae</p>
<p>mullein mustard Parry rush queen's-cup</p>	<p><i>Brassica</i> spp. <i>Juncus parryi</i> <i>Synthyris runiformis</i> <i>Disporum smithii</i></p>	<p>shoot weevil  spider mite (spruce)</p>	<p><i>Cylindrocoptera furnissii</i> <i>Oligonychus ununguis</i> <i>Eucosma sonomana</i> <i>Phyllophaga</i> spp., <i>Polyphylla</i> spp. <i>Pissodes strobi</i> Elateridae</p>
<p>Smith fairy-bell   (large-flowered fairycup) snakeroot starry false Solomon's-seal sword fern</p>	<p><i>Sanicula</i> spp. <i>Smilacina stellata</i> <i>Polystichum munitum</i> <i>Crinum arvense</i> <i>C. vulgare</i> <i>Trillium ovatum</i> <i>Linnaea borealis</i> <i>Achylis triphylla</i> <i>Polystichum munitum</i></p>	<p>western pine shoot borer white grubs</p>	<p><i>Eucosma sonomana</i> <i>Phyllophaga</i> spp., <i>Polyphylla</i> spp. <i>Pissodes strobi</i> Elateridae</p>
<p>thistle, Canadian thistle, bull trillium twinfleur vanillaleaf western sword fern</p>	<p><i>Anemone deltoidea</i> <i>Oxalis oregana</i> <i>Fragaria vesca bracteata</i></p>	<p>white pine weevil wireworms</p>	<p><i>Phyllophaga</i> spp., <i>Polyphylla</i> spp. <i>Pissodes strobi</i> Elateridae</p>
<p>windflower wood-sorrel woods strawberry</p>	<p><i>Anemone deltoidea</i> <i>Oxalis oregana</i> <i>Fragaria vesca bracteata</i></p>	<p>white pine weevil wireworms</p>	<p><i>Phyllophaga</i> spp., <i>Polyphylla</i> spp. <i>Pissodes strobi</i> Elateridae</p>
<b>Insects</b>			
<p>bark beetle Cooley spruce gall adelgid cutworm Douglas-fir engraver</p>	<p><i>Dendroctonus</i> spp. <i>Adelges cooleyi</i> Noctuidae <i>Scolytus unispinosus</i> <i>Steremnius carinatus</i></p>	<p>Hebeloma crustuliniforme Laccaria laccata Pisolithus tinctorius Rhizopogon vinicolor</p>	<p><i>Hebeloma crustuliniforme</i> <i>Laccaria laccata</i> <i>Pisolithus tinctorius</i> <i>Rhizopogon vinicolor</i></p>
<p>root-collar weevil</p>	<p><i>Hylastes nigrinus</i> <i>Cylindrocoptera furnissii</i></p>	<p><b>Shrubs</b> baldhip rose bearbrush blueberry, huckleberry   evergreen huckleberry   grouse huckleberry   thin-leaved huckleberry blue elderberry box-leaved garrya California coffeeberry</p>	<p><i>Rosa gymnocarpa</i> <i>Garrya fremontii</i> <i>Vaccinium</i> spp. <i>V. ovatum</i> <i>V. scoparum</i> <i>V. membranaceum</i> <i>Sambucus glauca</i> <i>Garrya buxifolia</i> <i>Rhamnus californicus</i> <i>Corylus cornuta californica</i> <i>Ceanothus</i> spp. <i>C. thyrsiflorus</i> <i>C. cuneatus</i> <i>C. integerrimus</i> <i>C. cordulatus</i> <i>C. sanguineus</i></p>
<p>Douglas-fir root bark beetle Douglas-fir twig weevil</p>	<p><i>Hylastes nigrinus</i> <i>Cylindrocoptera furnissii</i></p>	<p>California hazel</p>	<p><i>Rosa gymnocarpa</i> <i>Garrya fremontii</i> <i>Vaccinium</i> spp. <i>V. ovatum</i> <i>V. scoparum</i> <i>V. membranaceum</i> <i>Sambucus glauca</i> <i>Garrya buxifolia</i> <i>Rhamnus californicus</i> <i>Corylus cornuta californica</i> <i>Ceanothus</i> spp. <i>C. thyrsiflorus</i> <i>C. cuneatus</i> <i>C. integerrimus</i> <i>C. cordulatus</i> <i>C. sanguineus</i></p>
<p>giant conifer aphid</p>	<p><i>Cinara</i> spp.</p>	<p>ceanothus   blueblossom   buckbrush (wedgeleaf)   deerbrush   mountain whitethorn   redstem</p>	<p><i>Ceanothus</i> spp. <i>C. thyrsiflorus</i> <i>C. cuneatus</i> <i>C. integerrimus</i> <i>C. cordulatus</i> <i>C. sanguineus</i></p>
<p>gouty pitch midge</p>	<p><i>Cecidomyia piniopsis</i></p>	<p>redstem</p>	<p><i>C. sanguineus</i></p>

## Common and Scientific Names

snowbrush (slickleaf, varnishleaf)	<i>C. velutinus</i> var. <i>velutinus</i> , <i>C.</i> <i>laevigatus</i>	skunkleaf polemonium, showy polemonium	<i>Polemonium</i> <i>pulcherrimum</i>
squawcarpet	<i>C. prostratus</i>	snow bramble	<i>Rubus nivalis</i>
currant	<i>Ribes</i> spp.	tanoak	<i>Lithocarpus</i> <i>densiflorus</i>
chinkapin	<i>Castanopsis</i> spp.	thimbleberry, western	<i>Rubus parviflorus</i>
golden	<i>C. chrysophylla</i>	whipple-vine	<i>Whipplea modesta</i>
creeping snowberry	<i>Symphoricarpos</i> <i>mollis</i>	wintergreen (pyrola)	<i>Pyrola</i>
dwarf bramble	<i>Rubus lasiococcus</i>		
gooseberry	<i>Ribes</i> spp.	<b>Trees</b>	
hairy honeysuckle	<i>Lonicera hispidula</i>	Alaska-cedar	<i>Chamaecyparis</i> <i>nootkatensis</i>
hazel, California	<i>Corylus cornuta</i> <i>californica</i>	alder, red	<i>Alnus rubra</i>
hound's-tongue, Pacific	<i>Cynoglossum</i> <i>grande</i>	California-laurel (Oregon myrtle)	<i>Umbellularia</i> <i>californica</i>
manzanita	<i>Arctostaphylos</i> spp.	cherry	<i>Prunus</i> spp.
greenleaf	<i>A. patula</i>	bitter	<i>P. emarginata</i>
pinemat	<i>A. nevadensis</i>	chinkapin	<i>Castanopsis</i> spp.
whiteleaf	<i>A. viscida</i>	golden	<i>C. chrysophylla</i>
modest whipplea	<i>Whipplea modesta</i>	dogwood	<i>Cornus</i>
mountain mahogany	<i>Cercocarpus</i> <i>betuloides</i>	Douglas-fir	<i>Pseudotsuga</i> <i>menziesii</i>
oceanspray	<i>Holodiscus discolor</i>	fir	<i>Abies</i> spp.
Oregon boxwood	<i>Pachystima</i> <i>myrsynites</i>	balsam	<i>A. balsamea</i>
Oregongrape	<i>Berberis</i> spp.	grand	<i>A. grandis</i>
dwarf (Oregon hollygrape)	<i>B. nervosa</i>	noble	<i>A. procera</i>
Piper's	<i>B. piperiana</i>	Pacific silver	<i>A. amabilis</i>
Pacific rhododendron	<i>Rhododendron</i> <i>macrophyllum</i>	red	<i>A. magnifica</i>
poison-oak	<i>Rhus diversiloba</i>	Shasta red	<i>A. magnifica</i> var. <i>shastensis</i>
Pacific poison-oak	<i>Toxicodendron</i> <i>diversilobum</i>	subalpine	<i>A. lasiocarpa</i>
prince's pine, common	<i>Chimaphila umbel-</i> <i>lata</i>	white, California white	<i>A. concolor</i> , <i>A. concolor</i> var. <i>lowiana</i>
prince's pine, little	<i>C. menziesii</i>	Larch	<i>Larix</i> spp.
pyrola (wintergreen)	<i>Pyrola</i>	tamarack	<i>L. laricina</i>
rhododendron, Pacific	<i>Rhododendron</i> <i>macrophyllum</i>	Hemlock	<i>Tsuga</i> spp.
salal	<i>Gaultheria shallon</i>	eastern	<i>T. canadensis</i>
slender	<i>G. ovalifolia</i>	mountain	<i>T. mertensiana</i>
salmonberry	<i>Rubus spectabilis</i>	western	<i>T. heterophylla</i>
serviceberry, western	<i>Amelanchier</i> <i>alnifolia</i>	incense-cedar	<i>Libocedrus</i> <i>decurrens</i> ( <i>Calocedrus</i> <i>decurrens</i> )
Sierra laurel	<i>Leucothoe davistae</i>	madrone, Pacific	<i>Arbutus menziesii</i>
silktassel, wavy leaf	<i>Garrya elliptica</i>		
silktassel, Fremont	<i>G. fremontii</i>		



