Development and Distribution of Planted Seedlings, Naturally Regenerated Seedlings, and Competing Vegetation 6 Years After Wildfire

Diane L. Haase, Robin Rose, and Dave Henneman

Western Nursery Specialist, Forest Service, Portland, OR; Professor, College of Forestry, Oregon State University, Corvallis, OR; Reforestation Manager, U.S. Department of the Interior, Bureau of Land Management, Medford, OR

Abstract

Delays in reforestation following wildfire due to insufficient seedling supplies and other factors can result in competing vegetation occupying the area, thereby increasing reforestation costs and decreasing early seedling growth and survival rates. We established plots in 2004 to compare Douglas-fir seedling (*Pseudotsuga menziesii* Mirb. Franco) stocktypes for reforestation within the Biscuit Fire in southwestern Oregon. Because 10 plots were left unplanted, a unique opportunity existed to examine planted and unplanted areas side by side. We intensively surveyed all plots in June 2008 for spatial distribution and growth characteristics of conifer and woody shrub vegetation. The survival rate was high for all planted stocktypes. Container seedlings grew most during the first growing season, but thereafter all stocktypes were very slow growing on this harsh, droughty site. Very low numbers of naturally regenerated seedlings existed (approximately 28 trees per acre) relative to planted seedlings (approximately 400 trees per acre). Distribution and density of woody shrub species varied little across the site. This paper discusses implications for restoration management decisions after a wildfire as well as the potential for Stand Visualization System as a silvicultural tool.

Introduction

Fire suppression and the buildup of fuels have led to an increasing frequency and severity of forest fires in the Western United States often resulting in thousands of acres in need of restoration annually. These wildfires have a profound influence on plant communities (Agee 1993, Frost and Sweeny 2000). In a 2004 survey, Federal reforestation personnel identified documentation, cost, funding, NEPA (National Environmental Policy Act) requirements, delays, salvage, and vegetative competition to be critical issues that affect reforestation after a wildfire (Rose and Haase 2005).

Biscuit Fire

The Biscuit Fire began on July 13, 2002, in southwest Oregon as a result of ignition by lightning strikes. By the time it was declared controlled on November 8, 2002, nearly 500,000 acres (200,000 hectares) were burned. The Biscuit Fire was the largest fire ever recorded in Oregon history, as well as the most expensive fire suppression effort nationally in 2002, at an approximate cost of $150 million in Federal and State funds. Most (97 percent) of the area burned by the Biscuit Fire was in the Siskiyou National Forest. On the northwest end of the fire, nearly 10,000 acres (4,000 hectares) of U.S. Department of the Interior, Bureau of Land Management (BLM) land became involved in the fire approximately 2 months after ignition; many of those acres were burned intentionally as a control measure to establish a containment perimeter.

Natural Versus Artificial Regeneration

Considerable debate has occurred regarding the merits of natural versus artificial forest regeneration after a wildfire (Donato and others 2006, Newton and others 2006, Skinner 2006) and yet too few studies address the long-term implications across diverse environmental conditions. Regardless of the type of regeneration that is chosen, the establishment of a new stand is crucial for wildlife habitat, recreational uses, and timber production associated with a mature forest ecosystem. After a wildfire, the early successional community of rapidly growing broadleaf shrubs and hardwoods provides a vibrant wildlife habitat and soil stabilization. Competition for soil moisture and growing space, however, can be a challenge to the establishment of conifer seedlings. Natural conifer regeneration is a viable option for forest managers when long regeneration periods and high levels of variation are acceptable within the management objectives (Shatford and others 2007). When that is not acceptable, planting seedlings and controlling brush increases tree density, growth, and distribution during the early years of stand development (Hobbs and others 1992, Sessions and others 2004, Zheng and others 2006). Planting seedlings from site-specific seed sources after a wildfire does not adversely affect genetic diversity (Rajora and Plujar 2004) and may hasten the return to a large-conifer-dominated forest ecosystem by as much as 50 years (Sessions and others 2003).

