CLIMATE-INFORMED REFORESTATION GUIDANCE

FOR MIXED CONIFER FORESTS IN THE SOUTHERN CASCADES & NORTHERN SIERRA NEVADA

Southern Cascades & Northern Sierra Nevada Region of California

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Climate-Informed Reforestation Guidance For Mixed Conifer Forests in the Southern Cascades &Northern Sierra Nevada

Introduction to Climate-Informed Reforestation

Reforesting forests so they are resilient to future disturbances requires strategic planning, deliberate implementation, and follow-up management. In the face of climate change, those requirements are even more imperative. Changes in temperature, precipitation, and drought may push many species out of their bioclimatic envelop into environments that are more stressful, which can reduce health, survival, and productivity of trees. Generally, this stress will be exacerbated at lower elevations and for species which prefer colder and wetter climates.

Developing a strategic plan to assess the broader landscape context within which reforestation is considered is crucial for prioritizing reforestation success (Meyer et al., 2021; M. North et al., 2019). Climate-informed reforestation depends on effective site preparation, selection of appropriate planting material, and planting in densities, locations, and arrangements that will produce the best short- and long-term outcomes. Reforestation to produce resilient forests not only requires effective action during the first year of planting, but also follow-up actions in the years and decades to follow (Fig.1). Post-planting management includes repetitive treatments to maintain control of competing vegetation and encourage or maintain the desired species composition, densities, and arrangements identified during the planning process. In many instances a post-planting management goal may also be to introduce (or re-introduce) fire as an on-going component of the ecological system.

The guidance presented below describes how site preparation, planting, and post-planting management actions can promote climate- and fire- resilient forests. This guidance was co-produced with regional foresters and ecologists through workshops and group meetings. It incorporates both peer-reviewed literature and place-based knowledge and aims to provide recommendations for all land types (public and private) where possible.

The Reforestation Process

PUTTING IT TOGETHER:
A REFORESTATION TIMELINE

Figure 1. *Climate-informed reforestation is a long-term process. Key steps, including planting, vegetation control, reintroduction of fire, and monitoring, span up to 30 years. Specific activities and their timelines will reflect project and location-specific considerations.*

YEAR 0
Seedlings Planted

After a site has been prepared, reforestation begins with the planting of tree seedlings across the burned landscape to kick-start recovery.

Seedlings are planted with variable spacing to mimic natural forest structure and enhance resilience. Microsites are used as much as possible.

YEARS 2 – 5
Vegetation Control

Shrubs and other vegetation compete with young trees. Herbicide or mechanical treatment reduces surrounding vegetation to help seedlings grow.

Shrub & vegetation growth can outpace seedlings. Targeted treatment can help ensure that trees have enough sunlight and space to establish themselves.

YEARS 12 – 18
Beneficial Fire

Prescribed fire is first introduced to reduce surface fuels and support tree growth. Seedlings are now young trees, better able to withstand low-intensity burns.

Beneficial fires improve ecosystem health, recycle nutrients, reduce shrub cover & fuel loads, and increase the fire tolerance of young trees. Beneficial fire should be applied periodically.

YEARS 18 – 25+
Monitoring

A mixed-age forest is forming. Trees are taller, the structure is more complex, and ongoing monitoring ensures long-term success.

Monitoring reforested sites is a priority to track tree growth, survival, and fuel conditions over time.

SITE PREPARATION 1

Climate Change Considerations

Effectively removing wood biomass and managing competing vegetation are critical components of site preparation to offset the risks associated with drought and severe wildfire.

- **Drought resilience:** Where climate projections include an increased water deficit, site preparation should include actions to reduce plants that will compete with planted trees for scarce water resources. Increasing temperatures and drought stress can be offset with a focus on creating and maintaining protected microsites in locations where trees will be planted.
- **Wildfire resilience:** Fuels management should be prioritized in regions with a high likelihood of high-severity fire, including high-severity reburns.

Existing tools coupled with novel approaches for site preparation can achieve many climate-related goals. The particular methods (e.g., mechanical, burning, and/or some combination) selected to achieve these outcomes should be based on the operational and environmental context of the project, following existing guidance e.g., Stewart et al. (2021).

Key Actions

Fuels Management

Effective and timely wood biomass removal reduces the risk of severe fire and allows for safe planting and post-planting treatments. It is important to remove standing dead material (snags) and surface fuels to levels that reduce future high-severity fire. This involves managing 1 and 10 hour fuels, which cannot be effectively treated by hand or machine. Ideally, these fuels should be less than 3 to 10 tons per acre, depending on stand productivity, forest type, and fuel loads of the surrounding landscape (Scott and Burgan 2005). Remaining fuels that are patchy and discreet in coverage can contribute to structural heterogeneity, which is common in frequent, low severity fire systems and may reduce the risk of high-severity reburns (Lydersen et al., 2019; Lydersen & North, 2012). While extensive removal of wood biomass is critical for reducing fire risk, it is also desirable to retain some woody elements on the landscape for ecological value and wildlife habitat.