*Common and Scientific Names*

---

maple	<i>Acer</i> spp.
vine	<i>A. circinatum</i>
bigleaf	<i>A. macrophyllum</i>
Rocky Mountain	<i>A. douglasii</i>
oak	<i>Quercus</i> spp.
black	<i>Q. velutina</i>
canyon live	<i>Q. chrysolepis</i>
Oregon white	<i>Q. garryana</i>
California black	<i>Q. kelloggii</i>
Sadler	<i>Q. sadleriana</i>
pine	<i>Pinus</i> spp.
Jeffrey	<i>P. jeffreyi</i>
knobcone	<i>P. attenuata</i>
knobcone-Monterey hybrid	<i>P. attenuata</i> <i>x radiata</i>
lodgepole	<i>P. contorta</i>
ponderosa	<i>P. ponderosa</i>
red	<i>P. resinosa</i>
Scotch	<i>P. sylvestris</i>
sugar	<i>P. lambertiana</i>
western white	<i>P. monticola</i>
Port-Orford-cedar	<i>Chamaecyparis</i> <i>lawsoniana</i>
Spruce	<i>Picea</i> spp.
Brewer	<i>P. breweriana</i>
Engelmann	<i>P. engelmannii</i>
Norway	<i>P. abies</i>
Sitka	<i>P. sitchensis</i>
white	<i>P. glauca</i>
Pacific madrone	<i>Arbutus menziesii</i>
Redwood, coast	<i>Sequoia</i> <i>sempervirens</i>
tanoak	<i>Lithocarpus</i> <i>densiflorus</i>
western redcedar	<i>Thuja plicata</i>
yew, Pacific	<i>Taxus brevifolia</i>

## CONVERSION FACTORS

	<i>English-to-Metric</i>	<i>Metric-to-English</i>
Length	in x 2.540 = cm ft x 0.304 = m chain x 20.116 = m mi x 1.609 = km	cm x 0.393 = in m x 3.280 = ft m x 0.049 = chain km x 0.621 = mi
Area	in <sup>2</sup> x 6.451 = cm <sup>2</sup> ft <sup>2</sup> x 0.092 = m <sup>2</sup> ac x 0.404 = ha ft <sup>2</sup> /ac x 0.229 = m <sup>2</sup> /ha	cm <sup>2</sup> x 0.155 = in <sup>2</sup> m <sup>2</sup> x 10.763 = ft <sup>2</sup> ha x 2.471 = ac m <sup>2</sup> /ha x 4.356 = ft <sup>2</sup> /ac
Volume	in <sup>3</sup> x 16.387 = cm <sup>3</sup> ft <sup>3</sup> x 0.0283 = m <sup>3</sup> yd <sup>3</sup> x 0.764 = m <sup>3</sup> bd ft <sup>a</sup> x 0.00236 = m <sup>3</sup> fl oz x 29.573 = ml qt x 0.946 = liter U.S. gal x 3.785 = liter	cm <sup>3</sup> x 0.061 = in <sup>3</sup> m <sup>3</sup> x 35.314 = ft <sup>3</sup> m <sup>3</sup> x 1.308 = yd <sup>3</sup> m <sup>3</sup> x 423.729 = bd ft ml x 0.033 = fl oz liter x 1.056 = qt liter x 0.264 = U.S. gal
Mass	oz x 28.349 = g lb x 0.453 = kg	g x 0.035 = oz kg x 2.204 = lb

Temperature  
 $0.555 (°F - 32) = °C$   
 $1.8 °C + 32 = °F$

Pressure  
 bar x 10 = MPa

<sup>a</sup>Based on nominal measurement of 1 bd ft = 1 in x 1 ft x 1 ft

INDEX

**A**

*Abies* spp.—See Fir  
 Acceptable tree—351, 362, 364, 367  
 Adaptation—See Evolutionary forces  
 Aerial  
     Logging—See Harvest systems  
     Surveys—See Photography, Sampling methods  
 Aesthetics of regeneration methods  
     Clearcut 168-169  
     Group selection 171  
     Shelterwood 169-170  
     Single tree selection 171-172  
     Also see Management objectives  
 Age class 7, 403  
     Even-aged stands 5, 10-11, 13, 105, 168-170, 172, 176, 180-182, 195, 210, 273, 291, 389, 425, 428, 431  
     Uneven-aged stands 5, 10-12, 103, 126, 147, 168, 170-172, 176, 182-183, 195, 204, 210, 291, 407, 426  
     Also see Harvest, Regeneration methods  
 Air quality & public concern 6, 175, 427, 433  
 Alaska-cedar—See Cedar  
 Albedo 86, 126  
 Alder 36, 66, 94, 107, 138, 141, 144-145, 373, 389, 392  
 Allelopathic compounds—See Competition  
 Animal damage 9-10, 14, 37-40, 144, 146, 168, 179, 180, 187, 195, 233-234, 236, 239, 242, 264, 266, 268-270, 314, 317-318, 320, 322-324, 340, 349, 353, 377, 385, 387, 395-399, 412-413

Browsing 30, 38, 177, 180, 270, 393, 395-396  
 Grazing 29-30, 38, 43  
 Animals  
     Beaver, mountain 28, 38, 180, 233-234, 236, 395, 398-399, 413  
     Bear 7  
     Birds 168, 264, 266, 269, 322, 403  
     Cattle 29, 38, 393-394  
     Chipmunks 264  
     Cougar 28  
     Coyotes 28  
     Deer 7, 9, 28, 31, 38, 180, 270, 393, 395-396, 413  
     Eagle 8  
     Elk 7, 28, 38, 180, 270, 395-396, 413  
     Goats 29  
     Gopher, pocket 7-8, 38-40, 61, 65, 101, 151, 155, 170, 180, 182, 184, 233-234, 236, 240, 266, 270, 340, 389, 396, 413, 428, 430, 433  
     Junco 270  
     Livestock 7, 140  
     Marten 28  
     Mice 269, 389, 395, 405  
         Deer 395  
         White-footed 264  
     Otter 28  
     Owl, northern spotted 8, 35  
     Porcupines 7, 395, 397, 413  
     Rabbits 236, 239, 395, 398, 399, 413  
     Rats, wood 236, 399, 413  
     Rodents 7, 37-38, 41, 147, 236, 239, 264, 266, 270, 322-323, 388, 398  
     Sheep 28-29, 394-395  
     Shrews 264, 405  
     Swine 29

Ungulates 389, 394  
 Voles 389, 395, 398, 413  
 Also see Animal damage  
 Ashland Field Station 41  
 Ashland Forest Reserves 32  
 Aspect—See Site factors  
 Associations, plant—See Plant associations

**B**  
 Baker's cypress—See Cypress  
 Basswood 94  
 Beargrass 104, 109, 270  
 Bedstraw, catchweed 111  
 Beech 94  
 Bigleaf maple—See Maple  
 Biomass production 98, 101, 138  
 Bitterbrush 149-150  
 Blackberries 31, 141, 399  
 BLM—See USDI Bureau of Land Management  
 Blueblossom ceanothus—See Ceanothus  
 Bluegrass, roughstalk 111  
 Bole  
   Growth rate 301  
   Injuries 172, 194  
   Straightness, selection for 300  
 Boxwood, Oregon 100  
 Bracken 104, 108-109  
 Bramble  
   Dwarf 98  
   Snow 107  
 Breeding zones (units) 300-301  
 Brewer spruce—See Spruce  
 British Columbia Ministry of Forests 377  
 Brodiaea, purple 111  
 Brome, California 110-111  
 Browsing—See Animal damage, Clearcuts  
 Buckbrush ceanothus—See Ceanothus  
 Bunchberry 138  
 Bureau of Land Management—See USDI Bureau of Land Management  
 Burning  
   & air pollution regulations 175  
   Also see Air quality, Silvicultural practices, Site preparation

**C**  
 Cable logging—See Harvest systems, Site preparation  
 CACTOS—See Computer models  
 California black oak—See Oak

California Forest Experiment Station 40  
 California  
   Hazel—See Hazel  
   Laurel—See Laurel  
   Red fir—See Fir  
   White fir—See Fir  
 Canopy—See Overstory  
 Canyon live oak—See Oak  
 Cascade Geological Province 50, 56-58, 67, 95-97, 101, 107, 109, 235-236  
   Soil parent material rock types 56-58  
 Cation exchange capacity 63-64, 120-121  
 Ceanothus 65, 94, 109, 138, 146-147, 149, 152, 157, 159-160, 392, 428  
   Blueblossom 102, 140-141  
   Buckbrush 108-109  
   Deerbrush 140-141, 143, 147, 149-150, 159, 427-428  
   Snowbrush 32, 38, 97, 101, 105, 140, 141, 147, 149-150, 178, 185, 187, 244, 269-270  
   Squawcarpet 269  
   Varnishleaf 140-141, 156  
 Cedar  
   Alaska 93-94, 100  
   Incense—See Incense-cedar  
   Port-Orford—36-37, 93-94, 100, 102, 105-108, 289, 410-411  
   Western red- 36, 94, 104, 107-108, 267, 270, 289, 292, 298  
   Also see Plant associations, Seed sources  
 Chemical applications—See Competition control, Silvicultural practices, Site preparation  
 Cherry 149, 372  
 Chinkapin, golden 36, 38, 100, 104-105, 107-108, 138-139, 141, 143-144, 146, 150, 269, 372  
 Clearcuts 67, 173, 242, 269, 289  
   & browsing 395  
   & disease 408  
   & insects 402  
   & mycorrhizae 66-67  
   & public opinion 260  
   Soil temperature, effect on 61  
   Also see Harvest, Regeneration methods  
 Climate 9, 38, Chapter 4, 169, 176-177, 424  
 Change 87-88, 111, 294, 297  
 Global, & human activity 88  
   & natural regeneration 294  
   & species shifting 94