Stocktype Choices

Because the number of acres in need of planting cannot be predicted in advance, it is unlikely that the necessary amount of seedling stock will be available to reforest a burned area after a large wildfire. When using 2-year-old stock for reforestation efforts, planting may be delayed by 3 or more years. This delay period may allow for competing vegetation to occupy the area, thereby increasing reforestation costs and decreasing early seedling growth and survival rates. The use of 1-year-old stocktypes can reduce the length of time until outplanting for an area devastated by fire. Shaw (1996) discussed growth and survival among seedling stocktypes with 1-year-old container stock having lower initial cost and lead time but uncertain performance compared with larger bareroot stock (e.g., 1 + 1 or plug + 1). In the 2004 survey, respondents indicated that relative performance among stocktypes varied considerably depending on site conditions, annual precipitation, seedling species, and location (Rose and Haase 2005).

Vegetative Competition

After a disturbance from wildfire, a declining probability of success over time exists for seedlings that are planted without vegetation control (Newton and Lavender, unpublished in Sessions and others 2003). In a study with container-grown white spruce seedlings planted after wildfire and salvage logging, there was 93 percent survival with scarification site prep and 76 percent without scarification (Densmore and others 1999). In another study, removal of shrubs resulted in increased survival and growth following fire (De las Heras and others 2002). In addition, the use of grass seeding to control erosion and increase forage can result in significant seedling mortality (Lehmkuhl 2002). On the Medford BLM District, 10-year records indicate that delays that allowed for two or more seasons for vegetation to recover after disturbance negatively affected seedling survival and increased the need to interplant and replant from an average of 3 percent of the seedlings when planting in a timely manner to an average of 22 percent of the seedlings when planting delays occurred (D. Henneman, personal communication).

Control of competing vegetation can result in significant gains in conifer seedling stem volume. After 8 years, Douglas-fir (*Pseudotsuga menziesii* Mirb. Franco) grown in plots with 3 years of woody-weed control, herbaceous-weed control, or total weed control had stem volume increases of 81, 172, and 307 percent, respectively, as compared with seedlings grown in plots without control of competing vegetation (Rose and others 1999). In addition, increasing the weed-free area around a seedling results in increased volume and height growth (Rose and Ketchum 2002).

Stand Visualization System

The Stand Visualization System (SVS) generates semirealistic, 2-dimensional and 3-dimensional graphic images depicting individual stand components using detailed geometric models (McGaughey 1997). Robert J. McGaughey (U.S. Department of Agriculture [USDA], Forest Service, Pacific Northwest Research Station) developed SVS, and James B. McCarter (College of Forest Resources, University of Washington) developed an SVS add-in for Microsoft Excel. Both SVS and the Microsoft Excel add-in are available online for free download.

SVS defines each plant in a plot based on species, plant type, and position within the plot. The data can be used to display the overall structural diversity and density present within the stand by enabling differentiation between shrub and tree layers using different plant forms, colors, or other types of marking. The data can be examined using overhead, profile, and perspective views. In addition, tabular and graphical summaries of plot information can be generated to show current and future conditions and to predict effects of silvicultural treatments and other influencing factors on subsequent growth and yield.

Foresters and other land managers can use the visual illustration of forest stand structure and composition generated by SVS to support decisionmaking toward achieving specific land-use goals. SVS can show both commercial and noncommercial species, together or individually, thereby providing useful information applicable to timber, recreation, wildlife, and other forest management resource areas. SVS can be used to generate stand images for various applications, such as prediction of mountain pine beetle effects on lodgepole pine stands (Hawkes and others 2005), evaluation of wildlife habitat relationships (Parisi and others 2007), education of private forest landowners (Roth and others 2006, Roth and Finley 2007), and estimation of stand management activities on fuel loads and potential future fires (Reinhardt and Crookston 2003).

Objectives

The purpose of this study was to compare growth and survival of planted 1- and 2-year-old Douglas-fir stocktypes after the Biscuit Fire and to examine the distribution and development of seedlings and other vegetation through intensive surveys and SVS images of planted and unplanted plots.

