PUBLICATION 8237

FOREST STEWARDSHIP SERIES 7

Forest Regeneration

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An essential part of forest stewardship involves the careful planning and management of young trees and seedlings. When an opening has been created in the forest canopy, either from timber harvest or following a natural disturbance event such as windstorm or fire, there is an opportunity to influence what plants or trees will become established and thrive. In some situations, natural regeneration will occur in the opening when nearby trees drop seed, reducing the need to plant. In other situations, planting seedlings may be of value. Ensuring adequate regeneration and sustained productivity is at the heart of any scientific silvicultural system.

Objective

Understand the fundamental steps involved in successfully regenerating or restoring a forest.

Competencies

- *Know the differences between natural and artificial regeneration.*
- *Know the essential steps in preparing and planting a forest site.*
- *Be able to choose the right planting stock for your site.*
- *Understand the practices needed to enhance survival and growth of planted trees.*

Related Forest Stewardship Series Publications

- *Tree Growth and Competition, ANR Publication 8235*
- *Forest Ecology, ANR Publication 8233*
- *Forest Vegetation Management, ANR Publication 8236*

The California Forest Practice Act requires that landowners regenerate their forest after a timber harvest or leave it in a stocked condition with reserved trees. It is required that a stand have a minimum number of trees within 5 years following harvest, and stand conditions are monitored by a California Department of Forestry and Fire Protection (CAL FIRE) inspector. Planning before harvest will go a long way toward reducing costs and quickly securing adequate regeneration, as today's seedlings will become tomorrow's crop trees.

METHODS OF REGENERATION

Natural regeneration from seed requires adequate seed production, successful germination, and seedling growth. These requirements are subject to the effects of weather, site conditions, competition between species, predation, and plain chance. While natural regeneration may be the least expensive option for establishing a new stand after harvest or other disturbance, it is not the most reliable method. Of further consideration is that natural regeneration can create a new forest that does not have the most desirable species composition. For example, in the Sierra Nevada, if the goal is to promote pine seedling establishment, open areas will be required, as pine needs direct sunlight to become established. This is in contrast to white fir, which tends to become established in the shade of other trees. Additionally, stocking may be uneven: portions of a site may be fully stocked or overstocked with new seedlings, while other areas may have few seedlings. Successfully attaining natural regeneration from seed is more difficult for many forest types and tree species than the term "natural" implies. An exception is for coast redwood, which sprouts from its stumps. In this case, regeneration by sprouting can be all that is required to fully stock a stand after harvest.

In contrast, artificial regeneration involves sowing seed or planting seedlings to regenerate the stand. Artificial regeneration is used if natural regeneration is not feasible or if it produces unacceptable results. It may also be used to ensure a desired species composition, to establish a stand with superior genetic traits, or to give the young trees a better chance to survive in the face of adverse environmental and biological agents.

UC PEER REVIEWED

The standard artificial regeneration method in California is planting nursery-grown seedlings, as this allows for control of spacing, species, and genetic composition. The key to a successful planting project is proper planning, which should begin about a year in advance of the actual planting.

GETTING READY: SITE PREPARATION

There are many obstacles to growing trees from seedlings. Seedlings are subject to depredation by wildlife or livestock, are exposed to drought and frost, and are vulnerable to disease and insect attack. Whether they are planted or come from naturally germinated seed, seedlings need all the help the planter can give them.

The greatest challenge is making sure the seedlings have adequate soil moisture and nutrients. This is especially critical in California, with its Mediterranean climate characterized by long, rain-free summers. All the moisture that seedlings will have for survival and growth must be stored in the soil. Seedling roots grow slowly and take a while to find stores of water and nutrients in the soil. Shrubs, grasses, or weeds can compete with the seedlings for very limited water and nutrients. The goal is to give the planted seedlings the advantage.

