Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Pacific Northwest Research Station | General Technical Report PNW-GTR-1031 | February 2025

Informing Reforestation with the Experimental Network for Assisted Migration and Establishment Silviculture (ENAMES)

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Cover photo: Recently planted seedlings at the Gawley Panther 2 site. USDA Forest Service photo by Alyssa Smits.

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Abstract

Agne, Michelle C.; Slesak, Robert A.; Gonzalez Mantecon, Laura; Wright, Jessica W.; Kolpak, Scott E.; Baumgart, Erin E.; Bower, Andrew D.; Darbyshire, Robyn; Ellwanger, Claire; Erickson, Vicky J.; Ferreria, Arnaldo R.; Looney, Christopher E.; Roskilly, Beth A.; Sherlock, Joseph W. 2025. Informing reforestation with the Experimental Network for Assisted Migration and Establishment Silviculture (ENAMES). Gen Tech. Rep. PNW-GTR-1031. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 103 p. https://doi.org/10.2737/pnw-gtr-1031.

Recent climate and disturbance conditions in Western U.S. forests have led to significant reforestation needs, necessitating the development of climate-informed management strategies. Promising adaptation strategies include assisted population migration, the movement of seed sources or populations to new locations within the historical species range, combined with silvicultural establishment practices that can improve short-term seedling survival and longer term stand resilience to future climate. Presently, there are challenges to the operational use of assisted population migration and uncertainty regarding its success when combined with the effects of various silvicultural practices and seed transfer guidelines. We established the Experimental Network for Assisted Migration and Establishment Silviculture (ENAMES) to evaluate the short- and long-term success of operationally implemented reforestation treatments that incorporate assisted population migration and silvicultural establishment practices using a network of sites selected through science-management partnerships with federal, state, and tribal ownerships. Here, we document the context underlying ENAMES, describe the experimental network and its establishment, share lessons learned, and describe future opportunities for the network. The network consists of 37 sites from northern Washington to central California, including a wide range of pre-disturbance forest types and climatic conditions. The practitioner partner at each site selected planted species and silvicultural practices to ensure management relevance. The most common species planted were Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*), while the most common silvicultural treatments were comparisons of stock types or vegetation control methods. Planting of sites was initiated in 2021 and is expected to be completed in 2026. Comparisons of survival and growth by treatment are a key outcome of this study, with initial measurements planned for 1-year post-planting, and every 5 years thereafter. We anticipate that ENAMES will clarify uncertainties regarding assisted population migration and that planting sites will be used as demonstrations to showcase treatment effects. ENAMES provides a powerful opportunity to test the efficacy of assisted population migration and silvicultural establishment treatments, while using a science-management partnership model to ensure that practices are operationally relevant.

KEYWORDS:

Adaptation
Assisted population migration
Planting
Provenance trial
Regeneration
Science-management partnership

Contents

Introduction

Change and disturbance are inherent to natural ecosystems, but the current magnitude and rate of change in forested ecosystems are unprecedented. Since the start of the 21st century, the total area burned in Western U.S. forests has increased markedly, with an eight-fold increase in area burned with high severity over estimates from the 1980s (Parks and Abatzoglou 2020). While high-severity fire is a natural element of many forested ecosystems, warming conditions have been compounded by the effects of management practices (e.g., fire suppression), leading to shifts in fire regimes outside of the historical range of variability in many forests (Hagmann et al. 2021). The increase in total area burned by high-severity fire, as well as occurrences of extreme fire years such as 2020 (Higuera and Abatzoglou 2020, Reilly et al. 2022), pose challenges for reforestation by simultaneously creating large areas that require planting. Concurrently, occurrences of drought years have increased in the Western U.S., leading to a high frequency of postfire years coinciding with periods of high moisture stress and conditions that lead to natural regeneration failure (Stevens-Rumann et al. 2018). Further, extreme heat events are increasing in frequency (Fischer et al. 2021), and when such events coincide with drought, the effects of the individual events are compounded (Osman et al. 2022). Current climate and disturbance conditions are eroding the capacity of forests to return to pre-disturbance structure and function, and this trend is predicted to continue (Coop et al. 2020). Therefore, management approaches are needed to sustain forest ecosystem functions into a climatically uncertain future (North et al. 2019).

Many management approaches have been considered for sustaining forests under climate change, covering a wide range of activities that are implemented at various times in stand development (Nagel et al. 2017, Royo et al. 2023). Several frameworks have been developed to inform climate adaptation, which include a range of management objectives, investments, and risks (Millar et al. 2007, Schuurman et al. 2022). Although these frameworks are useful conceptually, in practice, much of the discussion around adaptation is focused on resisting ecosystem change (e.g., control of invasive species) (Beaury et al. 2020) or building resilience to change (e.g., application of prescribed fire or thinning in mature stands) (D'Amato et al. 2011, Moreau et al. 2022, North et al. 2019). However, approaches that direct ecological transitions are likely to become increasingly necessary in forest management as climate conditions continue to change (Moore and Schindler 2022), and the costs and operational and regulatory constraints associated with building resistance or resilience in mature stands can pose practical limitations (Lydersen et al. 2019). To sustain functional forests into the future, a range of climate adaptation strategies—including those that involve directing ecological transitions—will need to be implemented across large geographic areas and diverse ownerships with a range of management objectives and barriers to implementation of novel practices (Palik et al. 2022). Reforestation, which is conducted by most ownerships regardless of resource limitations, offers a tremendous opportunity to comprehensively implement climate adaptation strategies that create and sustain functional forests into the future. This is particularly important given the increasing acreage of disturbed area requiring planting to meet reforestation mandates at regional and national scales (USDA FS 2022).

One of the most promising adaptation strategies is the use of assisted migration, which is the facilitated movement of plants from climates in which they evolved to areas that are predicted to have a similar climate in the future. In general, populations of forest trees are assumed to be adapted to the climatic, biotic, and edaphic conditions under which they evolved at their source locale. However, because of warming temperatures and shifting moisture regimes associated with climate change, these populations are predicted to become increasingly maladapted to their local environment as climate changes more rapidly than trees can adapt, leading to declines in forest health and productivity (O'Neill and Gómez-Pineda 2021). The risk of maladaptation has led to increasing interest in assisted migration during reforestation as a management practice to facilitate climate adaptation (Palik et al. 2022, Pedlar et al. 2012). One promising assisted migration strategy is assisted population migration, or assisted gene flow, which is the movement of seed sources or populations to new locations within the historical range of a species, typically from areas south to north or lower elevation to higher elevation (Aitken and Whitlock 2013). Under assisted **population** migration, populations of a given species remain within the existing habitat range (Winder et al. 2011). Forest managers generally consider this type of assisted migration to pose lower ecological risk and have higher social acceptance. Therefore, they use it more widely than assisted **species** migration—the movement of species outside their current natural range to areas not likely to be colonized naturally over time (Aubin et al. 2011, Williams and Dumroese 2013).

Provenance trials and reciprocal transplant studies, where seed sources from different climates are planted across test sites that span a range of climates, can be analyzed to provide insights into the potential of assisted population migration based on genetic variation among populations of a given species (Aitken and Bemmels 2015, Leites and Benito Garzón 2023). Such studies use space-for-time substitution to understand how survival and productivity change as a function of climate transfer distance, or the difference in climate between the planting site and population origin (Rehfeldt et al. 2002, St. Clair and Howe 2007, Wang et al. 2006). Given a suitable number of populations and study sites spanning a wide range of climates and sufficient response times, transfer functions—equations that relate population growth to climate transfer distance—can be developed and used to predict safe climatic transfer distances and identify seed sources for a given species that are adapted to a site's projected future climate (O'Neill et al. 2014, St. Clair et al. 2022, Wang et al. 2010). Given their utility, there is a growing need for new trials that include more species across a wider range of environmental conditions and management practices to validate transfer functions and to address uncertainty associated with operational use of assisted population migration. In particular, there is a need to understand how assisted population migration performs under realistic field conditions as opposed to the carefully controlled and maintained conditions of most historical provenance trials.