- Retain 3-6 snags per acre but variable across the stand to create stand heterogeneity. Retain a combination of individual larger snags (>30 inches diameter at breast height (DBH)) and clusters of smaller snags for ecological value.
- Retain clumps of snags in well-protected microsites that are likely to ensure greater longevity and biological relevance compared to scattered, dispersed snags (Fig. 2). Additionally, in areas not considered important for strategic fuel treatments, retain snags on marginal and unproductive planting sites or sites where access is difficult for planting (e.g., steep slopes >30% and far from roads, structures, and infrastructure).
- Consider incorporating future fuel breaks into site preparation practices to include thinning around planting units, possibly in the form of shaded fuel breaks[1], which can enhance wildfire resilience and protect the planted areas.
- Where it is deemed appropriate to reduce fuels prior to planting, remaining dead tree removal should be completed in the first 3 years following the disturbance, possibly up to 5 years for trees and sites with slower rates of decay. Timely dead tree removal and other fuels reduction treatments reduces the risk of high-severity reburn and improves access for subsequent reforestation actions including additional site preparation, planting, and post-planting management. This timeline is particularly influenced by how rapidly snags become unmerchantable, which may impede the economic feasibility of removing the material from the site.

Managing Competing Vegetation

Managing competing vegetation can be an important climate-informed practice, as it can reduce the impact of projected increases in water stress and fire activity. Site conditions and the existing plant species inform whether vegetation on the site will compete with the planted seedlings or not, and determine the intensity at which vegetation on a site needs to be managed. When vegetation is expected to compete with planted seedlings for limited resources, controlling that vegetation provides those trees with a competitive advantage for accessing soil moisture, which is a primary determinant of the successful establishment of young trees following planting. Vegetation management can also help reduce fuel loading and continuity to lower the potential for future high-severity fire, and allow for fire to re-enter a stand sooner without negatively impacting planted trees.

[1] Shaded fuel breaks, between 0.25 and 0.5 mi in width and treated by mechanical thinning & prescribed burning to reduce ladder (trees < 20 inches DBH) and surface fuels that increase the risk of crown fires, can be located near roads and ridgetops (Low et al. 2023).

However, not all vegetation may impact planted seedlings equally. Retaining a small to moderate amount of shrub and herb cover may create opportunities to provide shaded and protected microsites for young trees, which can increase seedling survival (Marshall et al., 2023), and play a facilitative role in postfire and highly stressful climatic conditions (Fig. 2). Many native shrubs, grasses, and forbs are important for maintaining soil moisture, fixing nitrogen, providing heat sinks for fires at certain times of the year, and promoting carbon sequestration.

Some managers recommend eliminating all competing vegetation that might inhibit success of planted trees, others recommend controlling and maintaining <25%, while others may opt for controlling and maintaining up to 50% shrub cover depending on the site conditions, shrub species, tree species, and management objectives.

Examples of Conditions Affecting Level of Shrub Control

- **In xeric sites** or during periods of extreme drought when shrub growth may be reduced, shrubs may provide more beneficial shade coverage for seedlings and allow for maintenance of slightly higher shrub cover. However, **on mesic sites**, the benefit of shade coverage is only seen when planting happens in the first 2 years following fire (Sorenson et al., 2025).
- Extensive growth and high cover of *Ceanothus*, bear clover, and manzanita may require more shrub control than other less aggressive shrub species based on their potential to outcompete planted seedlings and impact establishment.
- **White fir seedlings** may be more tolerant of high shade cover by shrubs compared to pines.
- Some shrub species (e.g., blue elderberry, California hazelnut, several species of gooseberries and currants) provide high value as cultural resources and wildlife habitat and can provide shading for conifer seedlings where they exist. These species also rarely dominate a stand and do not create many competition problems for young seedlings.
- **Moderate to high levels of native grass or forb cover** (>25 to 50%) could benefit conifer seedlings by providing shading or increased soil nutrients in both xeric and mesic sites.
- **Following die-off from drought**, thorough monitoring will determine the need for and level of shrub control. Small openings of dead trees may not require aggressive competing vegetation removal.

Soil Management

An increase in high-severity fire and drought poses problems for soil health of forests. There are several suggested practices for minimizing negative impacts to soil health and soil moisture retention, though there is less consensus on the usefulness of these practices in every case and their applicability will vary based on specific soil properties.