If numerous plants are already growing on the chosen planting area or if there is too much woody material, some form of site preparation should be considered. Site preparation creates a suitable seed bed of mineral soil for germination of naturally produced seed. (Most conifers require mineral soil for successful seed germination.) Furthermore, site preparation can create access for crews or locations for planting, and it can remove competition from unwanted tree, shrub, and herbaceous plants. It can be done to varying degrees depending on environmental constraints. For example, a site may be only partially cleared to accommodate access for planting while retaining coarse woody debris and soil cover to prevent erosion. A variety of mechanical, chemical, and fire-related techniques are available, depending on the environmental conditions, forest type, and regulatory constraints.

Machine Site Preparation

Bulldozers or various devices attached to a bulldozer or farm tractor can be used to assist in regeneration projects by knocking down shrubs, pushing woody debris aside, or crushing dead trees. These machines perform best on flat or gentle slopes and should not be used on sites with steep slopes or erosive soils. Machines may compact soils, so it is best to use them when soils are dry. Assuming that the site is suitable, machine use can be an effective way to clear unwanted debris and vegetation, expose mineral soils, and potentially reduce fire hazard.

Machine site preparation produces cleared areas with interspersed piles of debris. These piles may be burned or left to decompose. It is critical that the amount of soil included in debris piles be minimized to reduce loss of productive topsoil. Unburned piles may serve as habitat for small animals that, depending on landowner objectives, can be considered an asset or a liability. Landowners who wish to encourage wildlife such as quail or rabbits might want to leave the piles. However, those who do this should plan for some seedling losses from small rodents that like to eat seedlings.

Controlled Burning

Used with care, controlled burning is an inexpensive method to reduce debris, eliminate piles of brush, and provide suitable seedbed or planting conditions. Controlled burning also reduces fire hazard by consuming fuels. However, burning alone may not be effective for complete site preparation, in part because fire can encourage the regeneration of certain undesirable shrub species. For example, seeds of Scotch broom, ceanothus, or manzanita can remain viable in the soil for 40 years or more until fire breaks seed dormancy and allows these shrubs to germinate and quickly occupy an area. A few years after a controlled burn it may be necessary to control unwanted brush to give the planted trees an advantage.

Cool, low-intensity fires are best. Hot fires may have undesirable effects on physical and chemical soil properties by removing soil nutrients and making the soil less permeable to water, potentially increasing runoff and erosion. Generally, most burn prescriptions for site preparation are intended to remove not all debris on the soil surface but just enough to allow access for planting. "Broadcast" burning of this type is not usually used on sites where natural regeneration is the only source for the new stand.

Controlled burning is not for the novice, although a landowner may be able to burn slash or debris piles. A professional forester and local fire officials must be consulted before attempting controlled burning. Controlled burns require a fire permit and a plan to control the fire should it escape. You may be required to submit a written smoke management plan or air pollution control plan that describes which direction you expect the smoke to go. In some areas, the local air resources board may collect a per-acre fee for burning. If the fire escapes, the landowner may be held legally liable for all damages and suppression costs related to the escaped fire.

While there are challenges involved in using fire as a site preparation tool, fire can be highly effective and very cost-efficient when used carefully. Fire is the tool of choice for site preparation in many commercial operations.

Chemical Site Preparation

Herbicides can be used to reduce competition from undesirable tree, shrub, and herbaceous plant species, especially in follow-up treatments. Herbicides do not provide all that is required for adequate site preparation; they simply kill unwanted vegetation. Other methods, such as machine clearing or controlled burning, must be used to clear debris and dead vegetation. Herbicides may be cost-effective for vegetation control, especially for large areas. Herbicides are generally applied using a backpack sprayer, though they can be directly injected into a stem of an unwanted shrub or tree or can be sprayed from a helicopter.