A key factor that can influence the efficacy of assisted population migration is that trees are subjected to a range of climate conditions across their lifespans. While adult trees from populations adapted to forecasted late-century (2071–2100) climate may be more productive in the future, they must first survive near-term local climate conditions and extreme events as seedlings (Aitken and Bemmels 2015, Ikeda et al. 2014, St. Clair et al. 2020), which is the most vulnerable stage of development. Use of silvicultural practices during stand establishment can enhance seedling survival and may increase resilience to future climate, but there are several aspects that create uncertainty about the necessity and effectiveness of these practices. Control of competing vegetation with herbicides is effective at increasing survival and early growth of planted seedlings (Dinger and Rose 2009, Fleming et al. 2018, Wagner et al. 2006), but herbicide use can be constrained by regulations, costs, and public perceptions of ecological impacts (Little et al. 2006). Alternative methods such as mechanical removal may be needed, but the efficacy of such methods is uncertain and can be more costly than herbicide treatments (McDonald and Fiddler 2010, Slesak et al. 2022, Thiffault et al. 2012). Furthermore, site quality modulates vegetation control effects, with high site quality leading to a potential long-term convergence of growth between stands with and without vegetation control (Zhang et al. 2006). Whether seed source may interact with vegetation control in a similar manner remains unknown. Seedling stock type is also known to influence establishment success, and many managers use types that have high survival and growth rates in their local conditions or are necessary because of resource constraints. Larger stock generally outperforms smaller stock (Aghai et al. 2014, Thiffault et al. 2014) and may be necessary for seedling establishment with assisted population migration, but larger stock also comes at additional cost that must be justified by a clear benefit to survival and growth (Pinto et al. 2011). Other variables, such as planting density and planting season (fall versus spring planting) (Grossnickle and MacDonald 2021), can influence early survival and growth (Harrington et al. 2009, Scott et al. 1998), which furthermore depend on site quality. Assessment of assisted population migration treatments in combination with silviculture practices is needed to understand what options and level of investment will be necessary for successful tree establishment (using assisted population migration) across a broad range of site productivity.

Addressing the questions of where to plant, what to plant, and how to plant (including post-planting activities such as control of competing vegetation) is a critical need to sustain forests through reforestation in the presence of climate change and the increasingly common postfire landscapes of California, Oregon, and Washington. To provide answers, we have established the Experimental Network for Assisted Migration and Establishment Silviculture (ENAMES) to evaluate short- and long-term success of reforestation treatments that incorporate assisted population migration and silvicultural establishment practices across a diverse network of sites. The objective of this report is to document the context and reasoning underlying ENAMES, describe the experimental network and the process by which it was established, share lessons learned, and describe future opportunities for the network.

Context

Based on our experiences and those of many colleagues, research findings are often not incorporated into operational practices, including those generated from applied research projects. This can be because of the difficulty of incorporating research methods into practice (e.g., requirement of a specialized tool or expertise, prohibitive cost), but more frequently it is because the research questions or associated approaches have limited practical effect on how managers accomplish their work (Beier et al. 2017, Carter et al. 2020, Naugle et al. 2020). From our earliest conversations when establishing ENAMES, there was a strong commitment to ensure that research findings were useful to managers in achieving their reforestation and climate adaptation goals. A key component of this project is the use of science-management partnerships through all stages of the research process to ensure that findings are directly applicable to management (Littell et al. 2012). These partnerships enable the exchange of information between researchers and practitioners from the project design stage through implementation and maintenance to ensure that findings are operationally relevant and to provide mutually beneficial learning opportunities.

Given our goal to ensure ENAMES findings are useful for forest managers, we are committed to implementing the project using operational techniques and approaches (Palik et al. 2022). In most research projects, applying treatments consistently is an important part of the experimental methodology to reduce statistical noise. However, consistency can rarely be achieved in operational settings. For example, planting seedlings on an evenly spaced grid in an experiment allocates equal growing space and reduces variation in growth, but in operational planting, favorable microsites are typically prioritized over precise spacing. Experimental units are also typically small with lower environmental variation (e.g., consistent slope, aspect, soils) compared to much larger units managed operationally that may have much greater variation (Puettmann et al. 2012). The operational reforestation practices used to establish the ENAMES study, as opposed to precisely defined and controlled experimental conditions, reduce the abstraction of experimental inference for forest managers. This approach comes with the cost of a reduced ability to detect treatment effects due to use of different silvicultural treatments across sites and lower precision of treatment application within sites than would be used in a typical research project. However, we believe the benefits of increased applicability of findings associated with operational implementation outweigh this cost.

Establishing the Experimental Network

Partner Engagement and Site Identification

Partnerships between practitioners and researchers were established at the outset to ensure that all parties were involved throughout the planning process, including network design, site establishment, measurement, and analysis. Practitioner partners were identified from federal, state, and Tribal ownerships across the study area. Initial meetings with practitioner partners were held to identify sites where assisted population migration and silvicultural establishment treatments could be installed.

At the time of publication, 37 sites have been committed to ENAMES. These sites range from northern Washington to central California (fig. 1), with elevations from 500 to 1800 m, and include diverse ownerships, including 4 U.S. Department of the Interior, Bureau of Land Management districts; Confederated Tribes of the Colville Reservation; Oregon Department of Forestry; Washington Department of Natural Resources; and 13 U.S. Department of Agriculture, Forest Service national forests (table 1). Historical (1961–1990) mean coldest month and warmest month temperatures at sites ranged from −7.2 to 6.6 °C and 14.4 to 24.4 °C, respectively, while mean annual precipitation ranged from 354 to 2676 mm (table 1; fig. 2). All target planting sites experienced severe wildfire (n = 34) or harvest (n = 3) between 2 and 11 years before planting so there was minimal existing overstory tree cover. All sites were planned for reforestation, with most sites planted within 4 years of the disturbance event (fig. 3). Site preparation activities varied with landowner, reflecting the typical operational practices of each organization. Salvage logging was conducted before planting at 40 percent of sites, and vegetation control was used at some sites, while others included no pre-planting management intervention following disturbance (fig. 4).

Practitioners identified the species for assisted population migration treatments as well as silvicultural establishment treatments relevant to their management objectives. This approach allowed for the testing of practices that are relevant to each landowner's management objectives and the development of strategies that could be used operationally. All sites included four seed sources of a single species (assisted population migration treatment) and most included at least one silvicultural establishment practice with two or more levels (silvicultural treatments). The predominant species selected for planting were Douglas-fir

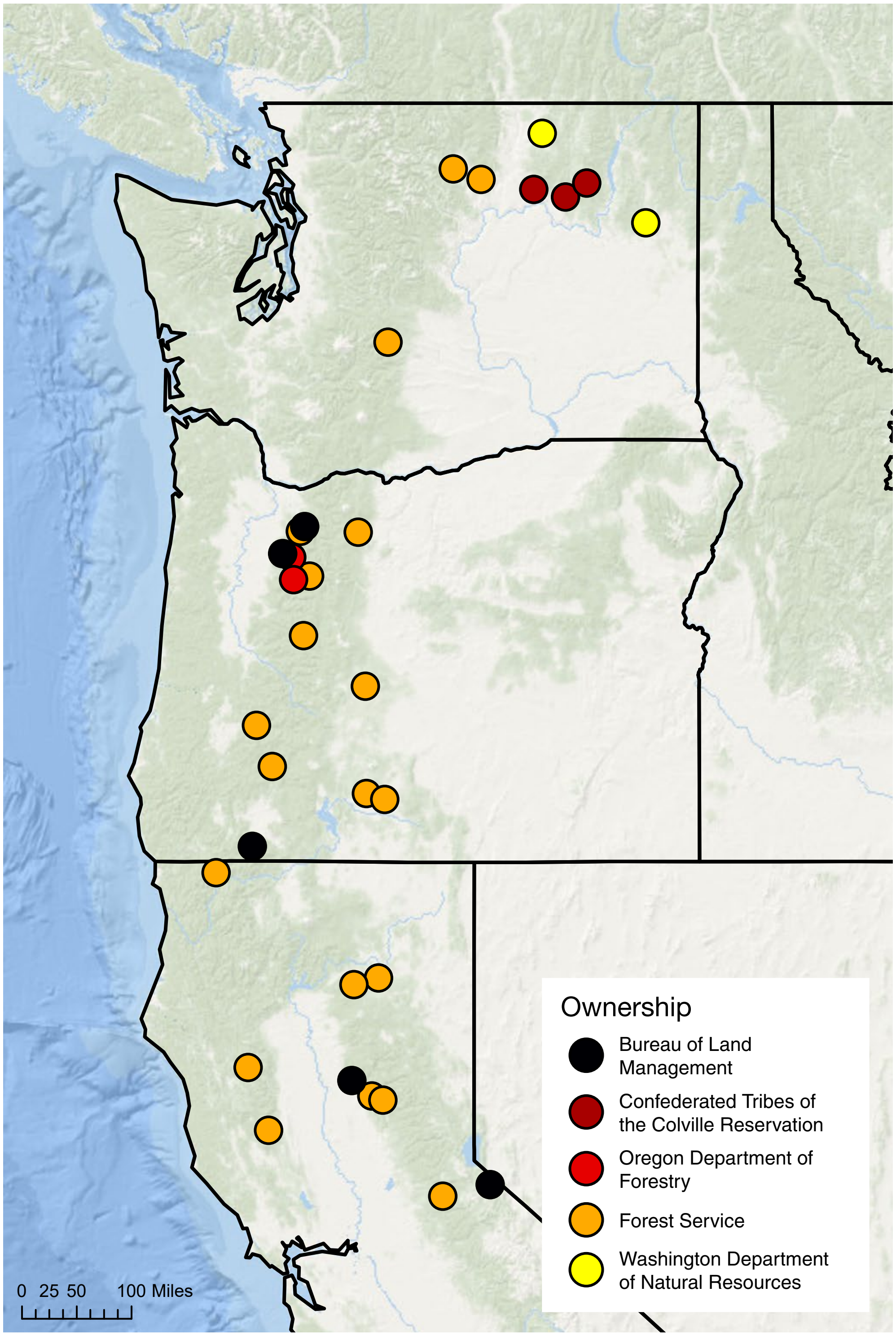

Figure 1—Experimental Network for Assisted Migration and Establishment Silviculture planting site locations by ownership (n = 37).