Materials and Methods

Site Characteristics

The study site was on Medford BLM land within the 2002 Biscuit Fire area (figure 1), located along Sourgrass Road approximately 25 miles NW of Merlin, OR (N 42° 33.129, W 123° 44.790) at an elevation of 3,800 ft (1,150 m). The site is in the northern extreme of the Mediterranean climate zone and is characterized by hot, dry summers and cool, moist winters with most precipitation falling as snow. The site was logged in 1988 and replanted with a mixture of 76 percent 1 + 1 Douglas-fir, 16 percent 1 + 1 sugar pine (*Pinus lambertiana* Dougl.), 6 percent styro-5 western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), and 2 percent styro-10 Port-Orford-cedar (*Chamaecyparis lawsoniana* [A. Murr.] Parl.). The site was later interplanted in 1994. The portion of the 2002 Biscuit Fire that occurred on this particular site was a nonstand-replacement fire, which led to the development of uneven-aged stands (Agee 1993). In the spring of 2004, after the Biscuit Fire, the area around the study site was planted with Douglas-fir (65 percent), sugar pine (29 percent), and Port-Orford-cedar (6 percent)—all were container seedlings.

Figure 1. Site on the Biscuit Fire chosen for the study. (Photo source: Diane L. Haase 2004).

Planted Seedlings for Stocktype Comparison

Three replications were installed on a relatively flat ridge top on the east side of Sourgrass Road and two replications were installed on a 10- to 15-percent sloping southwest aspect on the west side of the road. On March 23, 2004, three Douglas-fir stocktypes from the same seed lot were planted on the site at a spacing of 10 ft by 10 ft (3 m by 3 m). The three stocktypes were 1 + 1 bareroot seedlings, styro-15 container seedlings (250 cm^3 volume per cavity), and Q-plug transplant seedlings. The Q-plug stocktype is a 1-year-old transplant seedling, sown in a 1 in^3 (16 cm^3) stabilized media plug (International Horticultural Technologies, LLC, Hollister, CA) in midwinter, grown under greenhouse conditions, transplanted to bareroot beds in early spring, and lifted the next winter.

Experimental Design

The three Douglas-fir stocktypes were planted in a randomized complete block design (five blocks). Each plot was approximately 60 ft by 60 ft (18 m by 18m), which is equivalent to approximately one-twelfth of an acre (0.03 hectares). In addition to the three stocktype plots, two additional plots were established in each block and left unplanted.

Seedling Measurements

Seedlings planted in 2004 for stocktype comparison were measured for seasonal height, stem diameter, and survival at the end of the first three growing seasons (September 2004, September 2005, and October 2006, respectively). Seedlings were measured again in June 2008 (for estimate of 2007 growth) and September 2008. Instances of chlorosis, dead tops, and browning were also recorded. No animal damage was noted on any seedlings. Growth was calculated by subtracting initial and annual values.

Application of SVS to the Site

In June 2008, each of the 25 plots was intensively surveyed. The precise location of each conifer seedling and woody shrub in each plot was recorded as an x-y coordinate relative to a reference point using a Criterion Electronic Laser surveying instrument (Laser Technology, Inc., Centennial, CO). One person selected a plant to be surveyed and held a reflector paddle over the plant's center while a second person aimed the laser at the paddle to determine the azimuth and horizontal distance from the instrument (figure 2). Coordinates for larger trees (live and dead) and stumps were also recorded. For each conifer plant, the shoot height, crown ratio, crown radius, stem diameter, and dominance class were recorded. For all shrub species, height and crown radius were recorded. Large clumps of a particular shrub species were surveyed as one plant. After a plant's position and characteristics were recorded, it was marked with paint to ensure that all plants were surveyed and none were surveyed more than once.

Figure 2. The position and characteristics of each woody plant in every plot was surveyed using a reflector paddle (left) and Criterion Electronic Laser surveying instrument (right). (Photo source: Diane L. Haase 2008).

Data from each plot were entered into spreadsheets formatted for the SVS program. The x-y coordinates were generated using sine/cosine formulas from the distance and azimuth readings collected in the field. For each plot, an overhead image of all plants was created using colored solid shapes to show cover and spatial distribution of each species. In addition, a perspective view of each plot was created showing only conifers.