Warning: Use Chemicals Cautiously

- Pesticides and herbicides are poisonous. Always read and carefully follow all precautions and safety recommendations given on the container label.
- Store all chemicals in the original labeled containers in a locked cabinet or shed, away from food or feeds, and out of the reach of children, unauthorized persons, pets, and livestock.
- Confine chemicals to the property being treated. Avoid drift onto neighboring properties, especially gardens containing fruits or vegetables.
- Dispose of empty containers carefully. Follow label instructions for disposal. Never reuse containers. Make sure empty containers are not accessible to children or animals.
- Never dispose of containers where they may contaminate water supplies or natural waterways. Do not pour down the sink or toilet. Consult your county agricultural commissioner for correct ways to dispose of excess pesticides. Never burn pesticide containers.

You must use the correct herbicide at the proper rate and at the right time. Federal law requires that every herbicide be registered with the U.S. Environmental Protection Agency (EPA). The regulations require that all herbicides be labeled with information that tells the user how to safely and effectively apply the product. The user is required by law to read and follow the instructions on the label. In many instances, herbicides can be used only by a licensed pesticide applicator with a permit. Your county agricultural commissioner can provide information on the registration of different chemicals used in the forest and permits that may apply. Laws vary by county. Some counties do not allow aerial application.

STOCK SELECTION

If natural regeneration is to be relied on, it is extremely important that the best available parent trees be saved from harvest to provide seed. These trees should have good form and vigor, full crowns, and dominance in the stand.

Selecting stock for planting is an entirely different matter. Seedling survival depends on how well the species and seedling are adapted to the site. Adaptability depends on elevation, aspect, available moisture, and local soil conditions. When selecting planting stock, it is preferable to choose species already growing on or near the site. If possible, contract with a nursery to grow seed collected from the site, as the trees currently growing there are best adapted to the unique conditions of the property.

When buying seedlings, refer to the tree seed zones that have been established by CAL FIRE (fig. 1). These zones match seeds and seedlings to local conditions. The seedlings selected for planting should come from the same tree seed zone and same elevation as your planting site.

Seedlings are available from a variety of private and CAL FIRE nurseries. When ordering seedlings, specify your seed zone, county, nearest town, and elevation of the planting site. Large (10,000+) orders for seedlings can usually be contracted one or two growing seasons in advance of planting, depending on the type of stock being ordered.

Two types of seedlings are generally available: bare root and containerized. Bare root seedlings are grown outdoors in a nursery bed and are harvested by carefully lifting the seedlings from the nursery bed just before your planting date. The roots of these seedlings must be kept moist and cold until planted. Bare root nursery stock must be planted while the plants are dormant to avoid damage to the roots.