## Index

- Effect on evolutionary patterns 288-289, 292, 298, 303-304  
& soil development 53-54, 58  
& species diversity 95  
Also see Pacific Ocean
- Coast Range Geological Province 50-58, 67
- Coast redwood—See Redwood
- Coffeeberry, California 104
- Cold hardiness—See Seedling
- Common garden studies 286, 291-292, 296, 303
- Common prince's-pine 98, 100
- Competition 8-9, 38, 41, 61, 101-102, 104, 108, 111, 124-126, 128, 130, Chapter 7, 172, 177, 178, 181, 183, 187, 190, 193-195, 226, 261, 265-266, 268-271, 289-290, 294, 303, 314, 317-318, 320, 323, 324, 349-351, 353, 355, 361, 364, 367, 374, 377, 388, 412-413, 423-424
- Allelopathic compounds 49, 156, 266  
& artificial regeneration 155  
& climatic change 94
- Control 6, 10, 13-15, 61-62, 105-106, 110, 126, 128, 148, 168, 171, 183-188, 234-244, 246-247, 250, 259-260, 270, 318, 372, 389-395, 412-413, 424-425, 427-430, 433
- Burning 185
- Grazing 14, 175, 389, 394, 429
- Manual 389, 392-394
- Motor-manual 389, 392-394
- Mulching 389, 394
- Also see Silvicultural practices, Site preparation
- & disturbance 179-180
- Forbs 60, 111, 138, 140, 147-148, 150-151, 159-160, 180, 268, 393-394, 397, 427-428
- Germination & site disturbance 427
- Grasses 7, 40, 110-111, 137-139, 147-148, 151-152, 154-156, 159-160, 169-170, 180-181, 235-236, 239-240, 244, 268, 393-394, 397, 427-430
- Hardwoods 8-9, 12, 14, 38, 102-103, 105, 137-140, 142-147, 148-153, 155, 157-169, 170, 173, 179, 187, 191, 234-235, 237, 239-244, 246-247, 269, 389-392, 394, 403, 413, 428-429
- Herbaceous vegetation 7-9, 14, 38, 98, 101, 110-111, 125, 137-140, 145, 149-157, 168-170, 173, 179-181, 187, 234-238, 241-242, 244, 249-250, 270, 388-394, 395, 398, 413
- Management of 170, 175, 179
- Mycorrhizal host 179
- Nitrogen-fixing plants 156-157
- Regeneration, effect on 37-38, 168-172, 181, 183, 189-191  
& secondary succession 147-148  
& shelterwood management 146-147
- Shrubs 8-9, 12, 14, 32, 37-38, 60, 94, 101-102, 104-105, 109-111, 137-142, 145-153, 155-160, 168-170, 173, 178-179, 187-188, 191, 234-235, 237-242, 244, 246, 268-269, 271, 367, 388-394, 403, 413, 424, 427-429  
& site preparation 8-9, 14
- Weeds 39, 181, 233-235, 241, 244-245, 315-316, 343, 385, 403, 413
- Control 12, 151, 167, 169, 171, 176, 185, 195, 234-235, 237, 239, 241-242, 245-246, 294, 389-394
- Also see Harvest, Seedling survival, Silvicultural practices, Water competition
- Computer models 157, 423-424, 429, 432-433
- CACTOS 157, 173, 176, 191, 432
- ORGANON 157, 173, 176, 191, 432
- PROGNOSIS 432
- PSME 157, 159
- SYSTEM-1 157, 159, 173, 190, 429, 432
- VEGPRO 244, 391
- Conservation
- Laws, forest 347
- Also see Genetic diversity
- Costs
- Harvesting 6, 176, 203-204, 206, 210, 222, 226-228, 426
- Planting stock 314, 322-323
- Regeneration 12, 15, 171, 176, 203, 237, 243, 259-260, 273, 314, 320, 423, 426, 428, 431, 433
- Release treatments 387, 392-393,
- Road construction 427
- Seed collecting 300
- Site preparation 6, 237, 239, 244-245, 393, 423
- Survey 350, 353, 367, 373, 377
- Timber production 291
- Also see Economic considerations
- Creambush oceanspray—See Oceanspray

Crop tree—See Regeneration

Currant—See *Ribes* spp.

Cypress, Baker's 93

## D

Deerbrush 140-141, 143, 147, 149-150, 159

Degree growth stage model 123

Department of the Interior—See USDI

Desiccation—See Stress

Diameter classes—See Size classes

Disease 9-10, 145-146, 148, 180-182, 195, 233, 236, 247, 261, 264, 270, 289, 315-316, 323, 331-332, 385, 395, 404-411, 424, 426

Blister rust, white pine 99, 101, 181, 291, 300, 411, 413

Butt rot 407

Canker fungi 404

Caused by mechanical stress 172, 181

& clearcut regeneration 425

Control 4, 13-14, 247, 316, 406-407, 425

Also see Harvest, Site preparation

*Cronartium ribicola* 411

Damping-off 405

*Echinodontium tinctorum* 409

Foliar fungi 404

*Fomes annosus* 406

*Fusarium* spp. 291, 405

& harvest method 226

Heart rot 409

*Heterobasidion annosum* 406-407

Indian paint fungus 181, 409

*Leptographium (Verticicladiella) wagneri* 409

& nursery-grown stock 315-316

*Phellinus weirii* 405-407

*Pythium* spp. 405

Resistance, selection for 300

Root 7-9, 101, 181-182, 193, 236, 371, 405-406, 413

Annosus 181, 290, 407

Armillaria 181, 404, 406-407

Black-stain 181, 290, 400, 410, 413

Laminated 181, 406

*Phytophthora lateralis* 105, 404, 410-411, 413

Port-Orford-cedar root rot 410-411, 413

Shoestring root rot 406

& seeding 323

& seedling survival 9-10, 14

& species adaptation 289

Stem 181, 193, 405, 409, 413

Also see Regeneration success

Disturbance

& competing vegetation 9, 138-139, 147, 155, 179-180, 428

& disease 404

Fire 110, 147, 181, 234, 424

& site preparation 244

& forest succession 137-140

Grazing 110

Harvest 7, 110, 168-169, 172, 177, 179, 188, 203, 206, 207-208, 210, 214, 219, 234, 237, 270, 404, 424, 426

Landscape 424, 426

Landslides 59, 79, 179

Mining 110, 424

& nutrient conservation 247

Revegetation, effect on 111

Riparian areas 426

Skid roads/trails 62, 172, 179, 206, 210,

214-219, 222-223, 226-228, 237, 268,

272-273, 352, 410

& soil properties 59

Also see Road construction, Site preparation

Diversity, stand 101, 226

Horizontal 138, 168, 171, 181

Spatial 168

Vertical 11, 138, 168, 171, 180-181

Also see Genetic, Species

Dogtail, hedgehog 110-111

Dogwood 107

Dormancy—See Seedling

Douglas-fir 36-37, 40, 42, 61-62, 94-95, 98-111, 121-122, 124-125, 127, 129, 138, 141-142, 144, 149-159, 168, 174-175, 177-178, 180-181, 183-189, 190-194, 213, 234-236, 239-243, 247, 260, 262-263, 266-272, 286, 289-293, 295-296, 299-301, 303-305, 314-319, 321-323, 334, 336, 359, 373, 387, 388-396, 399-400, 402, 407-410, 413, 426, 430-431

Also see Plant associations, Seed sources

Drought—See Water

## E

Economic considerations 41-42

Harvest 182, 205

Of regeneration methods 168-172, 174-176, 273

Also see Costs  
 Elderberries 40  
 Elevation—See Site factors  
 Elm 94  
 Engelmann spruce—See Spruce  
 Erosion—See Soil  
 European larch—See Larch  
 Evaporation 60, 63, 85-86, 103, 117, 155  
   Evaporative demand 119  
   Evapotranspirational demand 63, 85, 94, 96,  
     102, 104, 119, 333  
   Transpiration 67, 117-119, 125-126, 290,  
     333  
 Evolutionary forces 285-288  
   Adaptation 288-290, 293, 296, 303  
   Also see Species  
   Gene flow 286-288, 299, 302, 304  
   Genetic drift 286-288, 293, 298  
   Mating system 286-287  
   Mutation 286-287, 298  
   Selection 286-288, 292-294, 299  
   Also see Gene, Genetic