Statistical Analyses

Data were analyzed using analysis of variance (ANOVA) for a randomized complete block. Tests for normality, linearity, and constant variance of the residuals were performed to ensure the validity of these assumptions—no data transformations were deemed necessary. Fisher's Protected Least Significant Difference procedure was used to determine significant differences in growth and survival data among seedling stocktypes at the $\alpha \leq 0.05$ level. To determine vegetative composition and characteristics on the site, planted plots (three plots per block for stocktype comparison as described previously) and unplanted plots (two plots per block) were grouped for comparisons of conifer and brushy vegetation between the two groups.

Results

Stocktype Comparisons

The container stocktypes (Q-plug and styro-15) had significantly more height growth during the first season (2004) than did the 1 + 1 bareroot seedlings (figure 3), which may be explained by the fact that two-thirds of the 1 + 1 seedlings had multiple tops or no terminal bud at the time of planting due to top pruning in the nursery. Styro-15 seedlings also had the greatest average stem diameter growth during the first season (figure 3). During the subsequent four growing seasons, however, height and stem diameter growth were minimal on

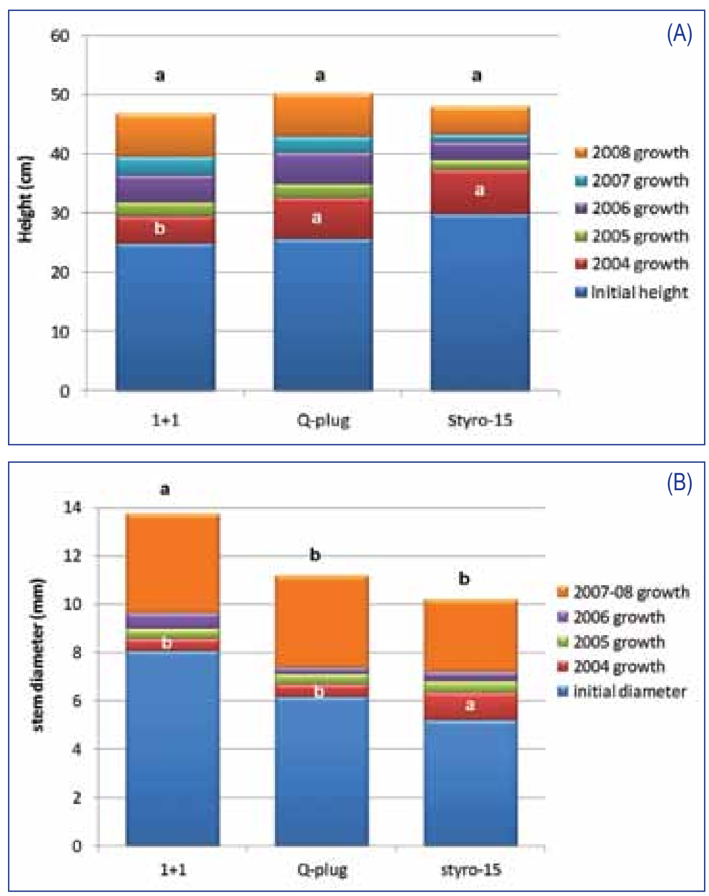

Figure 3. Annual height (A) and stem diameter growth (B) among stocktypes. White letters indicate differences among stocktypes for 2004 growth and black letters indicate differences among total size after five growing seasons. Those with different letters are statistically significant at the $\alpha \leq 0.05$ level.

this relatively harsh site and did not differ among stocktypes (figure 3). Bareroot 1 + 1 seedlings had significantly larger initial stem diameter than the two container stocktypes and that difference continued to be significant for overall diameter in September 2008 (figure 3).

Most seedlings exhibited chlorosis by the end of the second season; this was especially evident for styro-15 seedlings (figure 4), which were clearly stressed by the second season and had an 8-percent drop in survival during the third season. This demonstrates the importance of using a multiyear assessment to accurately evaluate the relative performance among stocktypes or treatments in a given forest regeneration project. Despite the slow growth, survival after five growing seasons was high for all three stocktypes (90.6 percent for styro-15, 95 percent for 1 + 1, and 95.6 percent for Q-plug seedlings).