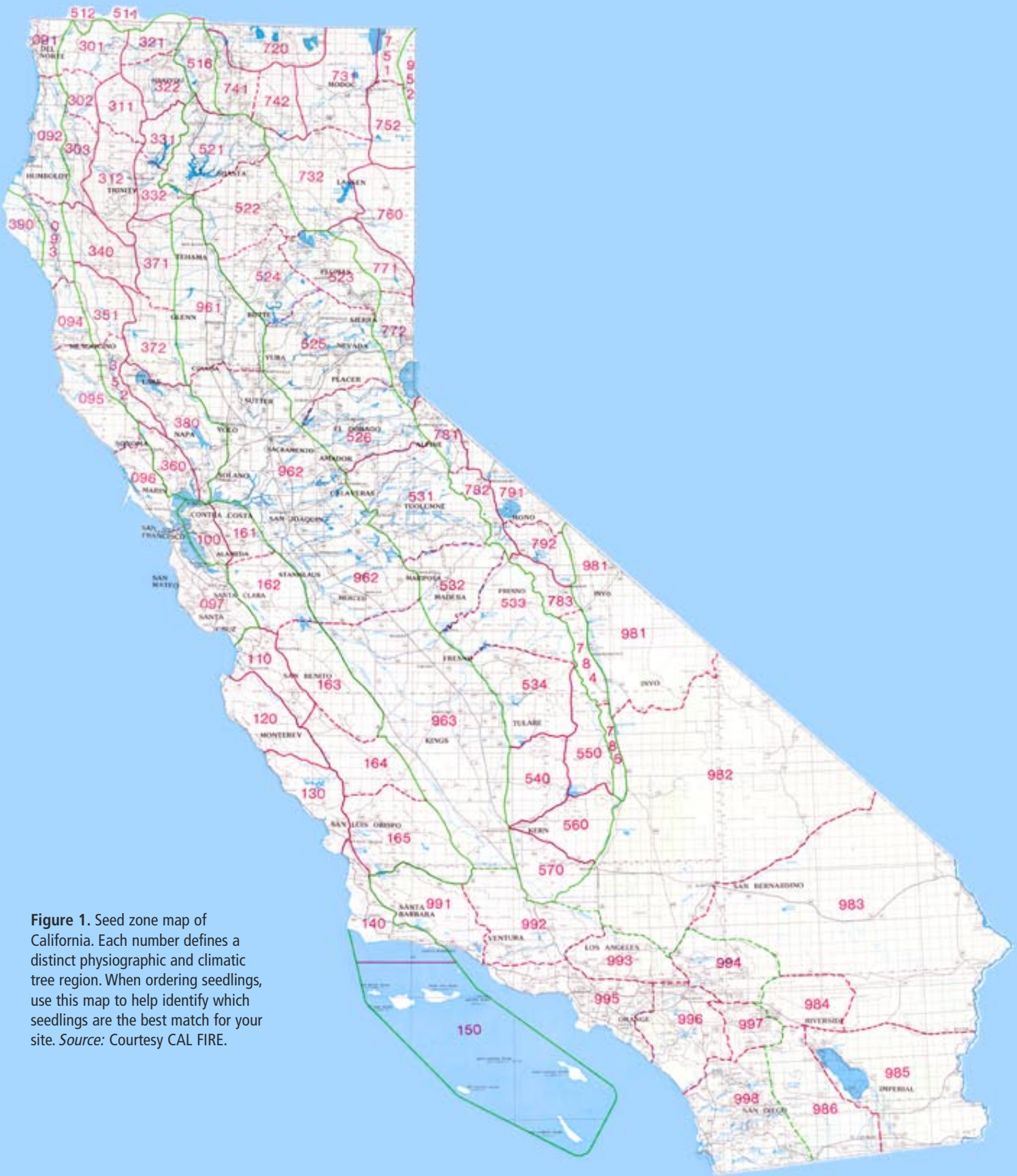

Figure 1. Seed zone map of California. Each number defines a distinct physiographic and climatic tree region. When ordering seedlings, use this map to help identify which seedlings are the best match for your site. *Source:* Courtesy CAL FIRE.

Nursery catalogs list bare root planting stock as 1-0 (said as "one-oh"), 2-0, 2-2, or some other combination of two numerals. The first numeral refers to the number of years the tree spent in the nursery bed. The second is the number of years spent in a transplant bed. Therefore, 2-2 stock is 4 years old and quite large. Trees that come directly from a seedbed (1-0, 2-0, 3-0) are called seedlings. Those that come from a transplant bed are called transplants. A rule of thumb is to use transplants on harsh sites and seedlings for easier sites. Transplants cost more because it takes more time and labor to produce them. Your particular site conditions determine your stock type. Typically, 2-0 or 1-1 stock is planted to regenerate most stands.

Planting stock should be evaluated when it is picked up from the nursery. Seedlings must be dormant and the buds firm with no evidence of new growth or shoot elongation. White root tips should be less than 1¼ inch long. A moldy or a sour odor is likely a result of improper storage, and these seedlings should not be planted. If you strip back the bark of the stem and root system on a couple of trees, the inner bark should be moist and glistening white. If it is yellow, brown, or has brown spots, the stock is badly damaged and has little survival potential.

