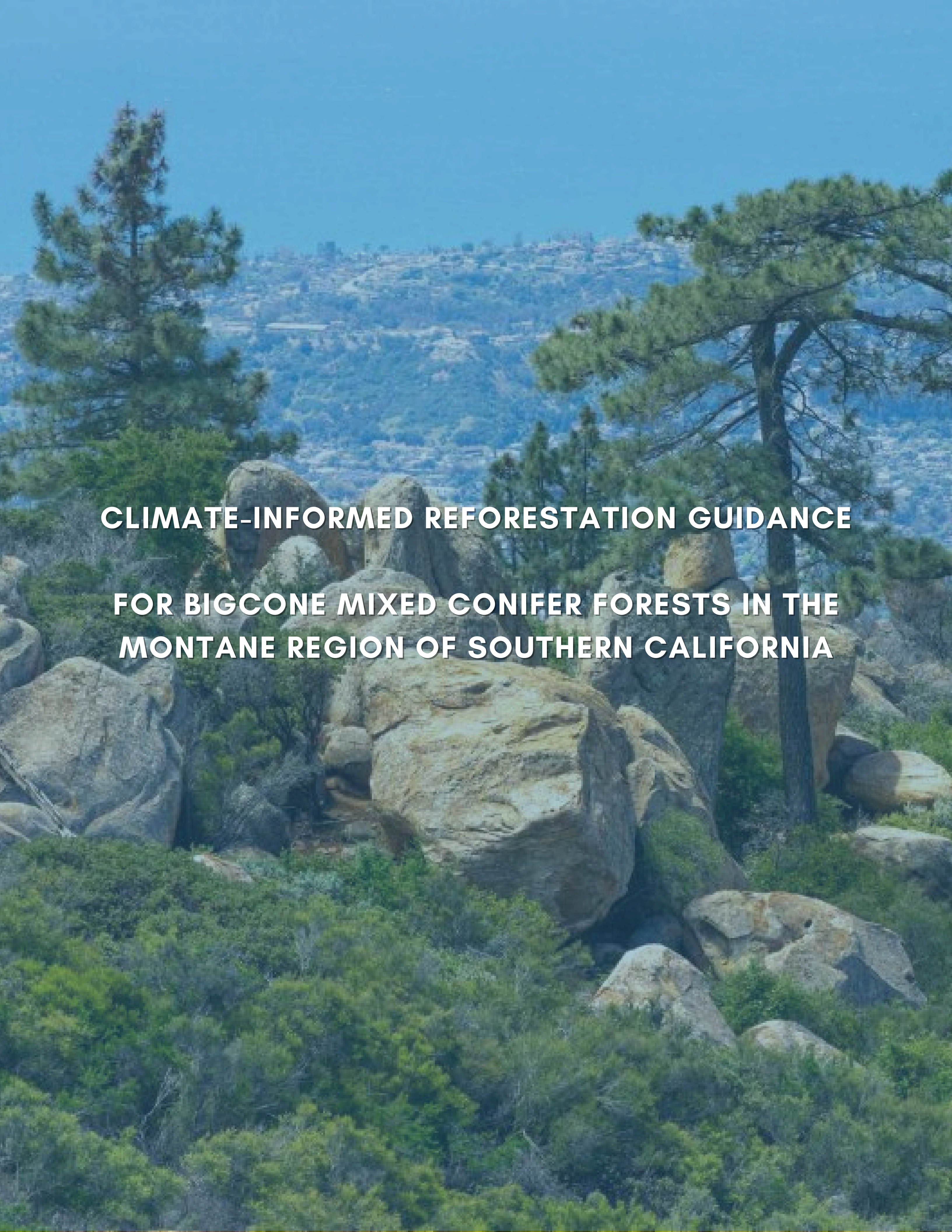
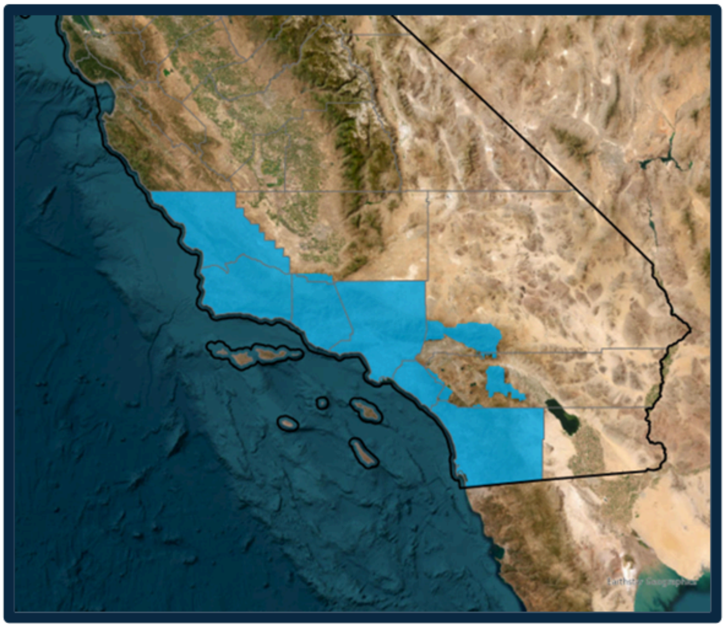