Table 1—Experimental Network for Assisted Migration and Establishment Silviculture site characteristics and experimental treatments

Site name	Latitude, longitude	Location	Ownership	Elevation	Mean annual temperature	Mean annual precipitation	Species planted	Silvicultural treatment	
								Practice	Levels
	DECIMAL DEGREE			METERS	DEGREES CELSIUS	MILLIMETERS			
Bald Fire	40.8440°, –121.2585°	Northeastern California	Forest Service (Lassen NF)	1494	9.1	495	Ponderosa pine	Seedling stock type, planting composition	Containerized, 1-0 bareroot; 100 percent ponderosa pine, ponderosa-Jeffrey pine mix
Berry Brush	39.6549°, –121.3472°	Northeastern California	Forest Service (Plumas NF)	926	13.6	1692	Douglas-fir	Planting composition	100 percent conifer, 80–20 percent conifer-hardwood
Burney Mountain	40.7774°, –121.5832°	Northeastern California	Forest Service (Lassen NF)	1441	9.5	1316	Douglas-fir	Seedling stock type, planting composition	Bareroot, containerized; 100 percent Douglas-fir, 50-50 percent Douglas-fir-Jeffrey pine mix
Burnt Creek	43.3186°, –122.8700°	Southwestern Oregon	Forest Service (Umpqua NF)	864	10.5	1871	Douglas-fir	Seedling stock type	2-0 bareroot, Styro-8 plugs, Q-plugs
Caldor Fire	38.6293°, –120.4100°	Northeastern California	Forest Service (Eldorado NF)	1648	10.0	1309	Douglas-fir	N/A—AM treatment only	N/A
Carlton	48.3379°, –119.9032°	North-central Washington	Forest Service (Okanogan-Wenatchee NF)	1140	5.2	445	Ponderosa pine	N/A—AM treatment only	N/A
Cedar Cub	48.4308°, –120.2827°	North-central Washington	Forest Service (Okanogan-Wenatchee NF)	1244	5.4	632	Ponderosa pine	Planting density	150, 200, 250 TPA
Detroit 1—salvage	44.7344°, –122.1712°	Northwestern Oregon	Forest Service (Willamette NF)	528	9.3	2081	Douglas-fir	N/A—AM treatment only	N/A
Detroit 2—no salvage	44.7369°, –122.1659°	Northwestern Oregon	Forest Service (Willamette NF)	635	9.1	2104	Douglas-fir	N/A—AM treatment only	N/A
Falls Creek	44.9458°, –122.5244°	Northwestern Oregon	BLM (NW Oregon District)	751	8.5	2071	Douglas-fir	Vegetation control	2 treatment radii × 1 entry versus 2 entries
Fuego	42.6334°, –121.4257°	South-central Oregon	Forest Service (Fremont-Winema NF)	1776	5.6	715	Ponderosa pine	Seedling stock type	2-0 bareroot, containerized
Gawley Panther 1—south aspect	44.9112°, –122.4038°	Northwestern Oregon	ODF	1207	6.8	2676	Douglas-fir	Planting density, vegetation control	300, 400 TPA; herbicide, no herbicide

Table 1 (continued)—Experimental Network for Assisted Migration and Establishment Silviculture site characteristics and experimental treatments

Site name	Latitude, longitude	Location	Ownership	Elevation	Mean annual temperature	Mean annual precipitation	Species planted	Silvicultural treatment	
								Practice	Levels
	DECIMAL DEGREE			METERS	DEGREES CELSIUS	MILLIMETERS			
Gawley Panther 2—north aspect	44.9269°, −122.3666°	Northwestern Oregon	ODF	736	8.0	2254	Douglas-fir	Planting density, vegetation control	300, 400 TPA; herbicide, no herbicide
Government 40	39.6129°, −121.2012°	Northeastern California	Forest Service (Plumas NF)	1162	12.7	1829	Ponderosa pine	Planting configuration, vegetation control	Uniform, clustered; herbicide, no herbicide
Hammerhorn	39.9482°, −122.9897°	Northwestern California	Forest Service (Mendocino NF)	1064	11.8	1301	Douglas-fir	Planting configuration	Uniform, clustered
Happy Camp 1—ponderosa pine	41.8873°, −123.4032°	Northwestern California	Forest Service (Klamath NF)	754	11.5	1679	Ponderosa pine	Seedling stock type	1-0 bareroot, containerized
Happy Camp 2—Douglas-fir	41.8873°, −123.4032°	Northwestern California	Forest Service (Klamath NF)	754	11.5	1679	Douglas-fir	N/A—AM treatment only	N/A
Hidden Road	47.9478°, −117.7336°	Northeastern Washington	WDNR	595	8.3	490	Ponderosa pine	Seedling stock type	Styro 5/6, Styro 10, Ellepot
Hillockburn Springs	45.2000°, −122.2334°	Northwestern Oregon	BLM (Northwest Oregon District)	499	9.5	1751	Douglas-fir	Vegetation control	2 treatment radii × 1 entry versus 2 entries
Huck	42.6030°, −121.1765°	South-central Oregon	Forest Service (Fremont-Winema NF)	1606	6.4	544	Ponderosa pine	Seedling stock type	2-0 bareroot, containerized
Keller Ridge	48.1816°, −118.7895°	Northeastern Washington	CTCR	1100	6.3	409	Western larch	Seedling stock type, vegetation control	Styro 10, Styro 2A [211A]; herbicide, no herbicide
Letts Lake	39.3042°, −122.7067°	Northwestern California	Forest Service (Mendocino NF)	1383	11.9	1317	Douglas-fir	N/A—AM treatment only	N/A
Lickety Split	42.1444°, −122.9237°	South-central Oregon	BLM (Medford District)	787	10.0	640	Douglas-fir	Vegetation control	No grubbing, grubbing at 1 year, grubbing at 2 years
Magalia	39.8118°, −121.6105°	Northeastern California	BLM (Northern California District)	680	14.5	1480	Ponderosa pine	N/A—AM treatment only	N/A

Table 1 (continued)—Experimental Network for Assisted Migration and Establishment Silviculture site characteristics and experimental treatments

Site name	Latitude, longitude	Location	Ownership	Elevation	Mean annual temperature	Mean annual precipitation	Species planted	Silvicultural treatment	
								Practice	Levels
	DECIMAL DEGREE			METERS	DEGREES CELSIUS	MILLIMETERS			
McKenzie	44.1746°, −122.2491°	North-central Oregon	Forest Service (Willamette NF)	550	10.0	1830	Douglas-fir	N/A—AM treatment only	N/A
Pettijohn	48.7403°, −119.1008°	Northeastern Washington	WDNR	1281	4.2	494	Ponderosa pine	Seedling stock type	Styro 5/6, Styro 10, Ellepot
Riverside	45.1544°, −122.2883°	Northwestern Oregon	Forest Service (Mt. Hood NF)	785	7.9	2297	Douglas-fir	Planting density	150, 250 TPA
Rosland	43.6949°, −121.4346°	Central Oregon	Forest Service (Deschutes NF)	1314	6.4	508	Ponderosa pine	Vegetation control	2 treatment radii × 1 entry versus 2 entries
Schneider Spring	46.8891°, −121.1346°	Central Washington	Forest Service (Okanogan-Wenatchee NF)	1371	4.7	1477	Ponderosa pine	Planting density	150, 200, 250 TPA
Sugar Pine	42.9224°, −122.6612°	South-central Oregon	Forest Service (Umpqua NF)	1243	8.5	1369	Sugar pine	N/A—AM treatment only	N/A
Summit Trail	48.3041°, −118.5096°	Northeastern Washington	CTCR	1498	5.0	605	Western larch	Seedling stock type, vegetation control	Styro 10, Styro 2A [211A]; herbicide, no herbicide
Tamarack 1—ponderosa pine	38.7478°, −119.7846°	Northeastern California	BLM (Carson City District)	1709	8.3	563	Ponderosa pine	Seedling stock type	Bareroot, containerized
Tamarack 2—Jeffrey pine	38.7478°, −119.7846°	Northeastern California	BLM (Carson City District)	1709	8.3	563	Jeffrey pine	Seedling stock type	Bareroot, containerized
Tamarack 3—incense cedar	38.7478°, −119.7846°	Northeastern California	BLM (Carson City District)	1709	8.3	563	Incense cedar	Seedling stock type	Bareroot, containerized
White River	45.1457°, −121.5267°	Northwestern Oregon	Forest Service (Mt. Hood NF)	945	7.2	751	Ponderosa pine	Planting density	150, 200, 250 TPA
Whitmore Fire	48.2485°, −119.2087°	Northeastern Washington	CTCR	831	7.3	354	Ponderosa pine	Seedling stock type	Styro 6, Styro 10, Ellepot
Winterfelled	44.7022°, −122.3798°	Northwestern Oregon	ODF	734	8.6	2225	Douglas-fir	Vegetation control	No herbicide, 1 application, 2 applications

Note: Climate data were obtained from ClimateNA (Wang et al. 2016) and represent historical (1961–1990) normals.

