V. SYNTHESIS

17 Reforestation Knowledge: Perspectives and Synthesis for Managers

Steven D. Tesch
Robert A. Lewis
David H. Lysne
Charles J. Brown

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 productivity. 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 methods 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, deer-brush 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 vegeta-tion 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 regenerate 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 relatively 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 composition 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 SYSTUM-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 knowledge 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., $NO3^-$ or 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 ft^2/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 greenleaf manzanita (lignotuber Bot.).

carriage clearance. The distance between the bottom of the carriage and the ground.

cation. Positively charged mineral ion (e.g. $NH4^+$ or 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 hardiness. 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 predesigned 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.

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^2 or per m^2.

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	*Haliaeetus leucocephalus*
deer mouse	*Peromyscus maniculatus*
deer	*Odocoileus* spp.
elk	*Cervus* spp.
hare (showshoe rabbit)	*Lepus americana*
hawk	several orders
mountain beavers	*Aplodontia rufa*
owl	several orders
northern spotted	*Strix occidentalis*
pocket gopher	*Thomomy* spp., *Geomys* spp.
porcupine	*Erethizon dorsatum*
rabbit	*Silvilagus* spp.
vole	*Microtus* spp.
wood rat	*Neotoma* spp.

Diseases

annosus root rot (butt rot)	*Heterobasidion annosum (Fomes annosus)*
Armillaria root rot	*Armillaria* spp.
black-stain root disease	*Leptographium (Verticicladiella) wagneri* var. *pseudotsuga* var. *ponderosum*
blister rust	*Cronartium ribicola*
damping-off	*Fusarium* spp., *Pythium* spp.
dwarf mistletoe	*Arceuthobium* spp.
Indian paint fungus (stem decay, heart rot)	*Echinodontium tinctorum*
laminated root rot	*Phellinus weirii*
Phytophthora root rot	*Phytophthora* spp.
Port-Orford-Cedar root rot	*Phytophthora lateralis*
seedling root rot	*Phytophthora* spp.
shoestring root rot	*Armillaria ostoyae (A. mellea)*
white pine blister rust	*Cronartium ribicola*

Grasses and Forbs

Alaska oniongrass	*Melica subulata*
American vetch	*Vicia americana*
annual ryegrass	*Lolium temulentum*
beargrass	*Xerophyllum tenax*
blue wildrye	*Elymnus glaucus*
bracken fern	*Pteridium aquilinum*
brodaiea	*Brodaiea*

California brome	*Bromus californicus*
catchweed bedstraw	*Galium aparine*
deer-fern	*Blechnum spicant*
dogtail, hedgehog	*Cynosurus echinatus*
fescue	*Festuca* spp.
Idaho	*F. idahoensis*
sheep	*F. ovina*
long-stolon sedge	*Carex pennsylvanica*
mullein	*Verbascum thapsis*
mustard	*Brassica* spp.
Parry rush	*Juncus parryi*
queen's-cup	*Synthyrus runiiformis*
Smith fairy-bell (large-flowered fairybell)	*Disporum smithii*
snakeroot	*Sanicula* spp.
starry false Solomon's-seal	*Smilacina stellata*
sword fern	*Polystichum munitum*
thistle, Canadian	*Cirsium arvense*
thistle, bull	*C. vulgare*
trillium	*Trillium ovatum*
twinflower	*Linnea borealis*
vanillaleaf	*Achylis tryphylla*
western sword fern	*Polystichum munitum*
windflower	*Anemone deltoidia*
wood-sorrel	*Oxalis oregana*
woods strawberry	*Fragaria vesca bracteata*

Insects

bark beetle	*Dendroctonus* spp.
Cooley spruce gall adelgid	*Adelges cooleyi*
cutworm	Noctuidae
Douglas-fir engraver	*Scolytus unispinosus*
root-collar weevil	*Steremnius carinatus*
Douglas-fir root bark beetle	*Hylastes nigrinus*
Douglas-fir twig weevil	*Cylindrocoptera furnissii*
giant conifer aphid	*Cinara* spp.
gouty pitch midge	*Cecidomyia piniiopsis*
grasshopper, locust	Acrididae
millipede	Diplopoda
pine reproduction weevil	*Cylindrocopturus eatoni*
pine resin midge	*Cecidomyia piniiopsis*
pine root bark beetle	*Hylastes macer*
ponderosa pine tip moth	*Rhyacionia zozana*
root-feeding weevils	*Steremnius carinatus*, *Pissodes fasciatus*
shoot weevil	*Cylindrocoptera furnissii*
spider mite (spruce)	*Oligonychus ununguis*
western pine shoot borer	*Eucosma sonomana*
white grubs	*Phyllophaga* spp., *Polyphylla* spp.
white pine weevil	*Pissodes strobi*
wireworms	Elateridae