- Experiment with biochar before planting or utilize biochar plugs when available at the nursey, particularly on xeric sites. Biochar can enhance water holding capacity, increase soil organic matter, nutrient retention and soil pH, which can increase the survival of planted seedlings (Marsh et al., 2023). It is likely more beneficial in low productivity or acidic soils.
- Experiment with mycorrhizal additions, when bareroots are not inoculated at the nursery. Mycorrhizal inoculation can improve the soil's physical characteristics, improve plant nutrient supply and lead to increased growth (Neuenkamp et al., 2019).
- Minimize disturbance to the duff, litter, and mineral layers after salvage logging to reduce shrub resprouting.
- **Following high-severity fire**, hydrophobic soils are often created. Breaking up this layer to minimize erosion and increase water infiltration can be beneficial, particularly on mesic sites.
    - Consider using contour tilling to address these issues as needed.
    - Only consider using deep ripping on in lower elevation stands where there were post-fire hydrophobicity effects on soil as this treatment can result in undesirable soil impacts (e.g., increase in invasive plant cover).
    - However, if soils are healthy post-fire, these intensive treatments can have negative impacts on soil health, such as degrading wildlife habitat and facilitating post-fire cheatgrass invasion.

Management of Surrounding Remnant Stand Following Disease-Driven Mortality

Disease driven mortality events necessitating reforestation are likely to increase in the face of climate change. These mortality events will require additional pre-planting preparation.

- Consider creating a species-specific buffer surrounding the planted area to ensure that the disease does not spread to newly planted trees. This buffer can be achieved by removing live host species that may have been exposed to the disease but are not yet showing signs of decline, and/or planting a buffer of non-host species between the remnant stand and core planted area. The width of the buffer is dependent upon the specific disease being addressed.
- Apply the necessary chemical or biological treatment to the area, when available.

SELECTING SPECIES & COMPOSITION

Climate Change Considerations

Changes in temperature, precipitation, and drought may create environments that are more stressful and outside the bioclimatic envelope of many species, which can reduce health, survival, and growth. In this region, managers have noted such impacts in low-elevation pine stands as well as in higher elevation red fir stands. Decisions in a reforestation project that can buffer these risks include:

- Increasing of the proportion of drought resistant species, particularly in xeric sites.
- Hedge your bets by planting a greater diversity of species and seed sources.

Key Decisions

Seed Sourcing

Seed and seedling source selection can be limited by seed crop availability, regional availability, and access. However, when the option is available, there are several recommendations for seed sourcing.

- Use planting as an opportunity to increase the genetic diversity of species within the planted stands to better provide for future climatic shifts.
- Use a mixture of seed from the same seed zone and seed from lower elevations (500-1000 ft below the site elevation, 1-2 elevation bands lower) or from further south in the range. Seeds from lower and more southernly elevation bands have been shown to be more tolerant of hotter and drier conditions projected to be more extreme in coming decades. Currently a mix of 50% local seed zone and 50% from lower elevations or further south is recommended.
- Ideally use a seed lot selection tool (e.g., CAST tool) and/or work with genetics experts for selecting non-local seed.
- Use seed from seed orchards where available for species as they generally have a broader band of elevations and climatic conditions that they are suitable for due to inherent genetic diversity in the orchards.

Species Selection & Composition

In the mixed-conifer forests of this region, experts recommend altering the relative abundance of species to account for climate and other stressors and increasing heterogeneity where possible, but do not recommend selecting completely different species than were present prior to the disturbance for planting.

- Use observations of pre-settlement composition, current stand conditions, and stressors, to guide species mixtures.
  - For example, if Douglas-fir is dying at lower elevations from insects and disease, reduce the number of Douglas-fir in the planting mixture, even when planting into a stand that was previously Douglas-fir or further increase the proportion of genetics from projected matching climates (see section above on seed sourcing). Several managers in this region reported reducing the percentage of Douglas-fir in their planting mixes for some areas.
  - **In a post-fire context**, base species composition on establishing stands within natural range of variation for the site, unless projected drought stress is high or disease factors preclude the ability to reestablish, in which case, enhance the proportion of existing drought-tolerant conifer (e.g., ponderosa pine, Jeffrey pine, California foothill pine at low elevations) and oak species.
  - **Following a drought-driven die off**, enhance the proportion of existing drought-tolerant conifer and oak species.
- Plant a mixture of drought tolerant pine and other species to increase biodiversity.
- Retain and promote hardwoods and encourage resprouting of oaks where feasible. Retention levels will depend on long-term objectives and current oak densities. Hardwoods such as California black oak are favorably adapted to wildfire and drought. Hardwoods typically resprout following wildfires, but post-fire management may include measures to promote their growth into fire-resilient stands (e.g., thinning of multi-stemmed sprout) (Ritchie et al., 2024). You may also consider planting California black oak or other hardwoods where resprouting is minimal following disturbance.

Specific site characteristics, at the project scale or units within the project, should also influence your selected species composition.

- **Xeric sites or sites anticipated to be drier:** Plant a higher proportion (up to 80%) of drought tolerant pine, with a lower mixture (as low as 20%) of other species with greater soil moisture requirements (e.g., Douglas-fir, incense cedar, rust-resistant (if available) sugar pine) depending on forest management objectives.
- **Mesic sites:** Plant a lower proportion (closer to 60%) of drought tolerant pine, with an increased mixture (up to 40%) of other species (e.g., Douglas-fir, incense cedar, sugar pine) depending on forest management objectives.
- **Topography:** Plant a higher proportion of pine on ridgetops and south/west-facing slopes (North et al., 2009). Promoting California black oak may also be a favorable strategy in these areas because of their drought resilience and compatibility with maintaining frequent, low severity fire regimes (Long et al., 2023; Meyer et al., 2021).