AM = assisted migration; BLM = Bureau of Land Management; CTCR = Confederated Tribes of the Colville Reservation; N/A = not applicable; NF = National forest; ODF = Oregon Department of Forestry; TPA = trees per acre; WDNR = Washington Department of Natural Resources.

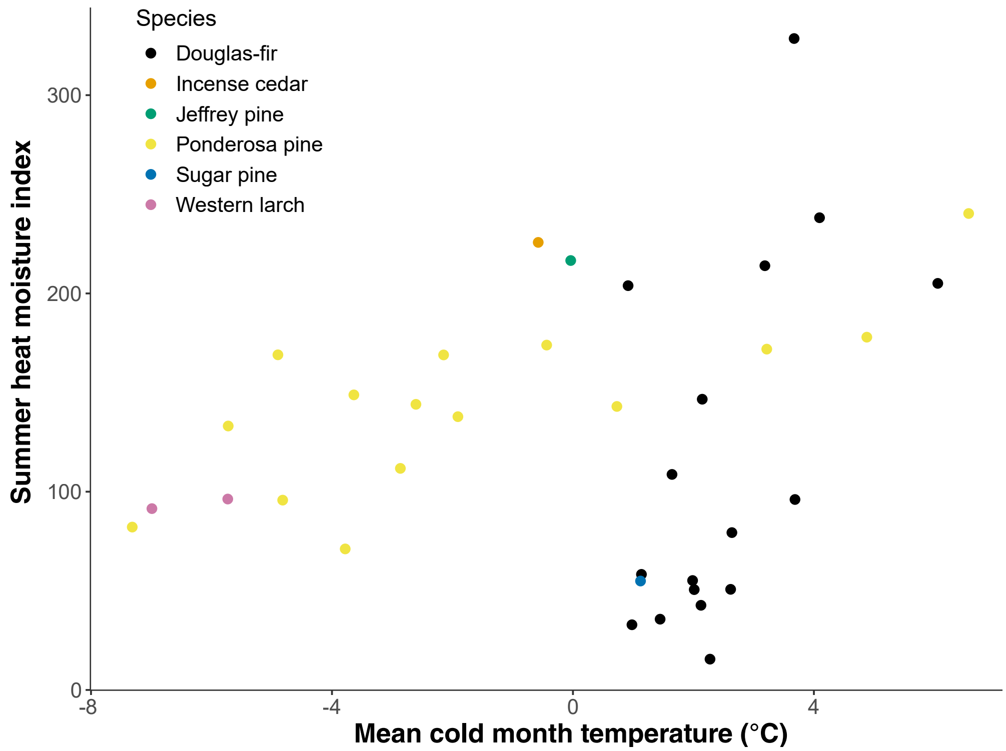

Figure 2—Historical (1961–1990) mean coldest month temperature versus summer heat moisture index by species planted at Experimental Network for Assisted Migration and Establishment Silviculture sites. Climate data were obtained from ClimateNA (Wang et al. 2016).

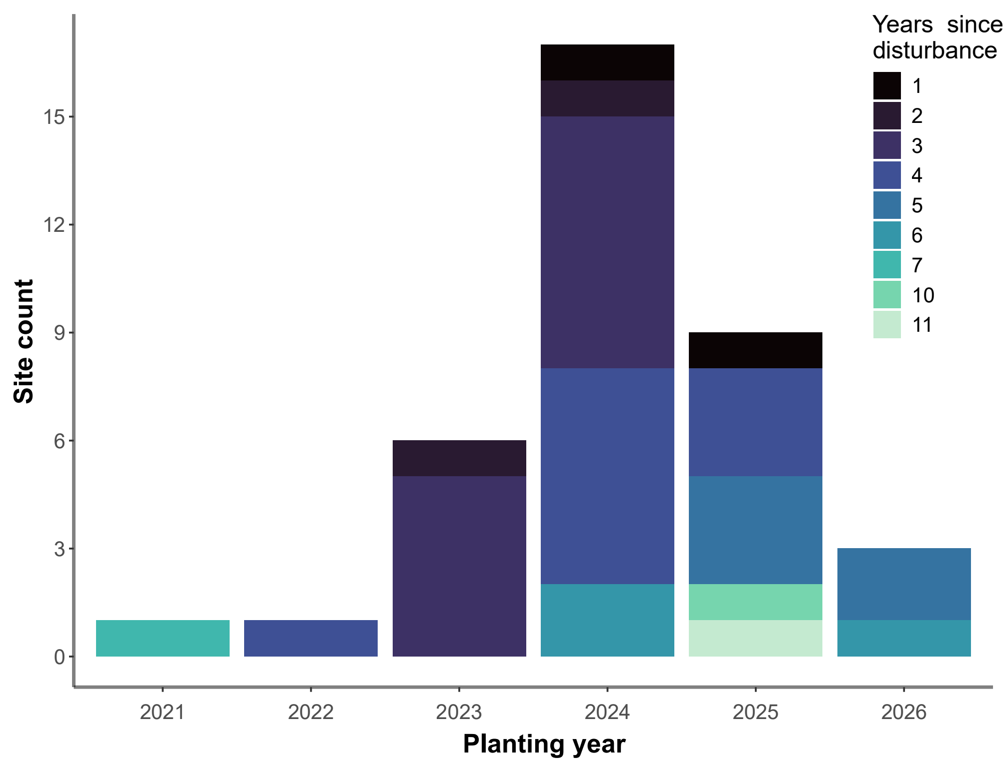

Figure 3—Total count of Experimental Network for Assisted Migration and Establishment Silviculture sites by planting year and years since disturbance (at time of planting).

Figure 4—Photos of Experimental Network for Assisted Migration and Establishment Silviculture sites representing a range of conditions before planting. Top left: Carlton site—salvage harvested after fire. Top right: White River site—no salvage harvest before planting. Photos by Michelle Agne. Bottom left: McKenzie site—planted during a late spring snowstorm. Photo by Scott Kolpak. Bottom right: Hillockburn Springs site—robust competing vegetation before application of vegetation control treatment. Photo by Broderick DeAngelis