CLIMATE-INFORMED REFORESTATION GUIDANCE

FOR BIGCONE MIXED CONIFER FORESTS IN THE MONTANE REGION OF SOUTHERN CALIFORNIA



Montane Region of Southern California

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Climate-Informed Reforestation Guidance For Bigcone Mixed Conifer Forests in the Montane Region of Southern California

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 envelope 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; 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.

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.*

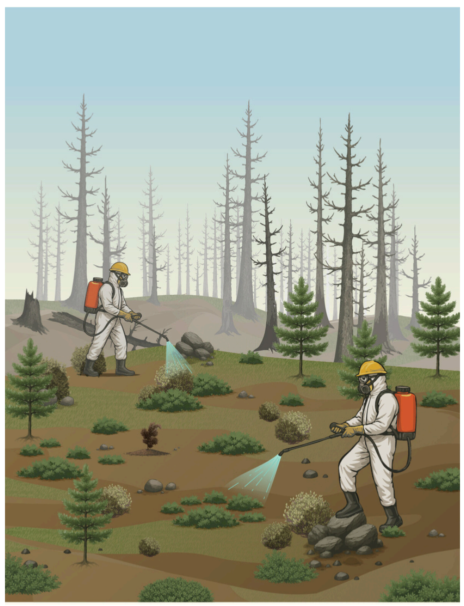
YEAR 0
Seedlings Planted

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 low levels that reduce future high-severity fire. This includes creating patchy and discreet coverage of the remaining surface fuels, which are made of 1 and 10 hour fuels that cannot be treated effectively by hand or machine. Pile burning is likely to be the primary method of biomass disposal, but biochar and chipping may be useful. 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, wildlife habitat, and the creation of mesic microsites.

- Retain 3-5 larger snags per acre. Snags that are >20 inches diameter at breast height (DBH) and >20 ft tall are less likely to fall and contribute to fuel load in the near term (Becker and Lutz 2023). Southern California National Forest Land Management Plans recommend, when possible, retaining a minimum of 10 to 15 snags (>16 inches DBH and 40 ft tall) per five acres (USDA Forest Service, 2005).
- Retain snags on marginal and unproductive planting sites and on sites where access is difficult for planting (e.g., slopes >35% steep, and far from roads, structures, and infrastructure).
- Additionally, retain downed logs to create microsites for planting (Fig. 2). Southern California National Forest Land Management Plans recommend, when possible, retaining a minimum of six downed logs (>12 inches DBH and 120 total linear ft) per acre (USDA Forest Service, 2005).
- Remaining large standing dead trees should be removed, ideally within the first 3-5 years following disturbance, either through salvage logging efforts or otherwise, to ensure timely reduction in fuels which reduces the risk of high-severity reburn and improves access for subsequent reforestation actions.
- **On xeric sites**, where elevation and aspect create drier soils, leave noncontinuous chipped mulch (no deeper than 3 inches) for moisture retention, particularly when the organic layer is disturbed.
- **Following drought or disease driven die off**, in areas with excessive surface fuels, consider pile burning in combination with mechanical thinning.