Climate Change Considerations

There are two important considerations with respect to planting for developing resilient forests in the face of climate change:

- **Wildfire resilience:** Wildfire resilience in mature stands can be promoted by planting trees at lower densities, which ultimately lowers fuel loads, and in variable arrangements to allow for the reintroduction of fire earlier. Continued management of fuels is still necessary to maintain wildfire resilience (see section below).
- **Drought resilience:** Competition for water resources between trees is lower at lower densities. Competition with other vegetation, especially shrubs is lowered with clumped planting. Often, clumped stems will more quickly have interlocking crowns, which can shade out competing vegetation in the understory.

Key Decisions

In addition to climate-related considerations, decisions about planting density and arrangement may reflect realities around survival of specific species and on certain sites. Survival within the initial establishment period can reflect differences in capacity for ongoing management and maintenance. Reforestation should generally not be undertaken if survival is anticipated to be low. In general, planting should be developed to plan for at least 90% survival of planted seedlings during establishment with some expected differences in planting survival across the landscape (e.g., lower survival is expected on xeric sites). Decisions around planting density and arrangement should reflect the abundance of natural regeneration present at the site. When available, use seedling plugs rather than bare root stock on harsher sites, for more sensitive seedlings, and during fall planting and periods of drought. Additionally, decisions around planting density and arrangement are dependent on capacity for post-planting management as described below.

Density

Variation in initial planting density recommendations reflect planting goals (e.g., desire to maximize merchantable timber, reestablish mature forest), capacity for follow-up treatments, and site characteristics.

Experts recommend aiming for ~50-120 canopy trees per acre (TPA) with some age-class diversity in mature stands, depending on the forest type, site conditions, and long-term forest management goals (North et al., 2022; Safford & Stevens, 2017). While initial planting densities should assume that a percentage of seedlings planted will be lost to mortality, planting plans should include all available management actions that may improve establishment outcomes and reflect a desire to be conservative with seed use.

Which statement best reflects your post-planting management capacity and goals?

The capacity for post-planting thinning is high. There is a desire to maintain flexibility in planted tree management.

Higher Intensity Management

- Some experts recommend initial seedling densities of ~170-200 TPA. Starting within these densities, final mature density targets can be accomplished with one or more rounds of pre-commercial thinning and should also account for natural causes of mortality. Decisions around specific levels of thinning should adapt to climate and ecological conditions at the time. These higher initial planting densities will require more extensive follow-up treatments of planted trees, particularly to manage fuel loads to reduce wildfire risk and density related risk for drought and insects. See sections below about arrangement and post-planting management for more implications of higher density planting.

The capacity for post-planting thinning is low. There is a desire to minimize planted tree management.

Lower Intensity Management

- Experts recommend an initial planting density closer to mature target levels, ~75-150 TPA. These lower initial planting densities will require a greater emphasis on use of microsites and more follow-up treatment to control competing vegetation. See sections below about arrangement and post-planting management for more implications of lower density planting.

- **Following drought or disease-driven die off**, plant at the lower ends of the ranges listed above as these regions may be experiencing other issues (e.g., limited water availability and/or other stresses that can lead to an increased incidence of disease) that could also impact planted trees.

- There is less variation in recommended planting densities between mesic and xeric sites because trees are not competing with one another at the early stages; rather, they are competing with shrubs and grasses for water. However, **mesic sites** can be planted with slightly higher initial densities than **xeric sites** based on perceived capacity of the site.
- **Topography:** Plant lower densities on ridgetops and south-facing slopes, and higher densities on canyon bottoms and north-facing slopes within the ranges identified above.

Arrangement

Decisions about planting arrangement are interdependent with decisions related to planting density and capacity for follow-up treatments.

- **Higher planting densities:** Experts recommend planting in a roughly gridded pattern (15 x 15 ft or 16 x 16 ft spacing), allowing some flexibility for use of microsites (Fig. 3). Through follow-up thinning and prescribed burns, a more heterogeneous forest structure can be cultivated while reducing stand density. Trees grown in a gridded pattern, as opposed to open grown trees, are often considered more desirable in form. The interlocking crowns of trees planted in a gridded form will also suppress growth of understory shrubs, reducing the need for competing vegetation management. See section below about post-planting management for more implications of planting arrangement.