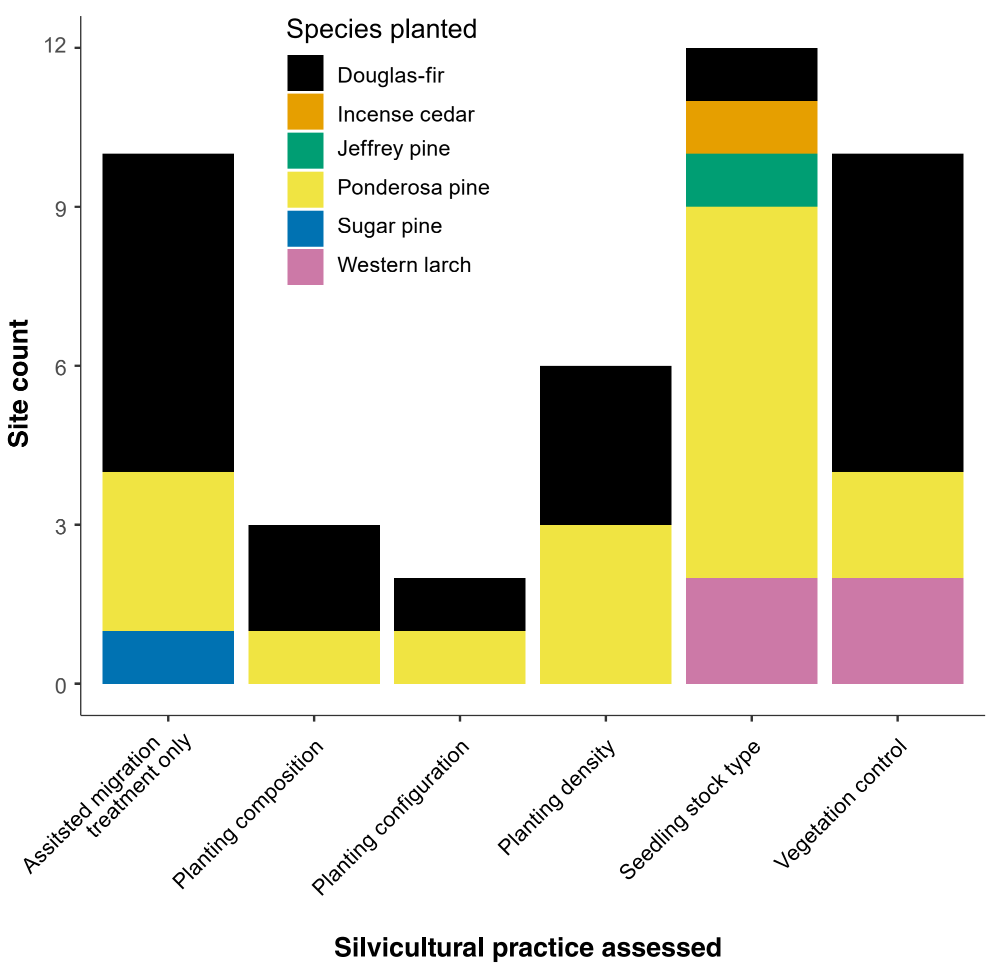

Figure 5—Total count of Experimental Network for Assisted Migration and Establishment Silviculture sites by species planted and silvicultural practice assessed. Sites that assessed two silvicultural practices are represented in both silvicultural practice columns.

(*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*), but several other locally important species were planted at individual sites, including incense cedar (*Calocedrus decurrens*), Jeffrey pine (*Pinus jeffreyi*), sugar pine (*Pinus lambertiana*), and western larch (*Larix occidentalis*) (fig. 5). The most common silvicultural treatments assessed were comparisons of different stock types (e.g., bareroot versus containerized, large containerized versus small containerized stock) or vegetation control methods (e.g., mechanical versus chemical, one versus two applications), but comparisons of different planting densities, planting configurations (uniform versus clustered), and planting compositions (the Berry Brush, Bald Fire, and Burney Mountain sites in the Forest Service's Pacific Southwest Region (Region 5) tested single versus mixed species plantings) were also assessed at some sites (fig. 5). Profiles for each individual site are provided in appendix 1.

Seed Source Identification

For each site, four different seed sources associated with four climate scenarios were identified for implementation of the assisted population migration treatment. The climate scenarios were (1) the local seed source adapted to that site's historical (1961–1990) climate; and seed sources adapted to a site's projected future climate for (2) early century (2011–2040), (3) mid-century (2041–2070), and (4) late century (2071–2100) (fig. 6). For sites in Washington and Oregon, we used the Seedlot Selection Tool (SST) (St. Clair et al. 2022; USDA FS et al., n.d.) to identify seed sources for these four climate scenarios. The SST uses historical and climate projections under Representative Concentration Pathways (RCPs) 4.5 and 8.5 emissions scenarios (van Vuuren et al. 2011) from ClimateNA (Wang et al. 2016) to map areas of climatic match within a user-defined transfer limit for the projected future climate at a point location (St. Clair et al. 2022). We used emissions scenario RCP 8.5 for worst-case scenario planning; RCP 4.5 represents a future with substantial greenhouse gas mitigation. Several climate variables are available in the tool, but we used mean coldest month temperature (MCMT) and summer heat moisture index (SHM), which are the default variables based on the presumption that temperate forest trees in the region are primarily adapted to cold temperatures and summer aridity (St. Clair et al. 2022). Using this approach, we considered seed sources to be optimally adapted to each climate scenario if they minimized the MCMT transfer distance (i.e., the difference between projected MCMT at the planting site and climatic center MCMT for the seed source was less than 2 °C, and usually less than 1 °C), and SHM (a unitless metric) was within 50 percent of the projected value.

For California sites, we primarily used the unpublished Climate-Adapted Seed Tool (CAST) (Reforestation Tools, n.d.) to identify seed sources. Similar to SST, CAST uses historical and projected future climate data to map areas of climatic match to a point location. The CAST uses a multivariate composite of mean annual temperature, mean annual precipitation, mean coldest month temperature, and temperature differential to characterize seed source and planting site climate, which are then applied to a transfer function to determine the percentage of productivity decline. Historical climate reflects 1940–1969 climate conditions obtained from PRISM (PRISM Climate Group 2023), while early-, mid-, and late-century climates are projections under the RCP 8.5 emissions scenario obtained from localized constructed analog (Pierce 2023) decadal normals centered around 2020, 2040, and 2080, respectively. Using this approach, we considered seed sources to be best adapted to each climate scenario if they minimized the expected percentage of decline in productivity compared with a seed source that historically demonstrated optimal productivity at the site. Occasionally, there were no appropriate seed sources representing climatic matches to future climate at a site generated using CAST. In this case, we used the Seed Zone Climate Tracker (Stewart Ecology, n.d.) to identify a climatic match based solely on mean annual temperature, rather than using the multivariate approach of CAST.

For each site, we compared the list of identified candidate seed sources best adapted to each climate scenario with the seed inventory of woods-run (wild) and orchard-grown seed of the manager of the planting site. As a part of the operational implementation of this work, we used the same seed banks available to the land managers of each site. Therefore, not all seed sources identified as climatic matches by the tool were available for our use at each site, but we selected the closest available match from the inventory. When multiple suitable seed sources were available, we favored seed sources with high germination rates and those that originated from a forest geographically closer to the planting site. Following selection of seed sources, we calculated MCMT and SHM for all seed zone/elevation band combinations

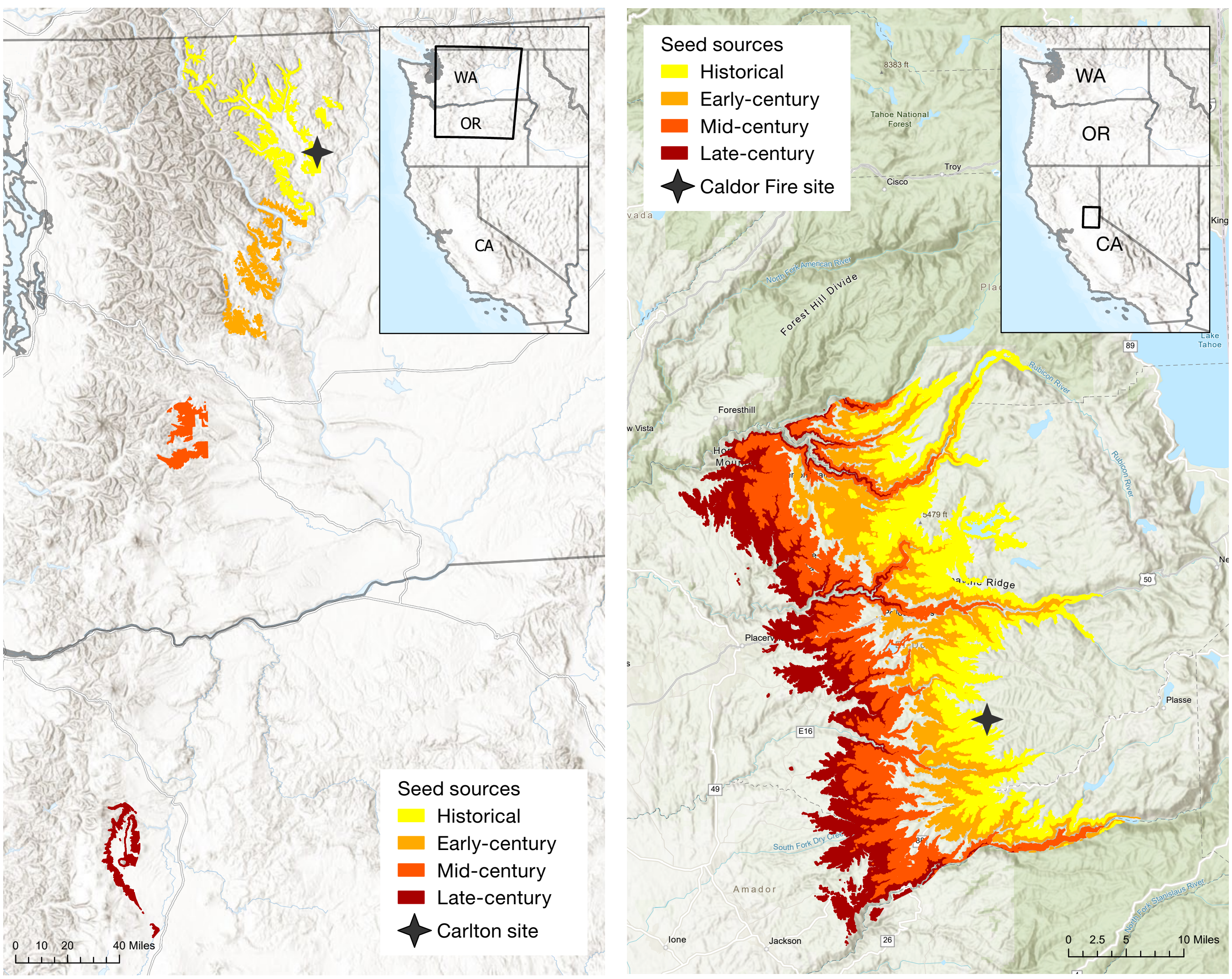

Figure 6—Two example sites with seed zone/elevation band combinations of seed sources planted. Seed sources for the Carlton site (left panel) follow a north-south gradient, with seed sources aligned to early-, mid-, and late-century projected climate increasingly farther south from the planting site. Seed sources for the Caldor Fire site (right panel) follow an elevational gradient, with seed sources aligned to early-, mid-, and late-century projected climate at decreasing elevation relative to the planting site. Early-, mid-, and late-century climate projections reflect Representative Concentration Pathway 8.5 emissions scenario.