Proper care of your planting stock is essential for seedling survival. Keep the roots moist and the trees cool (from 32º to 36ºF, or 0º to 2ºC) and out of the sun, including during transportation from the nursery to the site. Plant as soon as possible after receiving the seedlings. If you must store the trees for more than 3 days, heel in the seedlings by planting them temporarily in a soil trench in a cool, shaded place in the forest. You can store the trees this way for 7 to 10 days. An alternative is to use a large refrigerator to continue cold storage. The idea is to keep the seedlings cool and prevent them from breaking dormancy and growing new roots before the seedlings are planted.

Containerized seedlings have been grown from seed in a plastic container filled with a special soil mixture. Containerized seedlings are usually produced in a greenhouse under a carefully controlled environment. These seedlings can be planted during the growing season because their roots are protected in the growing medium.

Containerized seedlings are usually more expensive than bare root stock; however, they can be grown in a shorter time, 4 to 8 months, thus reducing the lead time involved in the planning process. Containerized seedlings may be easier to plant in rocky soils where it is difficult to open an adequate hole for the larger bare root seedlings. Evaluation of containerized stock is similar to that of bare rootstock.

TIMING

The best time to plant varies with the type of planting stock, soil conditions, climate, and location in the state. Before planting, the soil should be moist to a depth of at least 12 inches. This will require about 2 to 4 inches of rainfall for most timber soil types. The soil temperature at a depth of 3 inches should be 40ºF (4.5ºC) or higher and on a warming trend, with additional rain expected. These moisture and temperature requirements are essential for root growth to occur and for sufficient soil moisture to support the seedling through the dry season.

Many people prefer to plant during a light rain or drizzle. Avoid planting during extended warm and dry periods, or when frost or extreme winds are likely. At higher elevations, plant when the snow is gone and the chance of frost is minimal.

In California's Sierra Nevada and the eastern side of the Coast Range, planting conditions are usually optimal in late winter to early spring. On the warmer west side of the Coast Range, planting can begin as early as late fall, once the rains have saturated the soil, and can continue through to late winter.

STOCKING AND SPACING

The number of seedlings to plant depends on the size of the planting area and the spacing. Spacing is a function of the products you expect to harvest and your objectives. Timber is usually grown at spacing from 8 by 8 feet (680 trees per acre [tpa]) to 12 by 12 feet (300 tpa). Closer spacing is necessary if poor survival is expected. The Forest Practice Act requires stocking of at least 300 tpa within 5 years following a harvest. Ponderosa pine, Douglas-fir, and incense cedar usually have very high survival rates, greater than 80 percent, so overplanting to achieve 300 tpa is probably not necessary. Christmas trees are planted closer, commonly 5 by 5 feet (1,240 tpa) or 6 by 6 feet (1,210 tpa), because they will not need to grow to mature trees.

Calculating the Number of Seedlings Required

The following steps will help you determine the number of seedlings you will need.

- Calculate the number of square feet per tree for the desired spacing. For example, a spacing of 10 by 10 equals 100 square feet per tree (10 × 10 = 100).
- Obtain the number of trees per acre by dividing the number of square feet in 1 acre (43,560) by the number of square feet per tree.
- Obtain the total number of trees needed by multiplying the number of trees per acre by the number of acres in your planting area. Nurseries usually sell trees in lots of 100 or 500 trees, so round up the number that you need.

Example

- Number of square feet per tree: 10 × 10 = 100 ft^2/tree.
- Number of trees per acre: 43,560 ft^2/acre ÷ 100 = 435.6 tpa.
- Number of trees required: 435.6 × 20 acres = 8,712 trees.