- **Lower planting densities:** Lower densities may be planted in a roughly gridded pattern with greater spacing with ample flexibility for use of microsites (Fig. 4). Other experts recommend planting with variable spatial patterns (e.g., clumping trees and leaving gaps) focused on microsites conducive for growth for ecological and operational reasons (e.g., post-planting treatment of shrubs is more effective and efficient when shrubs are most dominant in openings between clumped planting of trees (Fig. 5). However, an increase in the complexity of planting pattern could slow the pace of implementation). Variable arrangements can include individual trees, clumps of trees, and openings (ICO) patterns.
    - Clusters may include 3-5 trees within a radius of 10-12 ft., with 20-25 ft. between clusters, and openings of 1000 sq ft, or a mixture of clusters within a gridded pattern (e.g., alternating clusters and individual trees in a planted row).
    - Clusters should be located where microsite conditions can help ensure higher seedling survival.
    - **Following drought or disease**, retain clusters, but reduce the number of trees per cluster.
    - Prioritize planting clusters in areas with <60% shrub cover.

A variable planting arrangement can also reduce future fire risk and increase the likelihood of survival in extreme conditions.

- **At the planting location,** maximize use of protected microsites (e.g., downed logs, cut stumps, standing snags, larger herbs) to protect from extreme heat, sun exposure, and soil drying (Fig. 2). When planting within a gridded pattern (Figs. 3 and 4), provide flexibility to adjust individual seedling location to take advantage of existing shaded microsites.
- **At the project level,** reduced planting densities around the perimeter of a plantation can create a fuel break. This wide, lower density perimeter can be a focus for intensive management of surface fuels. These could also be areas where a higher proportion of hardwoods are retained.
- **In a planted fuel break,** lower densities (~50 – 75 TPA) should be planted. Consider planting in variable planting arrangements to further introduce heterogeneity and discontinuity in the fuel profile.

Timing

Existing guidance on the timing of planting is applicable for climate-informed reforestation, where spring planting after snowmelt is generally recommended over fall planting, because the soil moisture is high in the spring. However, it is worth noting the additional benefits of fall planting in the face of climate change. When planted in the fall, seedlings are ready to receive water by the spring even as the amount and timing of precipitation becomes more variable. While climatic variability may make fall freeze events or precipitation totals more difficult to predict, seedlings planted in the fall will naturally harden off, preventing the need to freeze after lifting (taking the seedling out of the nursery). The spring planting window between mid-April to June is restricted as snow melts and opens up access to higher elevation sites. The timing of spring is anticipated to shift with climate change, leading to changes in the planting window. Additionally, planting as soon as possible following the initial disturbance remains a key factor leading to the success of any reforestation effort.