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. As with fuels management, existing guidance for the appropriate methods (e.g., mechanical, burning, chemical) can be used to achieve desired outcomes for competing vegetation. For example:

- **Following a recent high-severity fire**, herbicide is preferred for short-term removal of competing understory vegetation as the least destructive release method, compared to the desiccating effect of mechanical removal.
- **Many years after a fire**, physical shrub removal (pluck and pull) can be effective in areas with resprouting shrub. Mastication could also be considered but will require herbicide follow-up to control the resprouting response.

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.

Recommendations about how much competing vegetation should be maintained varies because there is a tradeoff between the benefit of vegetation moderating windspeed and temperature at the soil surface and the cost of belowground competition for moisture.

- Some managers recommend eliminating all competing vegetation that might inhibit success of planted trees, while others recommend retaining no more than 25% shrub cover, ideally in clumps and located in poor planting sites (e.g., rocky outcrops, shallow soils) where planted seedling survival is not expected and in places where they can be used to created protected microsites (Fig. 2). Shrubs can also be maintained as island outcrops on ridgelines.

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 moisture retention, though there is less consensus on the usefulness of these practices 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 absorbent hydrogel for bareroot planting.
- 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).

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.

- Enhance structural heterogeneity and create planting sites through selective gap creation (i.e., 0.5 acre gaps) utilizing mechanical thinning of remaining standing trees.
- 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. Generally, this stress will be exacerbated at lower elevations and for species which prefer colder and wetter climates. Decisions in a reforestation project that can buffer these risks include:

- Modifying the selection of drought resistant species, particularly in xeric sites.
- Potentially shifting the relative proportion of each species, based on specific site characteristics, pre-disturbance stand health, and post-disturbance monitoring, as well as a desire to increase diversity of seedlings to reestablish on a site.
- Using climate-adapted seeds when available.

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 within species 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 elevation and more southernly bands have been shown to be more tolerant of hotter and drier conditions projected to be more extreme in coming decades.
- A commonly recommended approach involves sourcing 50% of the seeds from the local seed zone and 50% from lower elevations or further south.
- Ideally, use a seed lot selection tool (e.g., CAST tool, Seedlot Selection Tool) and/or work with a genetics expert when selecting non-local seed.
- Consider working across international borders to acquire seed from Baja, Mexico. Monitoring outplanting success is a critical part of understanding the benefits of sourcing seed internationally.

Species Selection & Composition

Bigcone Douglas-fir is an endemic species that provides high-value wildlife habitat, especially for California Spotted Owl. There is a need for additional experimentation with this species to ensure retention at the landscape scale, including managed relocation. Managers should explore opportunities to conduct controlled trials (with follow-up monitoring) in carefully selected locations.

Where bigcone Douglas-fir mortality has occurred due to high-severity fire, it is recommended to:

- Attempt to reforest high elevation bigcone Douglas-fir. Avoid isolated low-elevation exposed locations, as these sites are unlikely to return to pre-fire conditions.
- Predominantly plant bigcone Douglas-fir in order to retain this species, with special attention to use of microsites to improve seedling survival (Runte et al., 2022).
- Where bigcone Douglas-fir is unlikely to return to pre-fire conditions, consider planting Coulter pine as a conifer adapted to future high-severity fire.
- Canyon live oak is a common associate of bigcone Douglas-fir and should be included in planting mixes as a more reliable species for reforestation.

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, to allow for the reintroduction of fire earlier. Additionally, altered arrangements can be used to create fuel breaks.
- **Drought resilience:** Competition for water resources between trees is lower at lower densities.