PLANTING TECHNIQUES

Various hand tools, power tools, or machines can be used for planting. Planting bars, hoe-dads (also called western planting tools), shovels, and mattocks can be used with easily worked soil. The hoe-dad is generally best in rough terrain with rocky soils (fig. 2). Power-driven augers are used to dig holes in compacted soils or soils with a hardpan. The

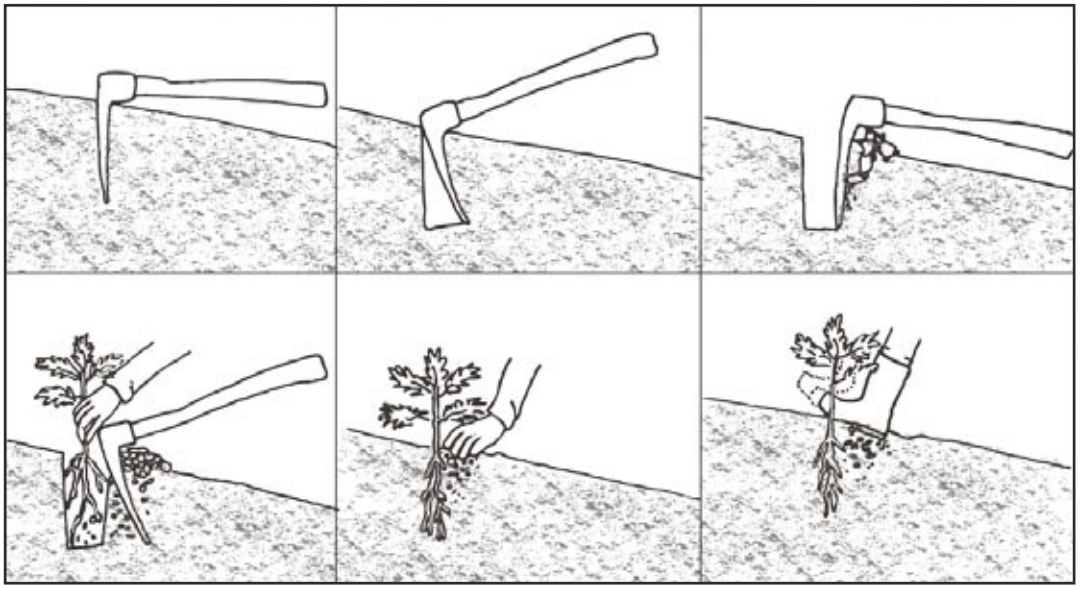

Figure 2: Planting technique using a hoe-dad.

use of planting machines is limited to fairly level sites with good site preparation. These machines are cost-effective only when planting large areas that can justify the move-in and equipment costs.

Whichever technique is used, care of seedlings and proper planting is of paramount importance (fig. 3). The roots should always be kept moist, with no more than 50 to 100 seedlings in the planting bag at one time. Each seedling should be planted erect at the depth it was planted in the nursery—to the root collar. The roots should be properly placed, making sure they are pointing downward in the planting hole. Kinked roots or roots planted in a bent J shape will strangle themselves in a few years. Air pockets should be eliminated by firming the soil around the roots.

Careful consideration should be given to the location where you plant the seedlings. They should be planted outside of the dripline of large conifer trees. Perfect spacing may not be that important or practical. If possible, scrape away the grass around the planting hole or choose locations that have less grass or brush for the seedling to compete with. On dry or exposed sites, choose locations that provide some natural shade, such as on the north side of a stump or other woody debris. Plant directly into the mineral soil. avoid locations with large amounts of woody materials in the soil, as these materials will dry out over the summer and make air pockets.

Planting should be followed by regular regeneration surveys to check seedling survival and to plan for any replacement trees. Survival of planted seedlings can vary considerably from year to year. Assess the need for releasing trees from competing vegetation or protecting them from animal damage. Regeneration surveys should be completed after the first and second year at least, and every other year until year 10. Competition from surrounding vegetation can severely limit seedling survival and growth.