Planting with Microsites for Seedling Protection

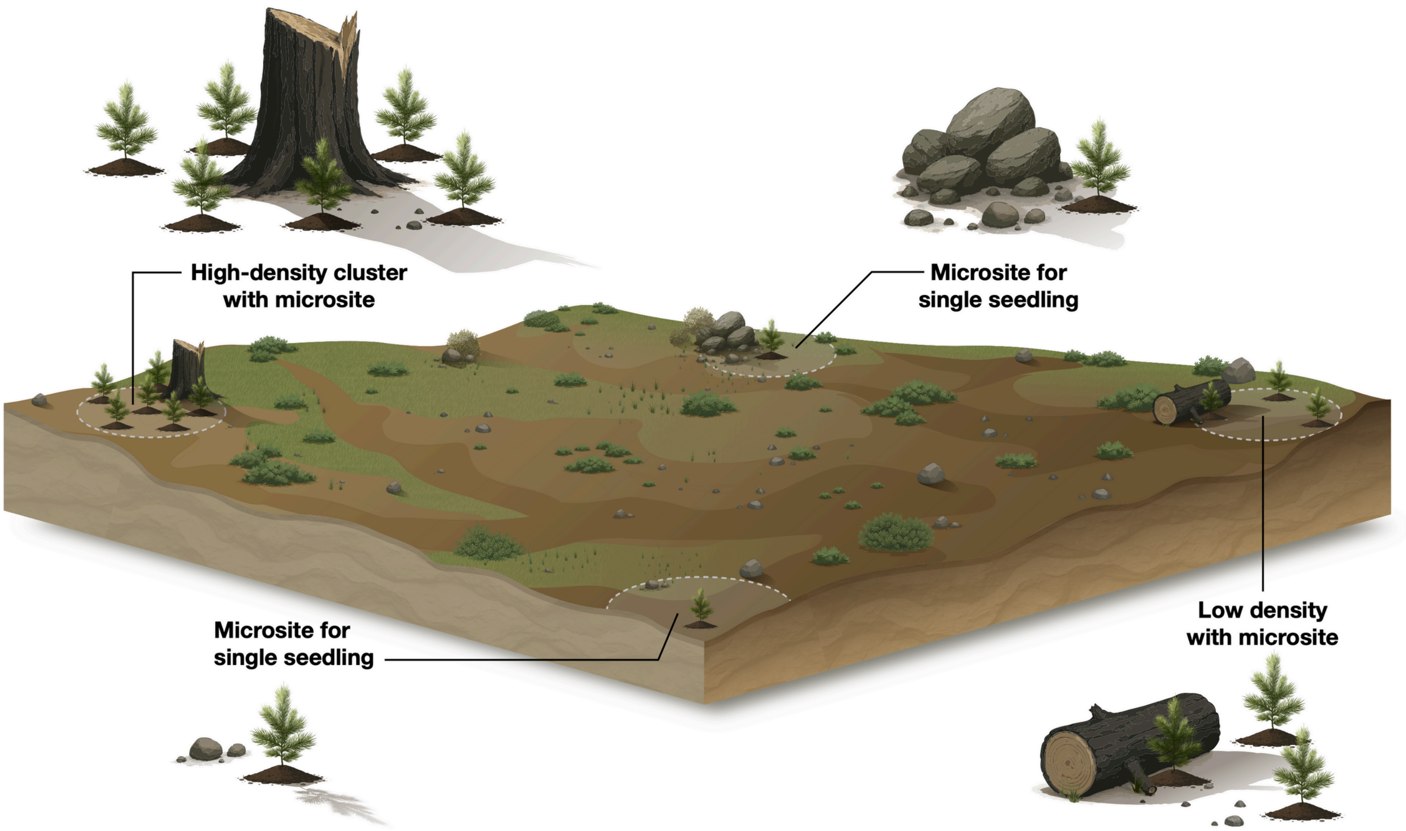

Figure 2. *Existing features within a planting area, such as shrub and herb cover, rocks, stumps, or downed logs, can create microsites with more shade, soil moisture, and protection from extreme heat and sun exposure. Planting to take advantage of these microsites can increase seedling growth and survival.*

Higher Initial Planting Density in a Loose Grid

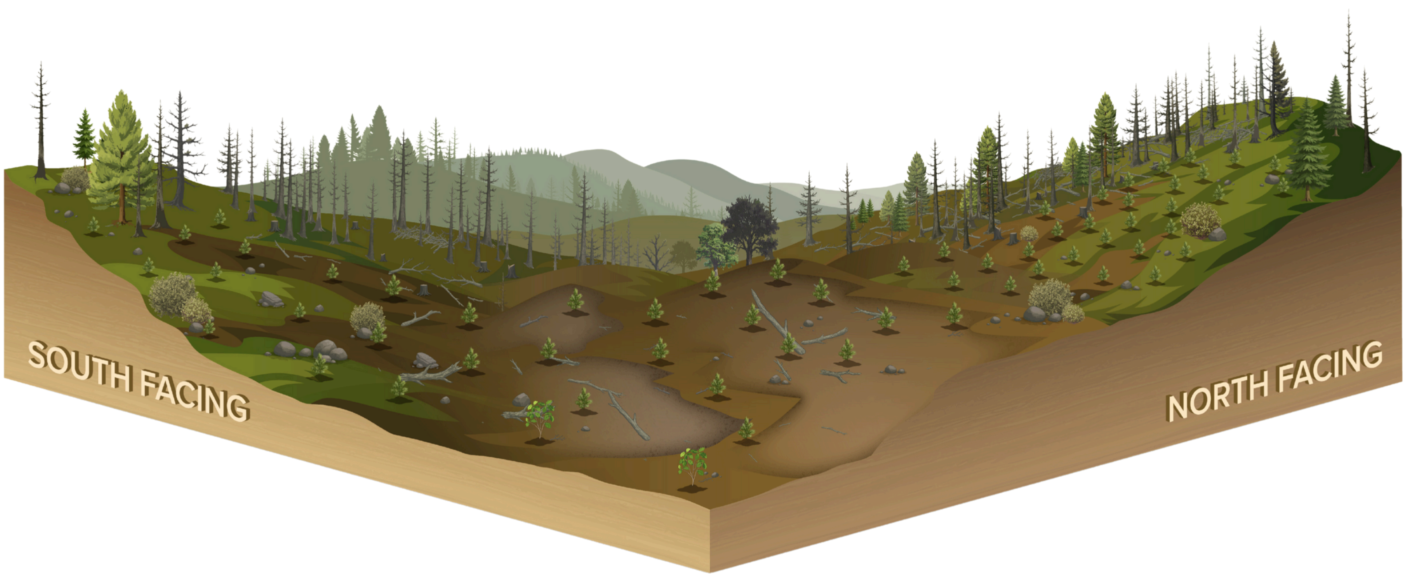

Figure 3. *Higher density plantings arranged in a loose grid can support the growth of trees in a desirable form for merchantable timber and efficient implementation of post-planting thinning and maintenance treatments. Planting at higher densities in a gridded pattern should still allow flexibility for the use of microsites (Figure 2).*