**F**

Fairy-bell, Smith's 105  
 Farming  
   As early occupation 29  
   Landscape, effect on 29  
   Use of timber 34  
 Fauna, soil 64-65  
 Felling patterns 214, 220, 223  
 Fern 138  
   Bracken 141  
   Deer- 105  
   Sword 102, 104, 106-109, 371, 373  
 Fertilizing—See Silvicultural practices  
 Fescue 101, 110-111  
 Fir  
   California red 93  
   California white 318  
   Douglas—See Douglas-fir  
   Grand 36, 93, 100, 144, 192, 262-263, 267,  
     270, 290-291, 389  
   Noble 93-94, 192, 291, 389  
   Pacific silver 93-95, 107  
   Shasta red 34, 36-37, 93-95, 98-101, 103,  
     175, 189, 192, 193, 262-263, 271,  
     289, 291, 323, 389, 391, 402  
   Silver 100, 192, 389  
   Subalpine 94, 98

True 101, 111, 139, 169, 172, 178, 181, 188,  
 194, 236, 261, 264, 271, 290-291,  
 315, 407-409  
 White 36-37, 93, 95, 98-111, 138, 144, 145-  
 150, 152, 175, 177-178, 183-184,  
 189-190, 191-192, 243, 262-263, 267,  
 269-271, 289-291, 389, 391, 394,  
 402, 404-406, 431  
   Also see Plant associations, Seed sources  
 FIR—See Forestry Intensified Research Program  
 Fire  
   Behavior, affected by nonconiferous species  
     137, 148  
   Hazard 5, 13, 172, 227, 237, 243, 272, 424  
   Historical use of 29-30  
   Landscape, effect on 27, 29, 31-32, 36-37,  
     43, 97  
   Seed bank germination, affected by 141  
   Suppression 40  
   Wildfire & secondary succession 147  
   Also see Silvicultural practices  
 Fireweed 138  
 Fisheries—See Management objectives  
 Forage 5, 10, 111, 147, 160, 171, 180  
   Also see Management objectives  
 Forbs—See Competition  
 Forest Homestead Act 30  
 Forest Practices  
   Acts 261  
   California Forest Practices Act of 1973  
     6, 173-174  
   Oregon Forest Practices Act of 1971 6, 173  
   Regulations 5-6  
   USDA Forest Service 174  
   USDI Bureau of Land Management 174  
   Also see Management objectives  
 Forestry Intensified Research Program (FIR) 27,  
 42, 43  
 Frost—See Site factors  
 Fuel accumulation 5, 7-8, 423-425  
 Fungi—See Disease  
 Fungi-microbe symbiosis 59  
   Also see Disease  
 Fur trapping, effect on landscape 27-28, 36, 43

**G**  
 Genetic  
   Composition 286  
   Diversity 94, 269, Chapter 12  
   Conservation 301-304

& seed transfer risk 291, 293-297  
 Also see Species diversity  
 Gradients 294-297  
 Improved stock 176, 260, 291, 304  
 Improvement programs 12, 300  
 Resources 294, 300  
 Variation—See Genetic diversity  
 Also see Evolutionary forces, Tree improvement program  
 Geographic Information Systems (GIS) 432  
 Glacial/interglacial cycles & species 288-289  
 Global warming & natural regeneration 294, 297  
 Gold mining—See Mining  
 Golden chinkapin—See Chinkapin  
 Gooseberries 99, 101  
 Grand fir—See Fir  
 Grazing, effect on landscape 27-30  
 Also see Animal damage, Competition control  
 Grasses—See Competition  
 Ground-based logging—See Harvest systems  
 Group tree selection—See Regeneration methods  
 Grouse shrub—See Shrub  
 Growth models—See Computer models

## H

Habitat  
 Management for seedling protection 396-399, 403, 413  
 & regeneration methods 169-171  
 Wildlife 5, 9-10, 101, 103, 137, 147-148, 160, 179-180, 215, 233, 236, 242, 244, 272, 389, 424-427  
 Also see Management objectives  
 Hardwoods—See Competition  
 Harvest 3-4, Chapter 9, 233, 237, 385, 412, 425  
 Aesthetic considerations 210, 227  
 Clear-cutting 12, 14, 37-38, 40, 146, 203-204, 206, 226, 407  
 Damage 172, 177, 179, 181, 193, 225  
 & diseases 404-405, 409-411  
 Environmental concerns 209  
 Genetic variation, effect on 285, 288  
 History of 30-31, 34-42  
 & microenvironment 176, 181  
 Planning strategies 210-219, 227  
 & regeneration 15, 111  
 & safety considerations 8, 193-194, 204, 206-207, 210, 214-215, 219, 226, 392  
 & secondary succession 147  
 Shelterwood 37-38, 40, 146, 169-170, 216,

301-302  
 Strategies 167, 167-170, 174-175, 203  
 Systems 204-210, 320, 347, 426-427  
 Aerial 6-7, 169, 204-205, 209-211, 222, 227-228, 412, 426-427  
 Cable 7, 169-170, 176, 179, 204-211, 212, 214-219, 221-228, 237, 410, 412, 426  
 Ground-based 7, 204-206, 211, 214-217, 219-223, 225-228, 237, 410,  
 & uneven-aged stands 170-171, 226-227  
 Also see Clearcuts, Costs, Management objectives,  
 Hawkweed, white-flowered 107  
 Hazel 100, 102, 104, 138  
 Heath 98  
 Height classes—See Size classes  
 Hemlock 66, 139, 373, 407  
 Mountain 36-37, 94-95, 98-101, 111, 192, 260, 262, 271  
 Western 36, 95, 98, 101-109, 111, 138, 262-263, 267-268, 315, 389  
 Also see Plant associations, Seed sources  
 Herbaceous vegetation—See Competition  
 Herbicides—See Silvicultural practices  
 Honeysuckle, hairy 104-105, 270  
 Horses for yarding logs 205-206  
 Hound's-tongue 108  
 Huckleberry 29, 138, 141  
 Evergreen 104-105, 107, 141  
 Grouse 98  
 Red 102, 107-108  
 Thin-leaved 98, 100-101, 107  
 Humus—See Soil organic matter

## I

Incense-cedar 34, 36-37, 98, 100-103, 105, 107-110, 191, 262-263, 267-271, 289-290, 389  
 Also see Seed sources  
 Indicator plants 181, 273, 431  
 Insecticides—See Silvicultural practices  
 Insects 7, 9-10, 75, 147, 149, 168, 180-182, 195, 239, 262, 264, 377, 385, 395, 399-404, 412-413  
*Acrididae* spp. 401  
*Adelges cooleyi* 399  
 Adelgid, Cooley spruce gall 399  
 Ants 399  
 Aphid, giant conifer 399, 403  
 Beetles, bark 37, 40-41, 400, 424



Benefits to forest 403  
*Cecidomyia pinitnopsis* 401  
*Cinara* spp. 399  
 Control 5, 14, 402-403, 412-413  
 Cutworms 37, 181, 269  
*Cylindrocoptera fumissi* 401-402  
 Douglas-fir engraver 402  
 Douglas-fir root collar weevil 400  
*Eucosma sonomana* 401  
 Gouty pitch midge 401-402  
 Grasshoppers 40, 155, 181, 401-402  
 Grubs, white 181  
*Hylastes macer* 400  
*Hylastes nigrinus* 400, 410  
 Infestations 37, 423-424, 426, 432  
 Locusts 401  
 Millipedes 181  
 & nursery stock 315-316, 323  
 Pests—See Stress  
 Pine resin midge 181  
*Pissodes fasciatus* 410  
*Pissodes strobi* 401  
 Ponderosa pine tip moth 401  
 Predators 403  
 Reproduction weevil 181  
 Root beetles 399-400, 403, 413  
 Root-feeding weevils 410  
*Rhyacionia zozana* 401  
 Sap-suckers 399, 413  
*Scolytus unispinosus* 402  
 Secondary bark beetles 399, 402, 413  
 & seeding 323  
 & seedling survival 9, 14, 377  
 Shoot borer 403  
 Spider mite 403  
*Steremntus carinatus* 400-401, 410  
 Terminal feeders 399, 401, 403, 404, 413  
 Twig weevils 401  
 Western pine shoot borer 401  
 White pine weevil 401  
 Wireworms 181  
 Also see Seedling damage  
 Integrated pest management (IPM) 180, 385  
 Interior Valley Zone 244  
 Irrigation—See Silvicultural practices

**J**

Jeffrey pine—See Pine, Jeffrey

**K**

Klamath Geological Province 50-52, 57-58, 67, 94, 97-98, 100-103, 106, 109, 111, 235, 288

**L**

Land ownership, effect on landscape 27, 29-30  
 Landscape diversity—See Overstory, Stand structure, Understory  
 Larch, European 37  
 Laurel  
   California- 36, 104, 107  
   Sierra 107  
 Leave trees—See Stand, residual  
 Lichen 140  
 Light—See Site factors, Stress  
 Limiting factors—See Competition, Site factors  
 Lodgepole pine—See Pine, Lodgepole  
 Logging  
   & competition regeneration 146  
   Landscape, effect on 27, 34-36, 43  
   As early occupation 29, 34-36  
   Railroad 35  
   & seed transfer risk 294, 297  
   Also see Harvest