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. Experts expect 30-45% survival in this region. Lower survival is expected on more xeric sites. Also, consider using shade cards, hydrogel (for bare root stock), and biodegradable mulch mats to enhance planting success.

Density

Experts recommend that stocking density at year 5 should reflect the lower range of natural range of variation (NRV) (80-100 trees per acre (TPA), inclusive of hardwoods) and aiming for 40-75 canopy TPA in mature stands, depending on the forest type and site conditions. Initial planting densities should assume that a percentage of seedlings planted will be lost to mortality in the first 5 years.

- Experts recommend an initial planting density higher than mature target levels with a buffer and expectation for mortality.
  - **Following drought or disease-driven die off**, plant at lower densities as the capacity for supporting the pre-disturbance tree densities of those regions is likely reduced.
  - **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

Increasing heterogeneity in the planting arrangement can increase wildfire resilience and improve seedling survival.

- Plant in a loosely gridded spacing arrangement with up to 50% flexibility for utilization of microsites (Fig. 3).
- Use all available microsites (e.g., stumps, downed logs, root holes, rocks, burn pile locations) when planting to protect from extreme heat, sun exposure, and soil drying (Fig. 2).
- Utilize multi-spot planting by sowing multiple seedlings per planting location ("spot") that are spaced at least 18 inches apart. This can help mitigate the need for future interplanting due to poor survival. The number of "spots" planted at each multi-spot should be based off known survival rates per species in your area (e.g. if 30% survival is expected, use 3 seedlings per spot; if 50% survival is expected, use 2 seedlings).
- When living trees remain within the reforestation area following disturbance, avoid planting within 16-20 ft of tree canopy of residual living trees.

Timing

Existing guidance on the timing of planting is applicable for climate-informed reforestation. Fall planting may be attractive but the window of time between first fall rain and winter freeze is very short. Planting logistics must be timed so that seedlings have a period of active root growth before soil temperatures drop and seedlings go into winter dormancy. In many cases it will be better to focus on conducting planting as early as possible in late winter (late February). However, spring planting can be complicated by climate change; for example:

- The timing of spring is anticipated to shift with climate change, possibly leading to changes in the planting window. Suitable planting conditions may occur sooner than in the past.
- Focus on conducting planting as early as possible in late winter (late February), incorporating elevational considerations when soils are 40 degrees and warming.
- Start planting lower elevation sites as soon as appropriate conditions are reached, rather than waiting for all sites to be simultaneously ready for planting.
- Avoid planting on windy days to limit desiccation and observe guidelines for relative humidity and temperature limits.

In addition, plan for multi-year projects to anticipate poor water years. Planting during years of deep drought will waste valuable resources if the planting fails. Reforestation is more likely to fail in southern California, relative to more northern forests, due to warmer and drier conditions.