Lower Initial Planting Density in a Loose Grid

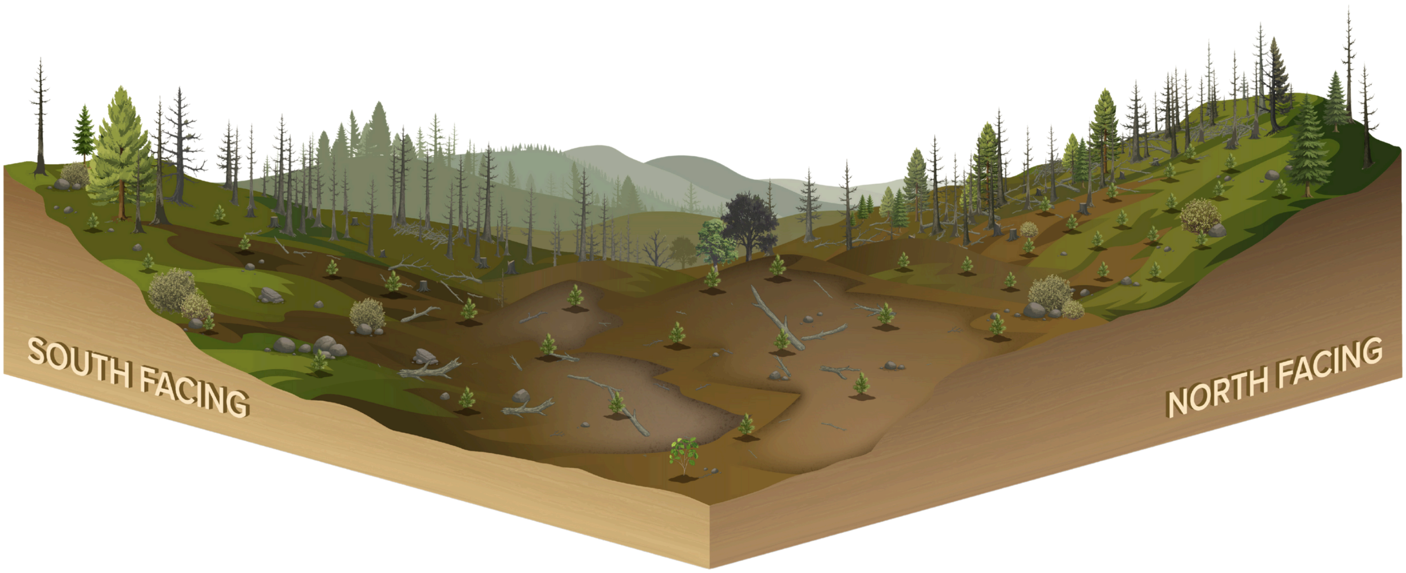

Figure 4. *Lower density plantings can be arranged in a loose grid that allows flexibility for the use of microsites (Figure 2). Seedlings can be planted in higher densities on north-facing than south-facing slopes. This type of planting density and arrangement can maintain open areas for ecological diversity while supporting the development of a structured forest.*