**M**

Madrone, Pacific 36, 38, 67, 94, 104-105, 109-111, 138, 141, 144-147, 149-151, 154, 155, 157, 158, 187, 190, 237, 247, 269, 289, 389, 425  
 Mahogany, mountain 110-111  
 Management objectives 3, 24, 36-40, 137, 140, 146-148, 347  
   Aesthetics 3-6, 12, 147, 167, 173, 175, 194, 210, 259-260, 425  
   & biological diversity 98  
   & firewood production 111, 137, 147  
   Fisheries 5, 167, 195  
   & forage 5, 100, 111  
   & genetic diversity 299-303  
   Land use objectives 5-7  
   & planting considerations 290-291  
   Recreation 5-6, 98, 100, 167, 171, 195, 423  
   Regeneration methods 172-173, 273  
   Sustainable forestry 167, 423-424  
   Timber production 5, 98, 100, 110, 167, 180, 195, 347, 423, 426  
   & tree improvement 300  
   Water 5, 111, 167, 173, 175, 195

- Wildlife 3, 5-6, 98, 100, 167, 175, 179-180, 195
- Manzanita 67, 94, 102, 139, 146, 147, 150, 152, 154, 157, 159-160, 187, 237, 242, 269-270, 394, 425, 428
- Greenleaf 125, 140-142, 149-150, 187, 239, 391-392
- Pinemat 98
- Whiteleaf 125, 141-142, 147, 149, 152, 154
- Whitethorn 140
- Maple 94, 107
- Bigleaf 36, 38, 138, 139, 141, 143, 144, 154, 160
- Rocky Mountain 100-101
- Vine 100-101, 104, 107-108, 138, 141, 237, 244, 273, 398
- Mechanical stress—See Stress
- Mining
- Landscape, effect on 27-30, 34, 43
- Gold 28-29
- Also see Disturbance
- Mistletoe 7, 180, 226, 405, 408, 413
- Arceuthobium* 408
- Dwarf 182, 261, 290, 408
- Moisture
- Dew 86
- Fog 84, 102, 104, 107, 210, 235
- Precipitation 7, 9, 54, 58, 76-79, 117, 186-187, 241, 249, 293
- & genetic gradients 295
- & operational environment 292, 303
- & species adaptations 289-290
- Soil 54, 61-62, 240, 244, 267, 269, 289-290, 291, 333
- Snow 7, 84-87, 128, 264, 268, 336, 338-339
- Stress—See Stress
- Vertical gradients 84, 86
- Also see Evaporation, Site factors, Water competition
- Mosses 109, 140
- Mountain hemlock—See Hemlock
- Mulching—See Competition control, Silvicultural practices
- Mustard 269
- Mutation—See Evolutionary forces
- Mycorrhizae 66-67, 120, 157, 178-179, 266, 269-270, 425
- Inoculation 311-312, 321-322, 324, 425
- Hebeloma crustuliniforme* 321
- Laccaria laccata* 321
- Pisolithus tinctorius* 321-322, 324
- Rhizopogon vinicolor* 321-322, 324
- Also see Nitrogen, Silvicultural practices
- Myrtle, Oregon 36
- N**
- National Climatic Data Center 83
- National Environmental Protection Act (NEPA) 5
- National Oceanic and Atmospheric Administration 89
- Natural regeneration—See Regeneration
- New Perspectives forestry methods 106, 203, 227-228, 272-273
- Nitrogen
- Competition for 66
- Cycle 49, 55-56, 64-66
- Deficiency 127, 156
- Depletion 179, 290, 425
- Fixation 65-66, 156-157, 179
- & mycorrhizae 66-67
- Storage 58
- Also see Mycorrhizae
- Noble fir—See Fir
- Non-coniferous vegetation—
- See Competition, also Chapter 7
- Northwest Tree Improvement Cooperative 300
- Norway spruce—See Spruce
- Nurse crops 236, 269
- Nurse logs & mycorrhizae 66
- Nutrients 9, 176, 242
- Conservation 247
- Cycling 49, 60, 64, 403
- Environment 127
- Imbalance 63
- Loss 179, 234, 243, 247-248, 425
- & plant physiology 119-120
- & regeneration 176
- & seedbeds 265, 268
- & species adaptations 290
- O**
- O&C (Oregon & California) Railroads 29-30, 34
- Timber 30-31
- Oak 94, 98
- California black 36, 110-111, 141, 144, 146, 155
- Canyon live 38, 102, 104-105, 108-109, 125, 138, 141, 143-144, 150, 247, 270, 389, 392, 394

## Index

- Sadler 93, 100-101, 104, 107, 109  
Valley 289  
White, Oregon 36, 100, 108, 109-111, 237  
Also see Plant associations
- Oceanspray, creambush 100-102, 108-109, 141  
Old growth in forest succession 138, 140  
Oniongrass, Alaska 101  
Operational environment 9, Chapter 6, 93-94  
Adaptation of species 289-290, 303  
& climate 96-97  
Definition 116  
& elevation 95-111  
& evolutionary forces 292  
& genetic composition 286  
& light 93  
& microhabitat 293-294  
& moisture requirements 96-111  
& site preparation 233-234, 244  
& temperature 96-111  
Also see Climate, Silvicultural practices,  
Moisture, Site factors
- Oregon and California Railroads—See O&C  
Railroads
- Oregon Myrtle—See Myrtle  
Oregon Office of the State Climatologist 89  
Oregon white oak—See Oak, Plant associations  
Oregongrape 138, 371, 373  
Creeping 108-109  
Dwarf 100, 102, 104-109  
Piper's 100, 102, 105, 108
- ORGANON—See Computer models
- Overstory 103-104, 107, 108, 110-111, 137-138,  
140, 144, 147, 160, 178-179, 181-  
184, 192, 203, 208, 226, 228, 242-  
243, 260-261, 263, 266-267, 270,  
272, 386, 407-408, 412  
Canopy 8, 103, 172, 178, 180-181, 183, 237,  
266-267, 428, 433  
Damage 223-224  
Density 176, 178, 190-193, 267, 272, 426  
Removal 10, 12, 14, 62, 168-170, 176-177,  
180, 188-190, 193-194, 212-216, 221,  
225, 227, 260, 272, 318, 408, 425-  
426, 428, 431  
Also see Regeneration methods, Stand  
structure
- Oxalis, Oregon 107
- P**
- Pacific madrone—See Madrone
- Pacific Northwest Forest & Range Experiment  
Station 32, 41-42
- Pacific Northwest Seeding & Planting  
Committee 361
- Pacific Ocean  
Effect on climate 75, 79, 85, 94, 96, 102,  
104, 235, 292, 295
- Pacific Southwest Forest & Range Experiment  
Station 40-42
- Pacific silver fir—See Fir  
Pacific yew—See Yew
- Parasites—See Pests
- Pathogens—See Disease
- Pesticides—See Silvicultural practices
- Pests 239, 261, 323, 427  
Animal—See Animal damage, Animals  
& genetic diversity 289, 298-299  
Insect—See Insects  
Management 5  
Mistletoe 7, 180, 226, 405, 408, 413  
Arceuthobium 408  
Dwarf 182, 290, 408  
& planting considerations 290, 303  
Plant—See Competition  
& shelterwood regeneration 169-170  
& species adaptations 289
- Photogrammetric methods 371-374  
Photography, aerial 371-374  
Photosynthesis 121-122, 125-128, 131, 146, 152,  
153, 155-156, 391
- Pine 94, 321  
Jeffrey 36-37, 63, 93, 108-109, 127, 149,  
175, 181, 262, 263, 267, 270, 289,  
291, 314, 318, 389, 391  
Lodgepole 36, 98-100, 184, 236, 239-240,  
262-263, 267, 269, 289, 291, 389,  
402, 413  
Ponderosa 36-37, 40, 42, 97-98, 100, 102,  
103, 105, 108, 110-111, 121, 122,  
124-126, 129, 138, 149-154, 157-159,  
168, 175, 177, 181, 184, 186, 187,  
190-191, 192, 213, 234, 236, 239,  
240-241, 247, 262-263, 267, 269-270,  
271, 289-291, 302, 314-315, 317-319,  
324, 343, 372, 373, 388-394, 397,  
399, 402-403, 407-408, 409-410, 413,  
430  
Red 292, 298  
Scotch 37  
Sugar 34, 36-37, 98, 102-104, 105, 108-110,

138, 149, 178, 181, 187, 191, 241,  
262-263, 267, 269-270, 289-292, 300,  
323, 389, 391, 411  
Western white 36, 95, 98, 101, 107, 108-110,  
184, 262, 267, 271, 289, 292, 300,  
323, 359, 389, 411  
Also see Plant associations, Seed sources  
Pinemat manzanita—See Manzanita  
Pinus—See Pine  
Plant associations 8, 49, 181, 235, 270  
Cedar  
Port-Orford- 95-96  
Western red- 95  
Douglas-fir 95-97, 103, 108-110  
Fir  
Pacific silver 95-96  
Shasta red 95-96, 270  
Subalpine 95  
White 95-97, 99-103, 108  
Hemlock  
Mountain 95-99, 260  
Western 95-98, 106-109, 270  
Oak  
Canyon live 270  
Oregon white 95-96, 110-111  
Pine  
Jeffrey 95-96  
Lodgepole 95-96  
Ponderosa 95-96, 97  
Western white 95-96  
Spruce, sitka 95, 103  
Tanoak 95-96, 97, 103-106, 109, 270  
Plant growth regulators & seedling growth 122,  
129  
Also see Degree growth stage model  
Plant hormones & seedling growth 128  
Plant moisture stress (PMS)—See Stress  
Planting—See Regeneration methods  
PMS—See Stress  
Poison-oak 100, 104-105, 108-110, 138, 270, 394  
Polemonium, skunkleaf 98  
Ponderosa pine—See Pine  
Port-Orford-cedar—See Cedar  
Precipitation—See Moisture  
Predators—See Animal damage  
PROGNOSIS—See Computer models  
*Prunus* spp. 141  
PSME—See Computer models  
Pyrola, whitevein 98, 100