Conifer Density in Stocktype and Nonplanted Plots

Conifers in the unplanted plots, as well as those in the planted plots that were not part of the stocktype trial, were separated

Figure 4. Styro-15 seedling exhibiting severe chlorosis after the second growing season. (Photo source: Diane L. Haase 2004).

into two size classes. "Large" conifers greater than 3.3 ft (1 m) tall were considered established prefire while "small" conifers less than 3.3 ft tall were considered established postfire. (Note: Because trees are very slow-growing on this site, it is possible that some of the smaller conifers were actually established before the 2002 fire.)

The average density of Douglas-fir seedlings planted for stocktype comparison was 33.7 trees per plot (407 trees per acre or 1,006 trees per hectare). In addition, stocktype comparison plots had an average of 2.4 naturally regenerated small conifers and 2.6 large (prefire) conifers per plot (figure 5). In unplanted plots, an average of 12.0 small conifers and 3.2 large conifers existed per plot (figure 5). During survey of the plots, however, it became evident that most of the small Douglas-fir and sugar pine seedlings were not naturally regenerated. These seedlings were of similar age, size, and form, were spaced at regular intervals, and were sometimes planted in rows—indicating that the operational planting crew strayed into the study plots while planting the surrounding area. To confirm this, we excavated a Douglas-fir and a sugar pine seedling and determined that each originated as plug seedlings (in fact, controlled-release fertilizer prills were found within the Douglas-fir root system). As a result, we concluded that approximately 90 percent of the small Douglas-fir and sugar pine conifers in the unplanted plots were actually planted nursery stock. For a more accurate estimate of naturally regenerated seedling density in the study area, the number of small conifer seedlings within the stocktype plots (not planted as part of the study) was used resulting in an estimate of 29 naturally regenerated trees per acre (72 per hectare).

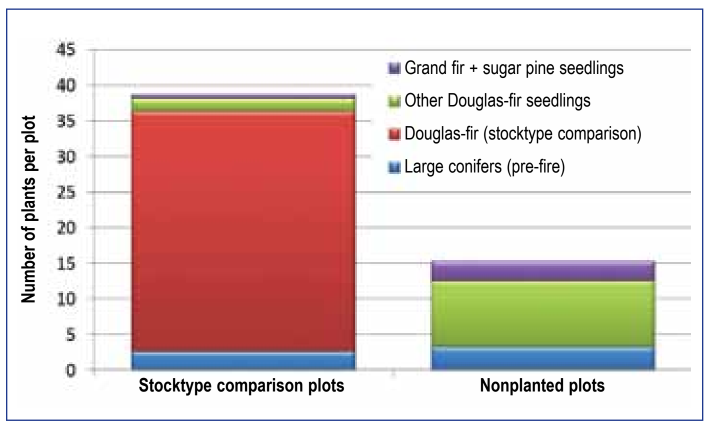

Figure 5. Plots planted for stocktype comparison had approximately 38 conifers per plot and unplanted plots had approximately 15 conifers per plot, although most of Douglas-fir and sugar pine seedlings in the unplanted plots were determined to have been planted during operational planting of the surrounding area resulting in an estimate of 29 naturally regenerated trees per acre (72 per hectare).

Table 1. Eight woody vegetation species were found on the study site (listed in order of abundance).