Lower Initial Planting Density with Variable Spacing

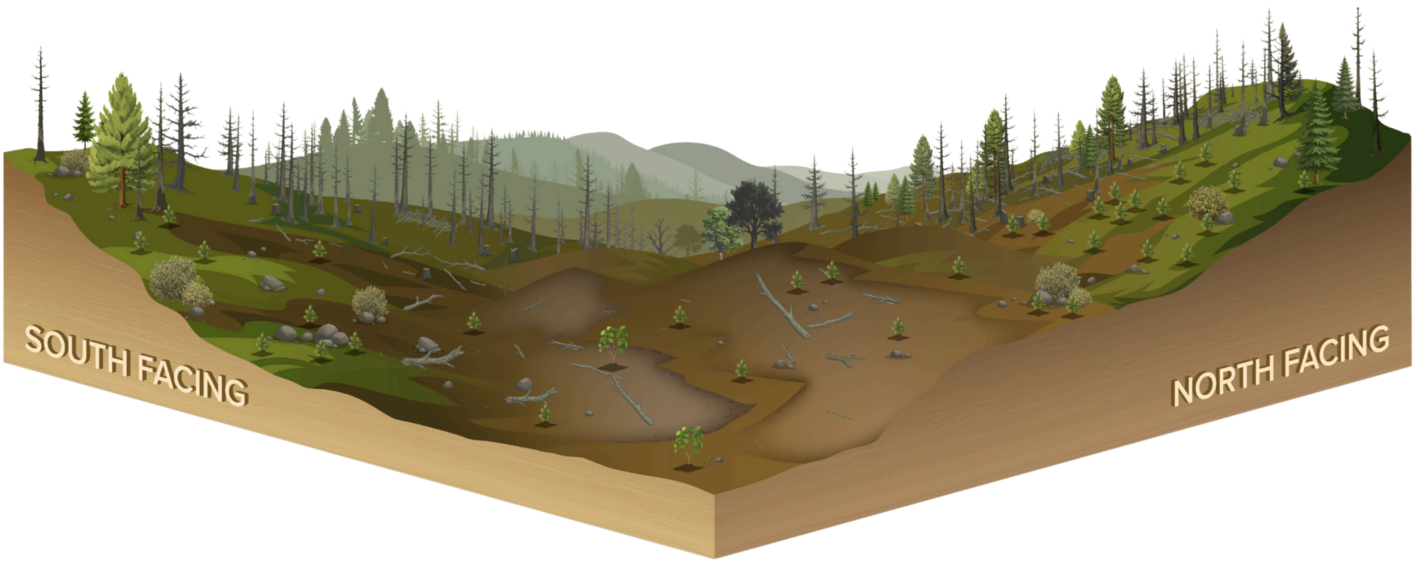

Figure 5. *Lower density plantings can be spaced variably to create a site with individual seedlings, clusters of seedlings, and larger openings without any seedlings. Seedlings should be planted in areas where microsites can support their survival (Figure 2). Planting in clusters may offer advantages, as clumps of seedlings more quickly outcompete other vegetation and may be able to accept the reintroduction of beneficial fire earlier.*

Key Actions

Reforestation does not end with planting. Continual management of forests following planting is important to ensure sustained climate and wildfire resilience into the future. As mentioned throughout this guidance, the capacity for varying degrees of post-planting treatment can impact decisions about species composition, density, and arrangement. A few common recommendations exist for all reforestation projects.

- Timely introduction of beneficial fire post-planting is a priority for climate-informed reforestation to promote wildfire resilience by reducing fuels and stand density, and reinforcing heterogeneity. It is also a very important ecosystem process that cannot be replaced or replicated with other treatment types.
  - Fire has been shown to reasonably be introduced around year 13-15, depending on site productivity, when a sufficient fuel bed has accumulated to carry fire, though studies are still in progress to determine when and how to best reintroduce fire in reestablishing forests.
  - There are trade-offs when considering at which time of year to introduce fire. Spring and winter burning could be more beneficial in terms of an increase in fuel moisture, which may produce a less intense fire (greater operational feasibility including burn window), though some early studies show higher mortality in spring burning. Fall burning would likely have less impact on the planted trees as they are not budding, is more aligned with a natural fire regime, and can result in greater surface fuels consumption within planted stands.
- Consider using one or more post-planting management practices (e.g., mechanical, hand treatments, fire, chemical, livestock grazing) timed appropriately to reduce competing vegetation, increase seedling survival and growth, and reduce fuels.
- Follow-up treatments to control competing vegetation, particularly aggressive shrub growth, are needed until trees are at least noticeably above the crowns of overtopping shrubs ("free to grow") to promote tree growth.
- Use continued stand management practices to maintain densities within 20%-35% of mature stand density target and below the zone of imminent mortality. Only consider interplanting if densities drop significantly below the target over a broad area.
- Post-planting monitoring is critical for assessing planting success (i.e., survival and growth of planted species, especially when planting a mixture of species from different seed zones), the effectiveness of site preparation actions to control competing vegetation, the need for density management, and the susceptibility to high-severity reburn based on fuel loads, and other management objectives (e.g., seedling spatial arrangement for facilitating heterogeneity in young stands).

Other post-planting treatment recommendations differ based on initial planting densities and arrangements as described above.

Lower Initial Planting Densities

- **When planting at lower initial densities (~75-150 TPA)**, seedling survival will require additional post-planting treatments focused on controlling competing vegetation, particularly shrubs. After trees are twice the height of shrubs, you can reduce intensive shrub management. However, you may need to focus on additional treatments that reduce shrub cover prior to reintroducing fire if shrub cover is homogenous across an area. There are many tools and methods available for managing understory growth (e.g., mastication, chemicals, fire, grazing), which can be selected based on existing guidance and operational considerations.
- In a low density planted site, you may need to be more conservative with the use of prescribed fire. With lower densities, young tree mortality has a greater impact on reforestation outcomes as there are fewer trees. Additionally, lower density plantings may favor fall burning to avoid compromising a more limited seed source. Finally, early use of fire in low density plantings should be used primarily as a surface fuels management tool.

Higher Intensity Management

- **Following higher initial planting densities (~170-200 TPA)**, there will be a greater need for managing tree density and crown growth after the first few years. This management of crown growth and trees will require a greater focus on machinery and associated methods. Post-planting management will entail multiple entries: (1) re-entry in early years 0-10 to reduce shrub cover, (2) thinning in the first 10-15 years to maintain crown separation, (3) multiple entries after 40 years, if a commercial thin is not already planned at this stage, to create gaps for regeneration of shade intolerant seedlings and to create diversity in age classes as well as reducing fuels and inter-tree competition. Pre-commercial thinning following higher initial planting densities can be used to create heterogeneity in forest structure, and offers opportunities for altering species composition, density, and disease management.
- Higher initial densities may allow for flexibility in managing future stand densities (e.g., trees could be removed later if site/microsite conditions are less productive than anticipated). However, higher densities also require follow-up treatments to reduce competition among neighboring stems and managing fuel loads.
- In higher density stands, which may allow for a higher tolerance of fire-killed trees, there is leeway to manage the stand with fire (i.e., pyrosilviculture) so long as fuel conditions are maintained to facilitate that option.

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