representing the seed sources. We followed the method used by the SST to calculate the climatic center (defined as the mean value of all pixels within the 5th to 95th percentile of the relevant climate variable) of each seed zone/elevation band combination for MCMT and SHM using ClimateNA historical data (Wang et al. 2016). We then calculated transfer distances between the site climate and seed source climate for all sites and seed sources (fig. 7). There was a general trend of increasing MCMT and SHM with increasing distance in the future, although change in SHM was more variable. Transfer distances for MCMT averaged 0.09, 1.4, 2.6, and 4.2 °C for historical, early-century, mid-century, and late-century seed sources, respectively (table 2). Transfer distances for SHM averaged 0.4, 25.3, 26.1, and 64.5 for historical, early-, mid-, and late-century seed sources, respectively (table 2).

Experimental Design and Site Establishment

Assisted population migration (seed source) and silvicultural treatments were typically applied using a randomized complete block factorial design replicated at each site within the network. The four seed sources described above were crossed with 1–4 levels of a given silvicultural practice (some sites had only the assisted population migration treatment), resulting in 4–16 treatment combinations per site (table 1). Each treatment combination had four replications per site applied to 0.202-ha square or rectangular plots. Where possible, blocking was largely based on proximity; while site arrangement varied, groups of plots nearest to one another represented blocks with each treatment combination represented by one plot in each block. Where blocking was not possible, a completely randomized design was used. For these sites, plot-level environmental variables (e.g., soils, slope, aspect) that

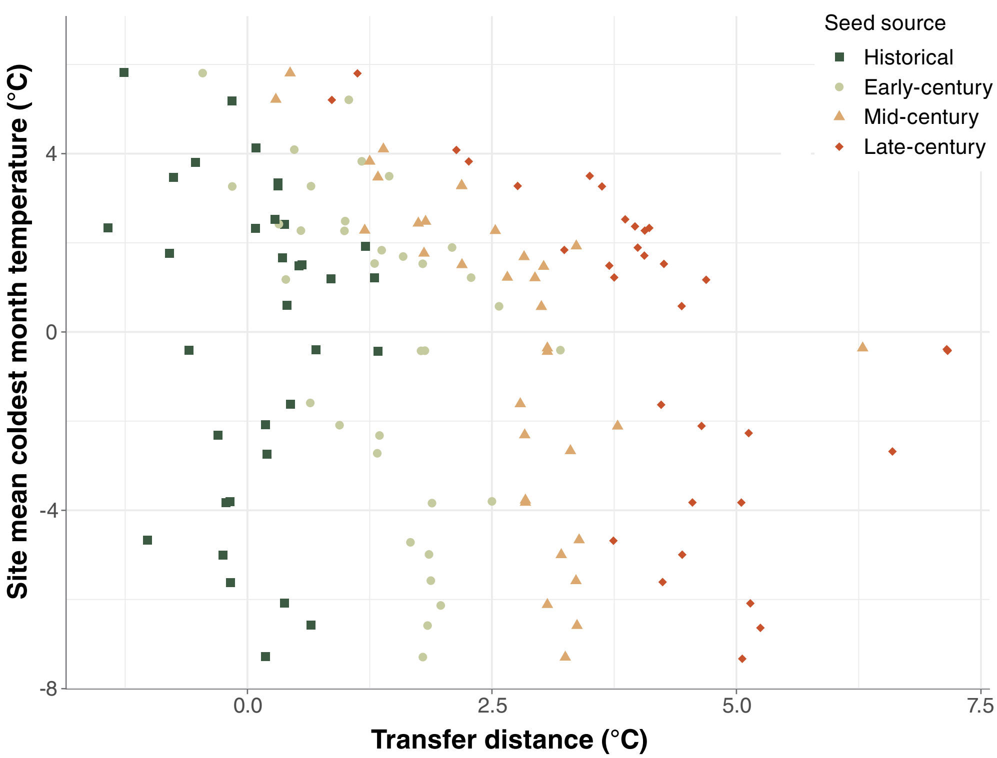

Figure 7—Historical (1961–1990) site mean coldest month temperature versus transfer distance by seed source. Transfer distance is the difference between the seed source climate and historical site climate. Climate data were obtained from ClimateNA (Wang et al. 2016).

Table 2—Summary of means (standard deviations) of historical site climate and seed source baselines and transfer distances by planted species for Experimental Network for Assisted Migration and Establishment Silviculture sites

Species	N[b]	Historical[c] planting site climate		Historical[c] seed source climate		Early-century[d] seed source climate		Mid-century[e] seed source climate		Late-century[f] seed source climate	
		MCMT[a]	SHM[a]	ΔMCMT	ΔSHM	ΔMCMT	ΔSHM	ΔMCMT	ΔSHM	ΔMCMT	ΔSHM
		DEGREES CELSIUS	UNITLESS	DEGREES CELSIUS	UNITLESS	DEGREES CELSIUS	UNITLESS	DEGREES CELSIUS	UNITLESS	DEGREES CELSIUS	UNITLESS
Douglas-fir	17	2.45 (1.29)	113.2 (88.1)	0.05 (0.79)	−2.8 (20.0)	1.03 (0.81)	17.3 (20.5)	2.07 (0.83)	24.5 (66.2)	3.51 (0.90)	29.0 (50.7)
Incense cedar	1	−0.40	195.9	0.70	1.1	1.81	132.5	6.29	117.2	7.15	183.8
Jeffrey pine	1	−0.40	195.9	−0.60	−26.0	1.78	63.4	3.07	79.7	7.16	437.7
Ponderosa pine	15	−1.61 (4.02)	149.4 (42.1)	0.07 (0.54)	9.0 (35.7)	1.60 (0.73)	22.1 (36.1)	2.84 (0.85)	24.0 (53.7)	4.57 (1.57)	62.7 (127.5)
Sugar pine	1	1.20	82.5	0.86	30.9	2.29	68.8	2.66	0.6	4.69	230.6
Western larch	2	−6.10 (0.71)	96.1 (27.6)	0.24 (0.58)	−31.1 (27.4)	1.86 (0.02)	15.0 (52.2)	3.36 (0.01)	−7.9 (13.0)	4.75 (0.71)	30.8 (27.6)
All species	37	−0.09 (3.60)	126.7 (70.0)	0.09 (0.67)	0.4 (28.5)	1.38 (0.79)	25.3 (35.2)	2.61 (1.09)	26.1 (58.9)	4.23 (1.46)	64.5 (115.2)

Columns from MCMT through the last ΔSHM fall under the spanning header "Transfer distance or deviation from baseline[a]".

Δ = change in.

Note: Climate data were obtained from ClimateNA (Wang et al. 2016).

[a] Transfer distances are deviations from a baseline that were calculated as seed source climate minus historical site climate for mean coldest month temperature (MCMT) and summer heat moisture index (SHM).

[b] Number of planting sites.

[c] Historical period is represented by 1961–1990 climate normal.

[d] Early-century period is represented by 2011–2040 projected climate normal (Representative Concentration Pathway [RCP] 8.5).

[e] Mid-century period is represented by 2041–2070 projected climate normal (RCP 8.5).

[f] Late-century period is represented by 2071–2100 projected climate normal (RCP 8.5).

are expected to influence the treatment response will be accounted for as covariates. When delineating plots before establishing them in the field, we selected areas that were uniform with respect to elevation, slope, and aspect. We avoided areas with live trees and features that would hinder planting (e.g., rock outcrops, stream beds). Further, we ensured post-disturbance management (e.g., salvage harvest) was consistent across a site. Experimental plots were established before planting using Geode[1] Global Positioning System (GPS) units (Juniper Systems, Inc., Logan, UT, USA) interfaced with ArcGIS Field Maps (ESRI, n.d.) for Washington and Oregon sites and Avenza Maps (Avenza Systems, Inc. 2024) in California to locate treatment plot corners. Plot corners and center points were monumented with PVC pipes or rebar and labeled to indicate the assigned treatment combination.