**Q**

Queen's cup 107

**R**

Radiation—See Site factors  
Rare and Endangered Species Act 5  
Ravel—See Site factors  
Recreation as a land use 33-34, 43  
Also see Management objectives  
Red alder—See Alder  
Red fir—See Fir  
Redwood 36-37, 93-94, 103-104,  
108, 138, 389  
Reforestation—See Regeneration  
Refractory seeds 242  
Regeneration 61-62, 116-117, 240  
Administrative issues 174-175  
Advance 8, 10-12, 14, 99, 105-106, 167,  
170, 171, 173, 182-183, 188-190,  
195, 208, 237, 242, 260, 267, 271-  
272, 349, 409, 428  
Artificial 5, 8, 10-12, 27, 37, 39-41, 67, 98-  
99, 102-103, 105-106, 167-169, 171,  
173, 175-176, 183-188, 192, 195,  
225, 238, 259-261, 273-274, 291,  
293, 301-303, 311, 318, 329, 333-  
343, 365, 425, 428, 431  
& safety considerations 338-339  
& climate 76, 86, 88  
Crop trees 14, 97, 101, 103, 105, 106, 111,  
170, 193, 267, 297-298, 351, 353,  
362, 365, 377, 407, 426  
& diseases 405, 408-411  
After disturbance 3, 103, 183,  
& the economy 41-42  
Failure 61, 125, 168, 185, 297  
& genetic variation 285  
& macroenvironment 176  
Methods 4, 10-12, Chapter 8, 203, 222-223,  
225, 350, 386, 425-426  
Clearcut 10, 11-12, 37, 61, 62, 98-99,  
144-145, 167, 168, 169, 173, 177-  
180, 183-184, 191, 195, 203, 242,  
271-273, 318, 425-426, 430  
Group selection 10-12, 37, 167, 168, 171,  
173, 176, 181-182, 191, 193, 195,  
203, 260, 273, 397  
Seed tree 8, 10-11, 167-169, 176, 182,  
191, 193, 195, 260-263, 270, 272-273,  
298, 300-302, 314, 322-323, 430-431

Shelterwood 10-12, 62, 99, 102, 126, 147, 167-170, 173, 176-178, 180, 182-184, 191-193, 195, 203, 222-223, 225, 227, 242, 260, 262, 272-273, 298, 301-302, 318, 397, 413, 425-427, 430

Single tree selection 10-11, 37, 147, 167, 168, 171-173, 176, 180-182, 191, 193, 195, 203, 260, 273, 427

& microenvironment 176-181, 397

Natural 5, 8, 10, 12-14, 32, 37-41, 67, 98-99, 106, 120, 155, 167-171, 173, 176, 182-193, 236, 242-243, Chapter 11, 291, 294, 300-304, 311, 395, 407, 412, 424-425, 428, 431, 433

Advantages & disadvantages 169, 259-261, 428

& clearcuts 260, 262-263, 267-271, 273

Ecological considerations 271

Planning considerations 270-271

Seeding 8, 10-13, 37-38, 40, 99, 168-169, 171, 183, 188, 311, 322-324, 365, 395, 412, 430-431

& neighboring properties 7

& pest control 408

Planting—See Regeneration, artificial

Propagules 12, 169, 233, 250, 311, 386

Regulatory issues 175

Social issues 175

Standards 173-174

Success 13, 125, 128, 130, 187, 240, 288, 314, 329, 343, 365, 385

& succession 140-147

Surveys 14-15, Chapter 15

Also see Competition, Costs, Economic considerations, Management objectives, Silvicultural practices, Site factors

Release—See Silvicultural practices

Remote Automated Weather Stations (RAWS) 85

Remote sensing technology 432

Residual trees—See Stand, residual

Rhododendron, Pacific 98, 101, 104-109, 138, 141, 270

*Ribes* spp. 99-101, 411

Riparian zones 96, 102, 104, 108, 144, 171, 226, 426

Also see Disturbance

Road construction 6, 79, 106, 169, 179, 210, 214, 425

Rock types Chapter 3

Rocky Mountain maple—See Maple

Rogue River National Forest 34, 61, 173, 175, 323

Site Resource Inventory 56

Root

Beetles—See Insects

Growth Potential (RGP) 130, 404

Regeneration stress (RRS) See Seedling

Rot—See Diseases

Also see Seedling, root

Rose, baldhip 100, 104-105, 109

RRS—See Seedling, root

Rub trees 219-220, 228

Ruderals 137-140, 141

Rush, parry 98

**S**

Sadler oak—See Oak

Safety—See Harvest, Regeneration, Silvicultural practices

Sage 149

Salal 100, 104-109, 138-139, 141, 160, 371, 373

Salmonberry 138-139, 398

Sampling methods Chapter 15

Sanicula 111

Sap-suckers—See Insects

Scenery, as a forest resource 147

Scotch pine—See Pine

Secondary bark beetles—See Insects

Seed

Availability 7, 10, 12, 428

Crops 261-263, 270, 273

Dispersal 188, 263-265, 271, 299

Lots 286, 291, 294-297, 300, 302, 303, 315-317

Orchards 300, 302

Predators—See Animal damage

Production 188, 273

Sources 7, 8, 10, 182, 191, 237, 270, 303, 349

Cedar 262

Douglas-fir 260, 262-266, 269

Fir 262, 263-264

Hemlock 262-264, 266

Incense-cedar 262, 264

Pine 261-264

Supply 6, 261-263, 271

Survival 264

Transfer 288, 291, 293, 297, 303-304

Risk 291, 293-294, 303

Tree—See Regeneration

Zone maps 295

- Seedbed 6, 10, 13, 172, 188, 233, 236-237, 239, 273, 312, 314, 427  
 Burning, effect of 242-243  
 Nursery 315-318  
 Preparation 261-262, 265-266, 268-269, 271, 272, 315
- Seedling  
 Bareroot 178, 186, 242, 311-321, 323, 332-333, 340, 400-401  
 & climate 38-39, 75-76, 88-89  
 Cold hardiness 122-123, 125-126, 127, 129, 313, 316-317, 332  
 Container-grown 311-312, 314-324, 342, 391  
 Damage 12, 63, 85, 155, 158, 170, 183, 193, 214, 219, 222-223, 225, 235, 236, 239, 260, 329, 331, 343, Chapter 16, 395-411, 426  
     From harvest 176, 214, 219-225  
     Also see Animal damage, Animals  
 Dormancy 121, 122-123, 125-126, 127, 129, 313-314, 315-316, 317, 330  
 Drought tolerance 321, 324  
 Establishment 49, 175, 233, 250  
 Genetically improved stock 176  
 Growth 8-9, 12, 38, 49, 63, Chapter 6, 148-160, 169-172, 176-182, 185, 187, 189-190, 233, 234, 235, 238-242, 243, 247-248, 266-270, 273, 285, 295, 311, 314-316, 319-322, 350, 391, 412-413, 423, 432  
 Handling 10, 12, 41, 129, 314, Chapter 14, 428  
 Inspection 330-331  
 Mortality 9, 12-14, 38, 63, 98, 126, 137, 155, 172-174, 178, 180, 184, 185, 188, 193-194, 234-236, 242, 266-270, 291, 297, 322, 332, 350, 387, 389-390, 391, 400-401, 410, 412, 424, 426-427, 429-430, 432  
 Nursery stock 6, 10, 12, 40, 41, 120, 155, 176, 183, 186-187, 259-260, 261, 291, 302, 311-312, 315-317, 320, 321, 324, 329-331, 336, 341-343, 388, 412  
     Also see Mycorrhizae  
 Nutrient cycling 403  
 Production 315-317  
 Propagules—See Regeneration  
 Protection 4, 13-15, 332, Chapter 16
- Quality 13, 116, 130, 168, 186-187, 313, 317, 319, 321, 322, 324, 330, 331, 336, 343, 428, 430
- Root 313, 315  
 Condition 331, 339-340, 343  
 Damage 172, 180, 193, 214, 332  
 Development 126, 129, 259, 394  
 Growth 9, 62, 67, 66, 125, 127-130, 158, 177-178, 267, 268, 270, 290, 291, 315-316, 319, 330, 333-334  
 & mycorrhizae 66-67, 179, 270  
 Regeneration potential (RRP) 313, 316  
 Rot—See Diseases  
 System 178-181, 194, 237, 314, 317, 322, 333, 339, 400  
     Zone 55, 57, 60, 254, 178  
 & shade 158, 183, 333-335  
 Shoot growth 125-126, 128-130, 176, 319, 391  
 Storage 10, 12, 129, 314, 316, 329-331, 332, 343, 428  
 Survival 8-9, 13-14, 51, 66-67, 102, 105-106, 110, 115-119, 125, 130, 152, 154, 155, 160, 176-179, 183-187, 188, 190, 191, 208, 233, 234-236, 238-243, 247, 265-270, 285, 311, 314, 318-324, 329, 333-336, 340, 343, 388-390, 392-393, 412-413, 423, 425, 431  
     Also see Animal damage, Competition  
 Tissue culture 311  
 Transplants 311-312, 314-315, 316, 318, 320, 323-324, 396, 401  
 Transportation 12, 329-331, 343, 428  
 Vigor 12, 38, 122, 125, 127, 129-130, 147, 157-159, 170, 177, 193, 265, 329, 332, 403  
     Also see Animal damage, Climate, Disease, Insects, Regeneration, Site factors
- Selection—See Evolutionary forces  
 Selection methods—See Regeneration methods  
 Senecio 138, 141  
 Series, plant Chapter 5  
 Serviceberry, western 100  
 Shade  
     Artificial 13, 183, 333, 387-388  
     Dead 265-267, 268, 333-335  
     & germination 265-266, 271  
     & heat damage 387-388, 412  
     Live plant 125-128, 178, 182-183, 215, 265-