Common name	Scientific name	Average height cm (in)
Chinkapin	*Chrysolepis chrysophylla* (Douglas ex Hook.) Hjelmqvist	84.1 (33.1)
Deer oak	*Quercus sadleriana* R. Br.	48.1 (18.9)
Pacific rhododendron	*Rhododendron macrophyllum* D. Don ex G. Don	60.6 (23.9)
Pinemat manzanita	*Arctostaphylos nevadensis* A. Gray	13.8 (5.4)
Greenleaf manzanita	*Arctostaphylos patula* Greene	40.6 (16.0)
Whiteleaf manzanita	*Arctostaphylos viscida* Parry	49.3 (19.4)
Salal	*Gaultheria shallon* Pursh	20.6 (8.1)
Canyon live oak	*Quercus chrysolepsis* Liebm.	70.7 (27.8)

Other Woody Vegetation

Nonconifer woody species found on the site are listed in table 1. The average total brush cover per plot was approximately 18 percent. Woody shrubs varied little among plots, although it was noted that pinemat manzanita occurred in greater abundance in Blocks 1 to 3 while whiteleaf manzanita occurred in greater abundance in Blocks 4 to 5. Salal occurred only in Blocks 4 to 5. Relative abundance and coverage of woody shrubs for the site are shown in figure 6.

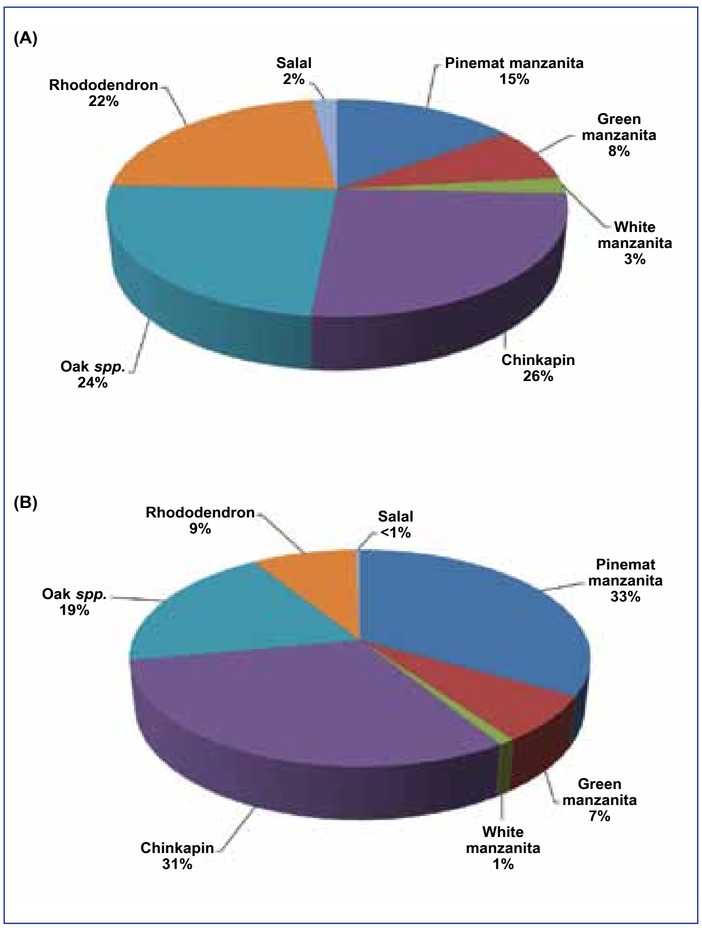

Figure 6. Relative abundance of woody shrub species found on the site by number of plants (A) and by coverage (B).

Stand Visualization System

Graphic images of the spatial distribution and cover for each woody plant on each of the 25 plots were generated with SVS. The perspective view (figure 7) shows the distribution and abundance of conifer seedlings in each plot and the overhead view (figure 8) shows overall cover of all species on each plot.

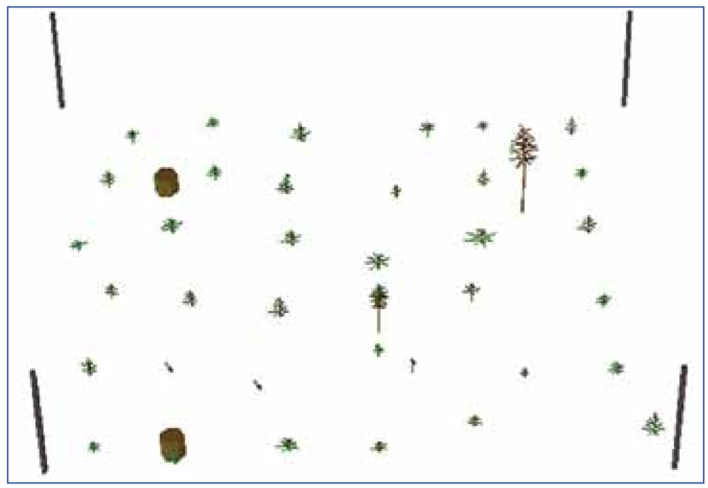

Figure 7. Example of perspective view of conifers in a plot.