Planting with Microsites for Seedling Protection

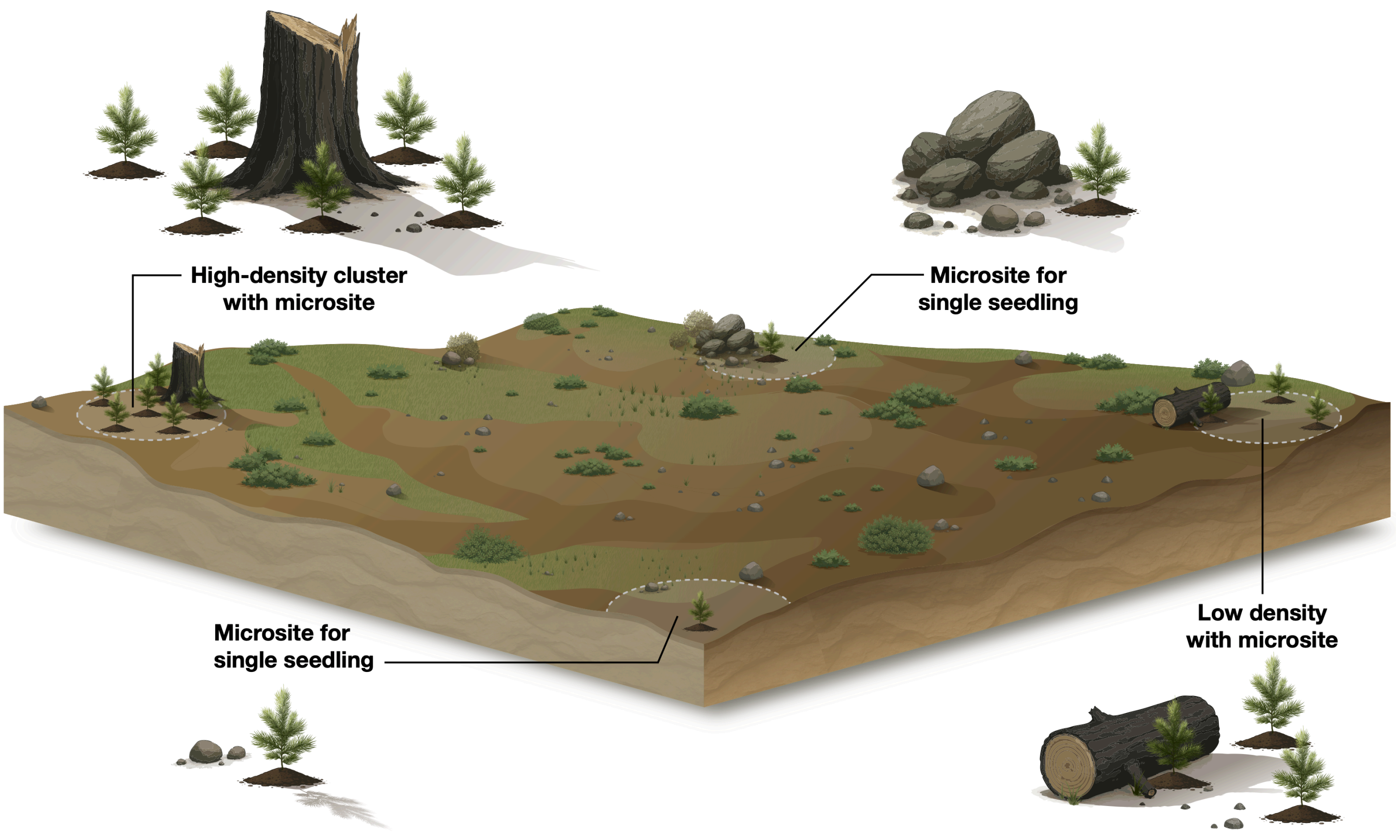


Figure 2. *Existing features within a planting area, such as shrub and herb cover, rocks, stumps, or downed logs, can create microsites with more shade, soil moisture, and protection from extreme heat and sun exposure. Planting to take advantage of these microsites can increase seedling growth and survival.*