- 267, 271, 388, 392, 412  
 Microsite 13, 169, 318, 323, 335, 387-388, 412-413  
 & seedlings 176, 235, 266-269, 271  
 Also see Seedling, Site factors, Species  
 Shasta red fir—See Fir  
 Shasta-Trinity National Forest 32  
 Shelterwood—See Age class, Competition, Harvest methods, Regeneration methods  
 Shrubs—See Competition  
 Silktassel 394  
 Silvicultural practices 126, 175, 270-273  
 Fertilizing 11, 64, 186, 203, 262, 294, 302, 315-316, 336, 425, 432  
 Herbicides 105, 127, 152, 183, 227, 234, 238, 240, 244-250, 290, 389-392, 427, 429  
 Application 203, 215, 244-245  
 & public concern 6, 14  
 & regulatory issues 175  
 & safety 250  
 History 37  
 Irrigation 294, 315-316  
 Insecticides 402-404, 413  
 Pesticides 37, 322, 399  
 Applicators 245  
 Licensing 245  
 Rodenticides 398  
 Prescribed burning 6, 10, 11, 13, 29, 31-32, 97, 108-109, 144, 175-176, 179-180, 183, 185, 203, 205, 208, 233, 234-236, 239, 242-244, 247, 248, 271, 290, 398, 399, 404, 412, 424, 427-429  
 Broadcast 62, 64, 171-172, 227, 240, 265-266, 268-269, 271  
 & competition 62  
 & erosion potential 62  
 & evaporation rates 62  
 & forage 30, 32  
 Management 243, 247  
 & public concern 6, 427  
 & site preparation 62  
 Slash 64, 237, 241  
 Smoke management 243  
 Underburning 105-106, 147, 261, 242-244  
 Also see Fire  
 Release treatments 3, 4, 6, 8, 10-11, 13, 14, 127, 138, 145, 148, 152, 157-160, 168, 170, 173, 175, 180-181, 185, 188, 189-190, 194, 227, 233-234, 236, 238, 240-247, 248, 250-251, 261, 266-267, 271, 290-291, 317-318, 323, 372, 391, 429  
 Chemical 6, 10, 13, 14, 158, 227, 391, 394  
 Hand clearing 152, 392  
 Manual 10, 13, 14, 158, 392, 394  
 Mechanical 10, 392  
 Mulch 13, 393-394  
 Also see Competition control, Costs  
 Safety 234, 249-250, 338-339, 392  
 Silviculture  
 Standards & regeneration surveys 350-352  
 Systems & regeneration 167-172  
 Single tree selection—See Regeneration methods  
 Siskiyou-Cascade Research Center 41  
 Siskiyou National Forest 28, 30, 32, 411  
 Soil Resource Inventory 54  
 Siskiyou Province 96  
 Site  
 Degradation 247-249  
 Evaluation 6-10  
 Factors & regeneration 176-181, 385-386  
 Abiotic 7, 9, 176, 385, 412  
 Aspect 6, 7, 9, 86-87, 125-126, 167, 178, 185-186, 267, 269-272, 274, 293, 295, 318, 333, 334, 349, 387, 412, 425  
 Biotic 7, 9, 176, 385, 412  
 Competition—See Competition  
 Elevation 95-111, 119, 124-126, 171, 176, 182, 185, 187, 268-270, 274, 292, 293, 294, 295  
 Frost 7, 9, 13, 40, 60, 61, 86, 98, 101, 103, 106, 169-170, 176, 178, 180, 183-184, 191-192, 195, 233, 236, 295, 320, 336, 385, 388-389, 413, 425, 428, 433  
 Damage 63, 126, 146, 260, 266-267, 268, 272, 274, 371, 377, 389  
 Hardiness—See Cold hardiness  
 Heaving 85, 126, 144, 268, 320, 324  
 Pockets 87, 95, 100, 126, 171, 182, 269, 272, 274  
 Light 9, 93, 103-104, 116, 144, 147, 151, 155-156, 168, 176-177, 234, 238, 244, 264-268, 269, 272, 295  
 Infrared radiation 79, 86-87  
 Solar radiation 9, 75-76, 79, 86, 88, 333  
 Moisture 8-9, 88, 96-111, 116-118, 125, 140, 145, 147, 151-153, 155-156, 168,

176-178, 187, 234, 238, 244, 264-268, 269, 273, 289-290, 293, 294, 295, 333, 343

Nutrients 63-66, 111, 116, 120-121, 147, 176, 234

Ravel 51, 59, 188, 268, 314, 334, 340, 385, 412, 413, 431

Shade 126, 293, 425, 428

Slope 7, 86, 126, 167, 270, 272, 274, 293, 295, 387, 431

Soil 7-8, 9, 12, 127, 151, 156, 157, 177, 179, 187, 268, 273, 289-290, 293, 343, 349, 424

Temperature 7, 9, 40, 94, 96, 103, 107-109, 111, 116, 126, 144, 151, 155, 168, 176, 178, 187, 233, 235-236, 242, 264-270, 273, 289, 292-293, 295, 303, 320, 333-334, 387-388, 412 & germination 264-266 & seedling survival 266-268, 273

Topography 7, 9, 171, 176-177, 274, 289, 293, 303, 424

Climate, effect of 77-79 & wind 85

Preparation 5, 6, 8-10, 12-15, 167-171, 173, 175, 176, 179-180, 203, 215, 225-226, Chapter 10, 272, 290, 317-320, 324, 371, 372, 385, 386, 423, 425, 427-428, 430

Burning 62, 67, 185, 234, 242-244, 236-237, 290, 318, 398-399

Chemical 10, 13, 203, 427

& competition control 146, 148, 159, 235, 237, 239, 391-392, 413

& diseases 404-405

& hardwood regeneration 146

& herbicides 180, 237-238, 244-248, 391

& insect infestation 401-403

& logging 237

Methods 10, 13, 62-63, 175, 180, 187, 203, 233, 235-242, 247-249, 266, 265, 268, 269, 392, 398-399, 425, 427-429

& microenvironment 176, 177-181, 337-339

& seed transfer risk 294-297

Also see Climate

Sitka spruce—See Spruce

Size class 7-8, 182, 194

Diameter 172, 182

Height 182, 370-371

Skid trails—See Harvest

Skyline logging—See Harvest systems

Slash

Burning 64, 179, 243, 248, 266, 268-269, 271

Disposal 168-172, 176, 214, 215, 225, 241, 261, 427

Management 5

Snow—See Moisture

Snowberry, creeping 100, 102, 104-105, 109

Snowbrush ceanothus—See Ceanothus

Soil

Cation exchange capacity 63-64, 121

Chemistry 49, 63, 64

Compaction 7, 13, 55, 62, 67, 172, 179, 206, 215, 223-226, 227, 234, 237, 239, 240, 242, 247, 260, 268, 271, 290, 333, 334, 352, 425, 427