Seedlings were grown at one of four nurseries using standard nursery practices for operational seedling production. Containerized seedlings planted at sites in Washington and Oregon were grown at Dorena Genetic Resource Center in Cottage Grove, Oregon, while bareroot seedlings were grown at J. Herbert Stone Nursery in Central Point, Oregon. Seedlings for sites established on Washington Department of Natural Resources and Confederated Tribes of the Colville Reservation lands were grown at the Webster Forest Nursery in Olympia, Washington. All seedings for sites established in California were grown at the Forest Service, Region 5 Placerville Nursery in Placerville, California. One-year-old seedlings were grown for all sites, except for three sites that compared 2-0 (two-year old) bareroot stock to containerized stock.

Seedlings were planted by contractors as part of the associated ownership's planting program (Washington and Oregon sites) or by the project team and partner volunteers (California sites). Planting followed operational practices that varied by management partner. Planting practices were consistent (e.g., using favorable microsites, such as adjacent to downed logs and stumps, rather than planting in a uniformly spaced grid) within each site, and approximate spacing (where density was not a silvicultural treatment) was determined by the land manager's target planting density. Planting was overseen by members of the project team to ensure that all seed sources were correctly planted in their assigned plots and all planted seedlings were pin-flagged (marked with a durable plastic material attached to a steel wire) at Washington and Oregon sites. Each treatment plot used a single seed source. No mixtures were planted, except as a separate experimental level at three sites to test for stand-level differences in productivity between monocultures and polycultures. At a given site, all plots were planted continuously until the entire site was completed (generally within 1 day). Sites were planted in spring as soon as they were accessible after snow melt, except for one site that was planted in the fall.

At the end of the first full growing season, we took first-year measurements on planted seedlings at sites that had already been planted, and these measurements are planned for sites that are not yet planted. Our goal was to measure about 50 live seedlings per treatment plot; measurement plot sizes were increased accordingly to include 50 trees (50 seedlings × 4 seed sources × 1–4 silvicultural treatment levels × 4 replications = 800 to 3,200 seedlings measured per site). This process varied at some sites where mortality was high or where seedlings were not pin-flagged immediately after planting. Live seedlings were permanently tagged and geolocated with Geode GPS units. Seedlings were measured for

[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

total seedling height, annual height growth (length between the previous year's whorl and the apex of the terminal bud), and diameter at 15 cm aboveground (D15), and assessed for overtopping by competing vegetation, animal browse, top dieback, and mechanical damage. All dead seedlings within the measurement plot were tallied. Additional diameter and height growth measurements are planned for 5 years after planting and every 5 years following.

In addition to seedling measurements, site characterization measurements are planned for all sites and will be taken within 1 year of planting. We will characterize sites by measuring trees, saplings, seedlings, downed woody debris, litter, and duff following the methods and layout used by the Forest Service, Forest Inventory and Analysis program (Bechtold and Scott 2005): 18-m-radius (0.102-ha) plots centrally located in each block per site. Bulk soil samples will be collected from three locations at each plot by depth increment (0 to 30 cm and 30 to 60 cm); samples will be composited by plot and depth, thoroughly mixed, and a subsample retained for analysis of chemical and physical soil properties. Soil bulk density will be estimated at each depth increment using either the core method or the sand cone method when coarse fragments are high. The soil samples will be analyzed for extractable macronutrients (Mehlich-3 extraction), total carbon and nitrogen via dry combustion, potentially mineralizable nitrogen using an aerobic incubation, and soil texture using the hydrometer method. Lastly, local weather conditions (rainfall, temperature, and relative humidity) will be monitored with weather stations at each site, as well as soil temperature and moisture content to a depth of 80 cm.

Analytical Framework

The overarching research questions we aim to address with the experimental network are: "What are the effects of seed source climate (in relation to planting site climate) on seedling growth and survival, and how do silvicultural establishment practices modify the response?" We hypothesize that (1) early (1–10 years after planting) survival and growth will be greater for seed sources adapted to historical and early-century climate than for seed sources adapted to mid- and late-century climate, which may experience significant early damage if the planting climate is too cold, (2) for surviving seedlings, longer term growth (10 or more years after planting) will be greatest for seed sources adapted to mid-century climate, followed by early- and late-century climate, (3) results will differ among species depending on the level of local adaptation (i.e., strong differences for specialists and weak differences for generalists), and (4) silvicultural practices will influence early and longer term seedling response according to how they influence the availability of growth-limiting resources:

- Larger stock types will have greater early survival and growth relative to smaller stock types, with the effects most pronounced for the mid- and late-century seed sources. Differences among treatment levels will be greatest early (1–10 years after implementation) and are likely to attenuate with time since planting.
- More intensive vegetation control treatments (e.g., herbicide application, multiple entries) will have greater survival and growth relative to less intensive treatments, with the effects most pronounced for the mid- and late-century seed sources. Differences among treatment levels will be greatest early (1–10 years after implementation) and are likely to attenuate with time since planting.

- Planting density will have limited effects on early growth and survival across all seed sources; treatment effects will become apparent after crown closure, with greater growth and survival for lower planting densities, and effects will be most pronounced in historical and early-century seed sources.

To address these research questions, we will assess the response variables—percentage of seedling survival, mean seedling height, and mean seedling diameter—as a function of the predictor variables—seed source and silvicultural treatment—and their interaction. We will fit site-specific, generalized linear mixed models of effects of seed source and silvicultural treatment at each site because management partners are most interested in outcomes specific to their site. Although we do not intend to fit a single model using data from all sites in the network, we will fit broader models of the same form, incorporating data from multiple sites that evaluate the same species and silvicultural treatment (e.g., six sites that evaluate Douglas-fir and vegetation control treatments). To standardize the effect of seed source climate across sites, we will evaluate the effect of transfer distance (deviation between seed source climate and planting site climate) rather than treating seed source as categorical. Models that incorporate multiple sites will require the inclusion of additional covariates that account for factors such as site climate, time of planting, vegetation cover, and soil properties. All site-specific models will include a random effect of block (or environmental covariates where a completely randomized design was used), while all models that include data from multiple sites will include random effects of block and site.

Lessons Learned

Seed Sources

Several challenges with seed source selection occurred during the implementation of this project. A key uncertainty underlying the process of seed selection is the use of climatic averages across broad seed zones to describe the climate associated with a seed source. Seed zones often have wide variation in climate, obscuring the specific climatic conditions for a given seed source (Young et al. 2020). While this is standard practice for assigning source climate, increasing precision for seed source locations would yield greater certainty for climatic transfer distances when those seeds are used for assisted population migration.

For sites at the lowest elevations, identification of seed adapted to late-century climate conditions was not always possible as no seed sources of the target species matched future climatic conditions. For such sites, we selected sources as close to predicted late-century conditions as possible, but the mismatch in projected site climate and seed source climates suggests that these sites may not support the species by the late 21st century. These sites may be useful for informing the utility of assisted population migration at the trailing edge of species distributions. In most cases, identification of seed sources adapted to projected future climate at a site was possible. However, neither the SST nor the CAST tools interface publicly with seed inventory, and many land management organizations have diverged from common seed transfer systems that were established in the mid-20th century (Johnson et al. 2004), so translation of output from the tools to available seed requires additional information from agencies that manage seed resources.

Obtaining seeds and seed inventory information was relatively easy for this project because of our partnerships and relatively small seed requests, but this step could be prohibitive for those lacking such partnerships. Currently, there is no central process for communication among seed owners to facilitate seed sharing. There is hesitancy within local jurisdictions to transfer seed, given uncertainties around future reforestation needs and abilities to replenish seed banks. This is especially true if attempting to transfer seed between management organizations and is challenging for managers not affiliated with major landowners. Policies and other factors (e.g., limited seed availability, non-overlapping inventory between land management organizations, differing seed zone systems among seed owners) that prevent sharing of seed across jurisdictional boundaries represent a key barrier to operational implementation of assisted population migration. However, current postfire reforestation needs have spurred development of cross-boundary approaches to address gaps in the reforestation pipeline, such as maximizing collection of cones in seed orchard and wildland settings, and sharing of cone and seed resources (Fargione et al. 2021).

Field Implementation

During the establishment of the first ENAMES sites, we learned that implementation of a research design using operational methods presents unique challenges. Planting at the earliest sites occurred with little oversight from the project team, and seedlings were not pin-flagged. This resulted in several problems for first-year measurements at two sites, including imprecise first-year mortality estimates (due to lack of documentation of the number of seedlings initially planted in each plot) and uncertainty regarding planted versus naturally regenerated seedlings. The process for site establishment was modified to include oversight from the project team during the planting process and placement of seedling boxes at each plot to ensure that seed sources are planted in the correct locations and that seedlings are pin-flagged immediately after planting to eliminate uncertainty in tree identities.