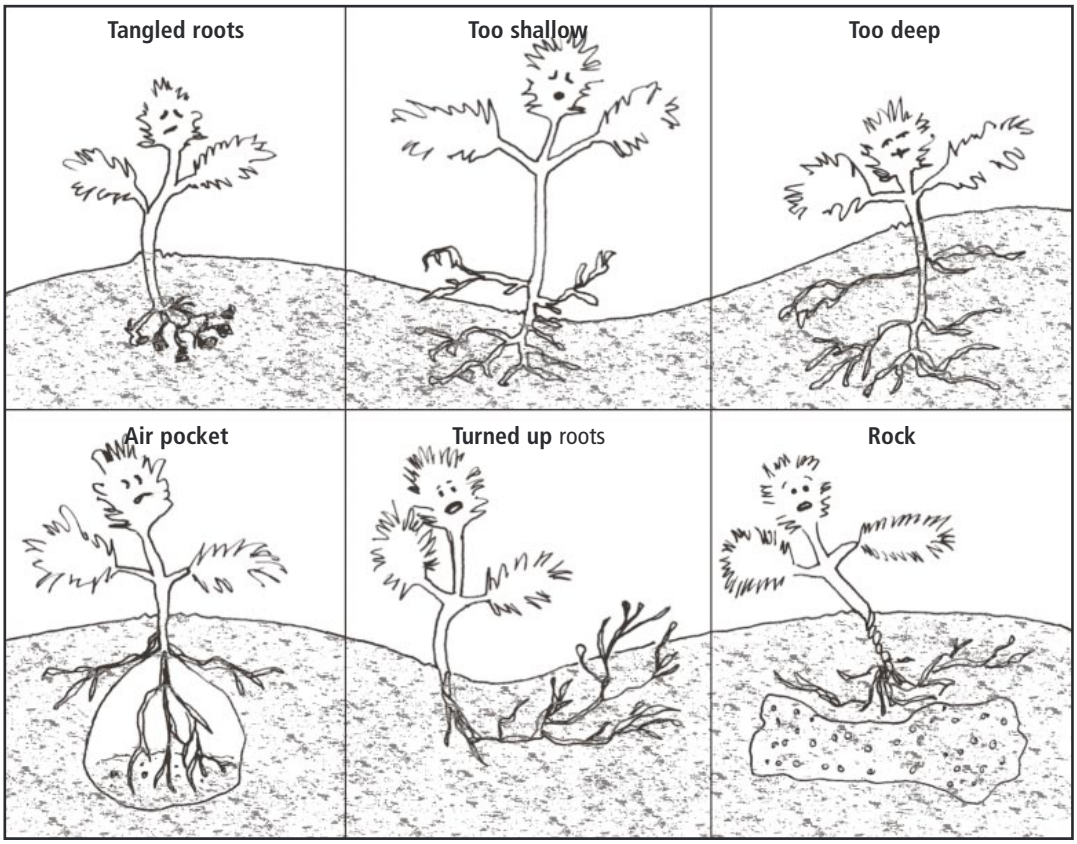

Figure 3: Avoid planting problems.

Release from competing vegetation is commonly done by hand-scalping grass or herbaceous plants around the seedling or by using herbicides to control brush. Safety is an important consideration in handwork, as working with sharp tools or machines on steep sites can be dangerous. If there are a large number of acres to treat, herbicides maybe preferable, as they are less expensive and are often more effective at controlling competing vegetation. However, herbicides have disadvantages. If not chosen or applied appropriately they can harm the planted trees. They may be harmful to nontarget organisms, and there can be water quality, wildlife, and human health concerns over their use. All herbicides or pesticides must be used properly, according to label instructions, and only after consideration of all treatment options.

Once your seedlings have been successfully planted, in many parts of the state young trees need to be protected from browsing by deer or wildlife. Plastic mesh sleeves that eventually degrade in sunlight can protect seedlings from browsing. Small tubes of deer repellant attached to the seedling have also been used successfully. Liquid repellants sprayed on individual plants are not very successful, as the repellant usually needs to be reapplied after each rain.