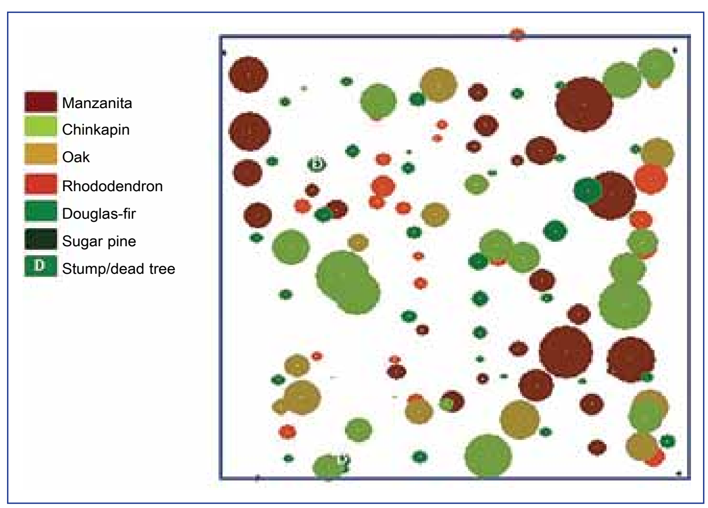

Figure 8. Example of overhead view of all woody plant species in a plot.

Discussion

Stocktype Comparison

After five growing seasons, the two 1-year-old stocktypes had high survival and similar growth to the 2-year-old transplant seedlings indicating that any of these stocktypes would be an appropriate choice for this type of site. It is important to note, however, that none of the stocktypes performed especially well. The arid conditions in this area are extremely limiting for seedling growth regardless of stocktype and are likely the primary factor determining seedling performance. On this site, average cumulative height growth and stem diameter growth were only 7 to 10 in (18 to 25 cm) and 0.4 to 1.0 in (10 to 15 mm), respectively, over the five growing seasons. This is less growth than would be expected in just one season on a site where soil moisture is not limiting. In a similar stocktype comparison study, three Douglas-fir stocktypes were planted in a droughty, skeletal soil in southwest Oregon. After 5 years, annual growth and shoot and root characteristics were similar among stocktypes suggesting that stocktype designation alone may not be adequate for predicting field performance on such sites (Hobbs and others 1989).

Naturally Regenerated Conifers

It was unfortunate and unexpected that operational planting activities resulted in some seedlings planted within the study area. Using the number of small conifers found in the planted plots (not planted for stocktype comparison) resulted in an estimate of two Douglas-fir seedlings and one sugar pine seedling per plot, plus one grand fir (*Abies grandis* [Douglas ex D. Don] Lindl.) seedling per every six plots, for an estimate of 29 naturally regenerated trees per acre. This is less than one-tenth the stocking that resulted from tree planting (approximately 400 trees per acre) and would not be adequate to meet stocking standards (USDI 2003). Using a reforestation model to compare unplanted with planted larch (*Larix gmelinii* [Rupr.] Rupr.) in an area burned by a catastrophic fire, it was found that it would take 30 to 40 years longer for tree abundance to return to prefire levels for unplanted versus planted scenarios (Wang and others 2006).

The proximity of a site to an abundant and viable seed source is an important factor in determining efficacy of natural regeneration (Tappeiner and others 2007). Seed dispersal is influenced by many factors, including physical, climatic, and biotic factors (McCaughey 1986), and lessens as the distance from the source increases. Distance to seed source can strongly influence the rapidity and density of new stand establishment through natural regeneration. In areas where no remaining live trees exist after a large intensive fire such as the Biscuit Fire, the nearest seed source could be several miles away, thereby reducing available seed for natural regeneration and delaying establishment of conifers in the area. One study found that naturally regenerated seedlings were abundant in plots evaluated 9 to 19 years after a wildfire (Shatford and others 2007). All of those plots, however, were within 1,600 ft (500 m) of a seed source.