Mycorrhizae

Hebeloma crustuliniforme
Laccaria laccata
Pisolithus tinctorius
Rhizopogon vinicolor

Shrubs

baldhip rose	*Rosa gymnocarpa*
bearbrush	*Garrya fremontii*
blueberry, huckleberry	*Vaccinium* spp.
evergreen huckleberry	*V. ovatum*
grouse huckleberry	*V. scoparis*
thin-leaved huckleberry	*V. membranacium*
blue elderberry	*Sambucus glauca*
box-leaved garrya	*Garrya buxifolia*
California coffeeberry	*Rhamnus californcus*
California hazel	*Corylus cornuta californica*
ceanothus	*Ceanothus* spp.
blueblossom	*C. thyrsiflorus*
buckbrush (wedgeleaf)	*C. cuneatus*
deerbrush	*C. integerrimus*
mountain whitethorn	*C. cordulatus*
redstem	*C. sanguineus*

snowbrush (slickleaf, varnishleaf)	*C. velutinus* var. *velutinus*, *C. laevigatus*
squawcarpet	*C. prostratus*
currant	*Ribes* spp.
chinkapin	*Castanopsis* spp.
golden	*C. chrysophylla*
creeping snowberry	*Symphoricarpos mollis*
dwarf bramble	*Rubus lasiococcus*
gooseberry	*Ribes* spp.
hairy honeysuckle	*Lonicera hispidula*
hazel, California	*Corylus cornuta californica*
hound's-tongue, Pacific	*Cynoglossum grande*
manzanita	*Arctostaphylos* spp.
greenleaf	*A. patula*
pinemat	*A. nevadensis*
whiteleaf	*A. viscida*
modest whipplea	*Whipplea modesta*
mountain mahogany	*Cercocarpus betuloides*
oceanspray	*Holodiscus discolor*
Oregon boxwood	*Pachyistima myrsynites*
Oregongrape	*Berberis* spp.
dwarf (Oregon hollygrape)	*B. nervosa*
Piper's	*B. piperiana*
Pacific rhododendron	*Rhodendron macrophyllum*
poison-oak	*Rhus diversiloba*
Pacific poison-oak	*Toxicodendron diversilobum*
prince's pine, common	*Chimaphila umbellata*
prince's pine, little	*C. menziesii*
pyrola (wintergreen)	*Pyrola*
rhododendron, Pacific	*Rhododendron macrophyllum*
salal	*Gaultheria shallon*
slender	*G. ovalifolia*
salmonberry	*Rubus spectabilis*
serviceberry, western	*Amelanchier alnifolia*
Sierra laurel	*Leucothoe davisiae*
silktassel, wavy leaf	*Garrya elliptica*
silktassel, Fremont	*G. fremontii*
skunkleaf polemonium, showy polemonium	*Polemonium pulcherrimum*
snow bramble	*Rubus nivalis*
tanoak	*Lithocarpus densiflorus*
thimbleberry, western	*Rubus parviflorus*
whipple-vine	*Whipplea modesta*
wintergreen (pyrola)	*Pyrola*

Trees

Alaska-cedar	*Chamaecyparis nootkatensis*
alder, red	*Alnus rubra*
California-laurel (Oregon myrtle)	*Umbellularia californica*
cherry	*Prunus* spp.
bitter	*P. emarginata*
chinkapin	*Castanopsis* spp.
golden	*C. chrysophylla*
dogwood	*Cornus*
Douglas-fir	*Pseudotsuga menziesii*
fir	*Abies* spp.
balsam	*A. balsamea*
grand	*A. grandis*
noble	*A. procera*
Pacific silver	*A. amabilis*
red	*A. magnifica*
Shasta red	*A. magnifica* var. *shastensis*
subalpine	*A. lasiocarpa*
white, California white	*A. concolor*, *A. concolor* var. *lowiana*
Larch	*Larix* spp.
tamarack	*L. laricina*
Hemlock	*Tsuga* spp.
eastern	*T. canadensis*
mountain	*T. mertensiana*
western	*T. heterophylla*
incense-cedar	*Libocedrus decurrens* (*Calocedrus decurrens*)
madrone, Pacific	*Arbutus menziesii*

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

CONVERSION FACTORS

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

Temperature

0.555 (°F - 32) = °C

1.8 °C + 32 = °F

Pressure

bar x 10 = MPa

[a]Based on nominal measurement of 1 bd ft = 1 in x 1 ft x 1 ft

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