SUMMARY

The use of natural regeneration to create a new stand after harvest or to reforest sites is constrained by several factors, including availability of seed trees, seed production, weather, suitability of the seed bed, and competition from existing vegetation. To improve the chances for successful natural regeneration, plan to prepare the site and implement follow-up treatments to control competing vegetation. Planting represents a large investment that is carried over the life of a stand. However, a successful plantation can increase the value of your property to potential buyers, while providing habitat and other ecological benefits to your forest. It is in your best interest to

- plan regeneration operations carefully
- prepare the planting site
- take proper care of the planting stock
- closely supervise the planting crew
- follow through with regeneration surveys, indicating replanting and competition control where necessary.

The success of the planting effort depends on each of these steps and can only be as successful as the weakest link in the planting process.

RESOURCES

Public Agencies

Several public agencies can offer information or assistance on vegetation management issues and restoration.

California Department of Fish and Game (DFG). A state agency that manages California's wetlands, wildlife habitats, and ecosystems. See their Web site at http://www.dfg.ca.gov.

California Department of Forestry and Fire Protection (CAL FIRE). A state agency that provides fire protection and natural resource management services. They have seedlings available for sale. Local units can be reached under the State Government listings in the telephone book or at the CAL FIRE Web site, http://www.fire.ca.gov.

Forest Stewardship Helpline. This service is provided under the USDA Forest Stewardship Program to provide information and referral to landowners, resource professionals, and others. The Helpline is an excellent information clearinghouse where you can ask questions about forest management including what to do, whom to call, and where to go for more information. Call toll-free at 1-800-738-8733 or e-mail ncsaf@mcn.org. The Forest Stewardship Program Web site can be found at http://www.fs.fed.us/spf/coop/programs/loa/fsp.shtml.

Natural Resources Conservation Service (NRCS). A federal agency with special expertise in soils; also administers federal cost-share programs such as the Environmental Quality Incentives Program (EQIP). See their Web site at www.nrcs.usda.gov.

UC Cooperative Extension (UCCE). The University of California offers an extensive county-based network of agricultural and natural resource services and information on many topics including pest management, animal and plant production, and natural resource management. Your local UCCE office can be found in the business listings in the telephone book or at the UCCE statewide directory, http://www.ucanr.org.

U.S. Fish and Wildlife Service (USFWS). This federal agency may be helpful when seeking information about wildlife habitats and endangered species environments. See their Web site at http://www.fws.gov/.

Restoration Funding Sources

A number of California (state) and federal grant programs encourage various kinds of restoration projects on private lands. Some programs are available to individual landowners, and some to larger ownerships. Funding sources change from year to year, so it is a good idea to check periodically to see what is available.

In some cases, funding is made available only to groups. There are many ways to qualify for such funds: as part of a watershed group, as a homeowners' association, as a local Fire Safe Council, and so on. Again, your forester, public agency representative, or UCCE office may be able to help you navigate the maze of requirements and show you how to qualify for a program appropriate to your needs.

Most counties in the state have a Resource Conservation District (RCD), many of which now have watershed coordinators who can help you. While the focus of each RCD varies, each has a program on the management of natural resources. Typically, members of RCD boards are local natural resource managers from the public and private sector as well as private landowners and other interested individuals. RCDs sometimes have existing grants that you as an individual landowner can apply for. It is worth a call to your local RCD to see if they have any ongoing projects you might become involved in. For more information, visit the Resource Conservation District Watershed Information Sharing Project Web site, http://www.carcd.org/wisp.

METRIC–ENGLISH CONVERSIONS

English	Conversion factor for English to Metric	Conversion factor for Metric to English	Metric
Length			
inch (in)	2.54	0.394	centimeter (cm)
foot (ft)	0.3048	3.28	meter (m)
acre (ac)	0.4047	2.47	hectare (ha)
square foot (ft^2)	0.0929	10.764	square meter (m^2)

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