Damage 122, 176, 425, 427

Development 53-55, 57-59, 67

Disturbance 172, 225

Erosion 7, 51, 57, 61-63, 79, 99, 106, 208, 234, 334

& burning 62, 179, 248

& clearcuts 169

& fertility 55-56

& harvesting 172, 179

Fertility 268

& germination 264-266

Microorganisms 10, 64-65, 234, 249, 425

Moisture—See Moisture, soil

Organic matter 55, 57-61, 63-64, 66, 99, 120, 121, 242, 247, 268, 290, 293, 425

Parent material 8, 53-58, 293

-plant-atmosphere continuum 117, 119-120

Properties 58-67

& species adaptation 289, 303

& regeneration 169, 177, 185

& seedbed preparation 265-266

& seedling survival 266-268

Stability 137, 140, 160

Temperature 40, 54, 57, 59-63, 67, 126, 387, 412

Types

Ash 61, 95, 97, 99, 111

Basaltic 96, 101

Basic 108

Clay 97



- Gneiss 49, 107  
 Granitic 51, 60-61, 99, 101, 103, 106, 111, 242-243, 336  
 Granodiorite 238  
 Marine sediment 107-108  
 Mesic 13, 392  
 Metamorphosed parent materials 101  
 Metasedimentary 101  
 Peridotites 63, 103, 127  
 Pumice 51, 60-61, 95, 99, 101, 111  
 Pyroclastic 99  
 Serpentine 51, 63, 103, 127, 176, 291  
 Skeletal 49, 51, 54-55, 59-60, 67, 105, 110, 319, 333, 339, 343  
 Ultrabasic 63, 103, 106, 111, 127, 176  
 Volcanic rock 107  
 Xeric 291, 391, 429
- Water  
 -holding capacity 59-61, 62-63  
 Limiting factor 60  
 Nitrogen-mineralization rate, effect of 65  
 Also see Disturbance, Moisture, Site factors
- Solomon's seal, starry false 107
- Species  
 Adaptation 181, 289-290  
 Biogeographical distribution 294, 297  
 Climax 93, 95, 97-98, 103, 105, 106, 108-110  
 Co-climax 101  
 Composition & regeneration 3, 5, 7-9, 12, 167, 173, 176, 181-182, 193, 350, 423-424, 432  
 Distribution 173, 303  
 Diversity 13, 93, 94-95, 101, 169-171, 226, 259, 269, 285, 288-291, 403  
 Also see Genetic diversity  
 Drought-resistant 260  
 Endemic 93-94, 101  
 Non-coniferous Chapter 7  
 Pioneer 67, 103, 138  
 Selection 126  
 Seral 11, 60, 105, 106, 168, 171, 180  
 Shade-tolerant 8, 12, 127, 130, 137, 140-144, 147, 160, 168-169, 171-172, 177-178, 181-182, 188, 190, 261, 269, 272-273, 291, 389, 428, 431-432  
 Succession 7-8, 11-12, 98, 181, 413, 425  
 Threatened & endangered 7-8
- Spruce  
 Brewer 93, 98, 100-101  
 Engelmann 97-99, 389  
 Norway 37, 267  
 Sitka 36, 94  
 White 299  
 Also see Plant Associations
- Stand  
 Density 5, 8, 10, 12, 14, 106, 138, 173-176, 182, 217, 294, 354, 361, 365, 376-369, 371-374, 376-377, 432  
 Development 176, 226, 352  
 Residual 168, 171-172, 191, 203, 210, 214-215, 219, 222-227, 301, 431  
 Spatial arrangement 350, 365, 367-368, 377  
 Structure 3, 5, 7-12, 167-173, 181-183, 203, 424, 426  
 & harvesting considerations 226  
 Also see Age class, Diversity, Overstory, Regeneration methods, Understory  
 Succession 7, 32, 137-140, 147, 148, 180-181, 270  
 Also see Stocking
- Statistical comparisons of methods Chapter 15
- Stock—See Seedling
- Stocking 260, 350, 354, 361, 367-369, 371-373, 431  
 Classes 361-362  
 Control 4, 13-14, 168-170, 273-274  
 Guidelines 173-174  
 Levels 98, 168, 170-172, 173, 221, 269, 273  
 Nonstocked area 352-354  
 Overstocked area 175-176, 273  
 Patterns 361  
 Percentage 361-362, 368  
 Requirements 12  
 Standards 13, 173-174, 347, 361  
 Voids 352, 361, 377  
 Also see Regeneration, Stand density, Surveys
- Stocktype Chapter 13  
 Considerations 320  
 Also see Seedling
- Strawberry, woods 110
- Stress 109, 122-129  
 Cold 297, 332  
 Desiccation 109, 125-126, 129, 178, 242, 264, 314, 329, 332-333, 340  
 Disease 172, 181-182, 291  
 Drought 288, 297, 316, 320-321, 333, 403  
 Heat damage 266, 267, 332

Light-induced 127, 131  
 Mechanical 125, 127-129  
 Moisture 62, 85, 102, 110-111, 117-119,  
 121, 122, 125, 128-130, 131, 146,  
 149, 150-151, 155, 158, 266-267,  
 290, 297, 335  
 Nutritional 127  
 Plant moisture stress (PMS) 118, 120, 149-  
 150, 155, 313, 331, 335, 343  
 Planting 329, 333-334, 336, 343  
 Temperature 125-126, 329  
 Thinning shock 14, 127  
 Tolerators 137-139, 140, 141, 142, 144  
 Transplant 129, 131, 259-260  
 Water 115, 117-119, 391  
 Also see Competition, Site factors  
 Subalpine fir—See Fir  
 Sugar pine—See Pine  
 Surveys, regeneration 13-14, Chapter 15, 426  
 Also see Regeneration  
 Sustainable forestry—See Management objectives  
 SYSTUM-1—See Computer models

**T**  
 Tamarack 299  
 Tanoak 36, 38, 93-95, 100, 102-109, 111, 138,  
 139, 141-146, 147, 149-150, 151,  
 154-158, 160, 187, 190, 237, 246,  
 247, 269, 289, 389, 392, 394, 428-  
 429  
 Also see Plant associations  
 Temperature 75-76, 79-84, 87-88  
 & regeneration 176-178  
 Soil 126, 387, 412  
 & mulches 394  
 & topography 171  
 Vertical gradients 84, 86  
 Also see Operational environment, Site  
 factors, Stress  
 Terminal feeders—See Insects  
 Thinning 5, 146-149, 158, 167, 172, 173-174,  
 193, 261, 263, 285, 300, 315-316,  
 432  
 Commercial 11, 137-138, 350, 359, 428  
 & nursery stock 316  
 Precommercial 3, 11-15, 37, 137-138, 157,  
 173-175, 241, 273, 297, 350, 400,  
 407-411  
 & seed production 263  
 Self- 137, 148

Shock 14, 127  
 Thistles 138, 141  
 Timber  
 & economy of region 34, 36  
 Production—See Management objectives  
 Also see Harvest, Logging  
 Topography—See Site factors  
 Transpiration—See Evaporation  
 Transporting of lumber 34-35  
 Tractor logging—See Harvest systems  
 Treatments—See Silvicultural practices  
 Tree  
 Improvement programs 115, 288, 299-301,  
 303-304, 322  
 Seed—See Regeneration  
 Trillium 100  
 True fir—See Fir  
 Twinflower, western 100, 102, 104, 107-108, 138

**U**

USDA Forest Service 85, 89, 152, 300, 302  
 USDA Soil Conservation Service 84  
 USDI Bureau of Land Management (BLM) 31, 41-  
 42, 85, 89, 152, 178, 185, 318  
 U.S. Geological Survey 89  
 Ungulates—See Animals  
 Understory 8, 12, 103-111, 137-144, 145, 148,  
 156, 159-160, 169-170, 178-179,  
 181-182, 188, 213, 220, 226, 237,  
 247, 260, 267, 269, 270, 272, 301,  
 409, 426  
 Also see Regeneration, Stand structure

**V**

Valley oaks—See Oak  
 Vanillaleaf 100-101, 104, 107-108  
 Vapor pressure—117-119  
 Varnishleaf ceanothus—See Ceanothus  
 VEGPRO—See Computer models  
 Vegetation management—See Competition  
 Vetch, American 100, 102  
 Vine maple—See Maple

**W**

Water  
 Competition 8-9, 38, 40, 60, 63, 66-67, 103,  
 105, 125, 128, 140, 145-147, 151-  
 157, 169, 170, 172, 177-179, 234,  
 236, 238, 240, 244, 266, 272, 389,  
 394, 424-425

- Drought 40-41, 49, 54, 59, 61, 67, 102, 146,  
155, 159, 181, 314, 318-321, 324,  
333-334, 336, 424, 429, 432
    - & diseases 403-405
  - Movement & seedling survival 117-119
  - Also see Moisture, Site factors, Soil water,  
Stress
  - Watershed
    - Protection 173, 175, 195
    - Also see Management objectives
  - Weeds—See Competition
  - Western Forestry & Conservation Association 347-  
348
  - Western
    - Hemlock—See Hemlock
    - Prince's pine 100, 101, 104, 109
    - Redcedar—See Cedar
    - White pine—See Pine
  - Whipple-vine 104, 107
  - White
    - Fir—See Fir
    - Oak—See Oak
    - Pine blister rust—See Disease
    - Spruce—See Spruce
  - Whiteleaf manzanita—See Manzanita
  - Whitethorn manzanita—See Manzanita
  - Wildlife
    - Protection 173
    - Also see Animals, Habitat, Management  
objectives
  - Wildrye, blue 110-111
  - Wind—See Site factors, Stress
  - Windflower 100
  - Wood production—See Management objectives
  - Wood-sorrel, western yellow 105
- X**
- Xylem
    - Pressure potential 118, 178, 391
    - Sap tension 151, 158, 391
- Y**
- Yarding—See Harvest systems
  - Yew, Pacific 100, 102, 104, 107, 108