It is evident that a wide range of factors must be integrated to evaluate forest conditions and management options to meet specific forest regeneration goals. In this study, more than 60 large conifer trees were located in plots established before the Biscuit Fire. The presence of these trees results in a local seed source for natural regeneration; however, the abundance of naturally regenerated seedlings was very low. Droughty soil conditions, animal predation, and occasional high winds are likely inhospitable for abundant seed production, germination, and seedling growth.

Other Woody Vegetation

The drought-tolerant, woody shrub species found on the Biscuit Fire site are typical of the forest vegetation community found in the Klamath-Siskiyou region of southwestern Oregon. Chinkapin was the most abundant species on the plots and accounted for 26 percent of the woody plants and 31 percent of the total brush coverage by area. Chinkapin is an evergreen species and grows primarily in northern California and southern Oregon. It is a minor component in a wide range of forest communities (Eyre 1980) and sprouts rapidly and prolifically after a fire or other injury. Deer oak, rhododendron, and manzanita were the other prevalent brush species on the site and are also evergreen shrub species that regenerate readily after a fire. At the time of planting in 2004, just 17 months after the fire, these species already had a notable presence on the site.

The shrub species covered an average of 18 percent of the surface area. The SVS images show that the shrubs are fairly evenly distributed throughout the site, with many large clumps. It is likely that coverage by these woody shrubs will expand over time and pose a significant competitive factor for available resources.

Stand Visualization System

The images generated by SVS provide far more information to foresters or researchers than can be learned from vegetation data tables alone. The graphic representation of stand characteristics is effectively a real-time visualization of stand composition, structure, and spatial distribution. The images can also be employed as a decision support tool by providing dynamic temporal simulations of stand growth and yield.

For purposes of this project, we used SVS to show the spatial distribution of relatively small plants with equal emphasis on conifer species and woody shrub species. More commonly, SVS is used to visualize older stands with an emphasis on growth and yield of conifer species. Nonetheless, by manipulating the color display for various shrub species, overhead images can give a graphic representation of shrub cover and distribution. In the future, it would be ideal if the color palette selection and plant graphics options were expanded for improved representation of small plants of many species. By taking periodic measurements over time, SVS can be used on any stand to not only evaluate density and distribution but also to simulate temporal effects of available silvicultural management options such as thinning or harvest to develop appropriate stand management plans. As such, the visual format of SVS can be a supplemental tool that is readily understood by foresters and the public.

Conclusions

Natural regeneration is beneficial on some sites and with some species (Thanos and others 1996, Shatford and others 2007). Concern remains among scientists and foresters, however, that it can be too slow and too unpredictable (Kozlowski 2002, Sessions and others 2004). Data from this study indicate a wide distribution of woody competitive species with few conifer seedlings established through natural regeneration during the 6 years since the Biscuit Fire.

Seedling stocking density can be quite variable and slow with natural regeneration, especially for harsher sites like the one examined in this project, where the germination environment and seed source viability were likely inadequate. When there are specific reforestation objectives for a particular level of spatial distribution and density to meet ecological management goals within a specified timeframe, it is recommended that seedlings be planted as soon as possible after a wildfire (or any disturbance) to achieve those goals. Such decisions must also integrate consideration of the local environment, vegetation community, and other factors.

The use of SVS imagery provides an extra tool that enables forest managers to graphically evaluate the spatial distribution, density, cover, and size of specific species within the forest vegetation community. These data can lead to a better understanding of stand recovery after a catastrophic wildfire and can be used as a predictive tool for silvicultural restoration options.

Address correspondence to:

Diane L. Haase, Western Nursery Specialist, USDA Forest Service, P.O. Box 3623, Portland, OR 97208; e-mail: DLHaase@fs.fed.us; phone: 503–808–2349.

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