Higher Initial Planting Density in a Loose Grid

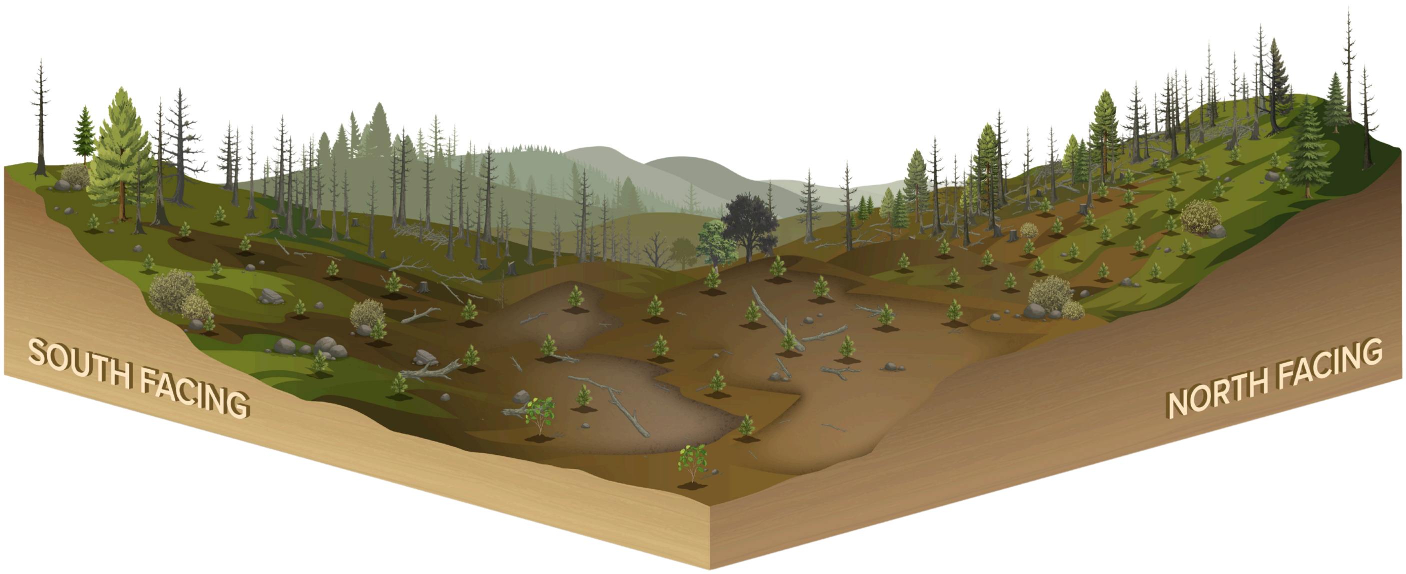


Figure 3. *In Southern California, initial planting densities should include a buffer for anticipated seedling mortality, which is often higher in this region compared to others due to its climate and less productive soils. Planting at higher densities in a loose grid should still allow substantial flexibility for the use of microsites (Figure 2).*

POST-PLANTING MANAGEMENT 4

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. Selection of post-planting treatments can vary based on decisions about species composition, density, and arrangement, as well as capacity for particular management actions. A few common recommendations exist for all reforestation projects.

- Consider using one or more post-planting management practices (e.g., mechanical, hand treatments, fire, chemical, plant herbivory) timed appropriately to increase seedling vigor, reduce fuels, and increase reforestation success.
  - Release seedlings in both year 1 and 2 post-planting. Re-evaluate the need for additional release in years 3-5.
  - Herbicide is preferred as the least destructive release method. However, the desiccating effect of manual grubbing may be offset with mulch placement around seedlings.
  - Timing of treatment is important (e.g., treatment for non-native annual grasses must be done during spring green-up before seeds are mature).
  - Follow-up treatments to control competing vegetation, particularly shrubs, is needed until trees are twice the height of the shrubs ("free to grow").
- Timely introduction of beneficial fire post-planting is a priority for climate-informed reforestation to promote wildfire resilience by reducing fuels, stand density, and reinforcing heterogeneity. Strategic introduction of fire is key given the importance of ensuring seedling survival on low productivity sites.
  - Fire can be introduced 13-15 years after planting, depending on site productivity. At this point, a sufficient fuel bed to carry fire has likely accumulated.
  - There are trade-offs when considering at which time of year to introduce fire. Fuel moisture is higher during spring and winter, which may produce a less intense fire, but some early studies have shown higher mortality in spring burning. Fall burning is more aligned with a natural fire regime.
- 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 elevation bands), 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).

- Plan for inter-planting to adaptively manage in response to year 1 seedling survival. In response to seedling mortality, consider species composition adjustments before abandoning the site, including experimentation with native drought and fire-tolerant species, such as oaks and Coulter pine, that may have higher survival rates.
- If mortality occurred in the absence of drought, this is an indicator that the site may ultimately need to be allowed to transition to shrubs, and multiple years of replanting should not be undertaken.

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Cover Photo: Pine Ridge in Santa Barbara (Los Padres Forest Watch)