Sites were also planted under variable conditions because of differences in winter accessibility, challenges with coordinating seedling delivery with appropriate planting weather, and managing planting contracts. While differences in planting conditions add to the real-world sources of experimental noise, this is a feature of establishing a network across a broad range of environmental conditions and ownerships, and weather at the time of planting should be controlled for in subsequent analyses.

Early results from ENAMES sites also show that competing vegetation is a significant contributor to seedling mortality across seed sources. We have adjusted our protocol to track seedling survival from a larger sample—using a larger plot size—than initially planned to ensure that our sample size captures treatment effects.

Science-Management Partnership

A core tenet of this project is the use of a science-management partnership throughout the development, establishment, and measurement of the experimental network. Science-management partnerships represent a framework where researchers and practitioners participate equally in the generation of information needed for decision making (Littell et al. 2012). Whereas the traditional research model involves scientists developing knowledge and delivering an end product to practitioners that have limited involvement in that process (Kirchhoff et al. 2013), science-management partnerships involve all parties in the research process (Halofsky et al. 2018). In general, research conducted using the science-management partnership model is more likely to be actionable because of early participant involvement that allows operational concerns and needs to shape the direction of research (Beier et al. 2017, Cash et al. 2003). Development of climate adaptation strategies using science-management partnerships has been especially successful, as these partnerships draw on technical expertise from scientists and on-the-ground knowledge from practitioners to understand vulnerabilities of specific resources at a local scale (Halofsky et al. 2011, Littell et al. 2012, Raymond et al. 2013). Development of management approaches for climate adaptation during reforestation similarly requires technical expertise and local knowledge, supporting our use of this approach for ENAMES.

While science-management partnership in research has many benefits over using a traditional research model in applied science, the model also presents specific challenges that can be more demanding than traditional approaches (Naugle et al. 2020). Open communication between the project team, practitioner partners, and seed bank and nursery personnel is essential for successful implementation. Communication among all parties involved in a site required significant time and effort because the partnership comprises individuals with a range of priorities and backgrounds. Furthermore, given the scope of ENAMES, many individual science-management partnerships were required to implement this project. This led to logistical challenges and variability in quality of the partnership. The benefit of generating management-relevant information exceeds the costs associated with the science-management partnership model. However, we recommend dedicating substantial time and effort to developing relationships among all partners involved in project implementation to foster success.

Future of the Experimental Network

ENAMES aims to address questions regarding the effects of assisted migration and specific establishment silviculture practices on stand growth and survival through several decades of stand development. Remeasurements of height, diameter, and survival are planned on a 5-year cycle in collaboration between science and management partners. Establishment of experimental sites will continue through at least 2026 (fig. 3), with potential for new sites to be added to address specific knowledge gaps (e.g., ownership types, species, silvicultural practices). The project team is committed to maintaining this network over time, but the availability of future funding will influence the capacity to conduct planned remeasurements and add sites to the network.

An important outcome of ENAMES is the facilitation of knowledge exchange between researchers and practitioners to overcome social and logistical barriers to implementation of assisted population migration. Although there is scientific evidence supporting its utility for forest management (Aitken and Bemmels 2015), many individual practitioners remain concerned about the uncertainty of outcomes (Findlater et al. 2022). Additionally, the policies of some organizations prevent managers from pursuing assisted population migration (Neff and Larson 2014).

We aim to support the development of new projects that address specific scientific gaps by using the established network, as well as develop communication avenues that convey scientific information in a form useful to managers. For example, we expect that the network could be used to investigate additional questions regarding seed source interactions with edaphic and biotic factors (including forest pests and pathogens, mycorrhizae, and understory plant communities), which represent key uncertainties in the use of assisted population migration (Aitken and Whitlock 2013, Simler et al. 2019). We have also developed a website that will provide up-to-date information on ENAMES, summaries of our recent findings, summaries of available information on assisted population migration, and descriptions of relevant tools (USDA FS 2024). We also anticipate that the experimental sites will be useful as demonstration sites to showcase treatment effects for managers and other interested parties.

ENAMES provides a powerful opportunity to test the efficacy of assisted population migration and silvicultural establishment treatments across broad environmental gradients in operational reforestation settings in the Pacific west and northwest of North America. Effective implementation of assisted population migration as a climate adaptation practice requires a sound scientific basis and consideration of the policies and procedures that guide forest management across ownerships. Our use of a science-management partnership model to develop ENAMES accounts for both aspects, ensuring its findings are actionable and relevant to forest management.

Acknowledgments

We acknowledge our site partners at U.S. Department of the Interior, Bureau of Land Management; Confederated Tribes of the Colville Reservation; Oregon Department of Forestry; U.S. Department of Agriculture (USDA), Forest Service; and Washington Department of Natural Resources for providing logistical and technical assistance. We appreciate the field support of Forest Service staff, including M. Aguilar, L. Brodie, S. Dahms-May, B. DeAngelis, J. Dollins, A. Foster, T. Franklin, H. Holvorson, S. King, M. Lukey, A. Phillips, K. Sanghera, A. Smits, N. Stragier, and A. Teets. We thank Forest Service employees R. Cronn, J. Crotteau, J. Halofsky, J. Reinhardt, and J. Strunk for comments on an earlier version of the manuscript. Funding in support of this work was made possible by a special allocation from the Forest Service Deputy Chief for Research and Development; the USDA Northwest Climate Hub; the Western Wildland Environmental Threat Assessment Center; the Forest Service, Pacific Northwest Research Station; and American Forests.

U.S. Standard Equivalents

When you know:	Multiply by:	To find:
Millimeters (mm)	0.0394	Inches
Centimeters (cm)	0.394	Inches
Meters (m)	3.28	Feet
Hectares (ha)	2.47	Acres
Degrees Celsius (°C)	1.8 °C + 32	Degrees Fahrenheit

Metric Equivalents

When you know:	Multiply by:	To find:
Feet (ft)	0.305	Meters
Miles	1.609	Kilometers
Acres (ac)	0.405	Hectares
Trees per acre (TPA)	2.47	Trees per hectare

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APPENDIX 1
Experimental Network for Assisted Migration and Establishment Silviculture (ENAMES) Site Profiles

Bald Fire Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 40.844048°, −121.258504°; Lassen National Forest, Hat Creek Ranger District (nearest town: Little Valley, California)

SITE CHARACTERISTICS: The site is at a mean elevation of 4,850 ft, split into four disjunct blocks, on gently sloping terrain facing a variety of aspects (figs. A1.1, A1.2, A1.3). The soils are a mix of fine-loamy, mixed, mesic Ultic Argixerolls and loamy-skeletal, mixed, frigid Ultic Haploxeralfs. The mean annual temperature is 8.9 °C (coldest month 0.6 °C, warmest month 19.4 °C), and mean annual precipitation is 495 mm (45 mm as snow).

SITE HISTORY: The site, originally an east-side marginal pine forest, burned in the 2015 Bald Fire. We located the study site in mixed ponderosa pine/Jeffrey pine (*Pinus ponderosa/ P. jeffreyi*) stands, with scattered California black oak (*Quercus kelloggii*) and western juniper (*Juniperus occidentalis*).

PLANTED SPECIES: Primarily ponderosa pine with a mix of Jeffrey pine in some treatments

PRE-PLANTING SITE CONDITIONS: The land manager salvaged the site in the years prior to planting, with large trees removed and small trees and branches chipped on-site. Several attempts at planting without vegetation control were unsuccessful in the droughty late 2010s. Occasional planted ponderosa pines survived from these previous plantings, and we did not target them for removal prior to study site establishment. One experimental block had scattered sprouting California black oaks, but we repositioned plots where possible to avoid non-target herbicide effects on these hardwoods. Damage from cattle trampling and browse has contributed to regeneration failures.

PLANTING DATE: Planned for spring 2025

SITE PREPARATION: The site preparation crew backpack sprayed with a tank mix of Imazapyr (Polaris SP) and glyphosate (RoundUp Custom/RoundUp Pro Concentrate) herbicide with MSO surfactant and HiLite blue dye in late August–early September 2023, targeting green shrubs.

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We will use the Climate-Adapted Seed Tool (Reforestation Tools, n.d.) to choose four seed sources for planting.

SILVICULTURAL TREATMENTS: Four treatments: stock type (bareroot versus containerized) and species mix (pure ponderosa pine versus 50:50 mix of ponderosa and Jeffrey pines for bark beetle resistance) in a 2 × 2 factorial. All seedlings will receive Vexar shelters to protect against ungulate browsing.

PLANTING DENSITY: Operational contract crews will plant 250 trees per ac with a target surviving density of 125 trees per ac. Higher planted density acknowledges harsh conditions and prior planting failures.

SEEDLING STOCK TYPE: 1-year-old containerized stock and 1-0 bareroot stock (50:50 mix).

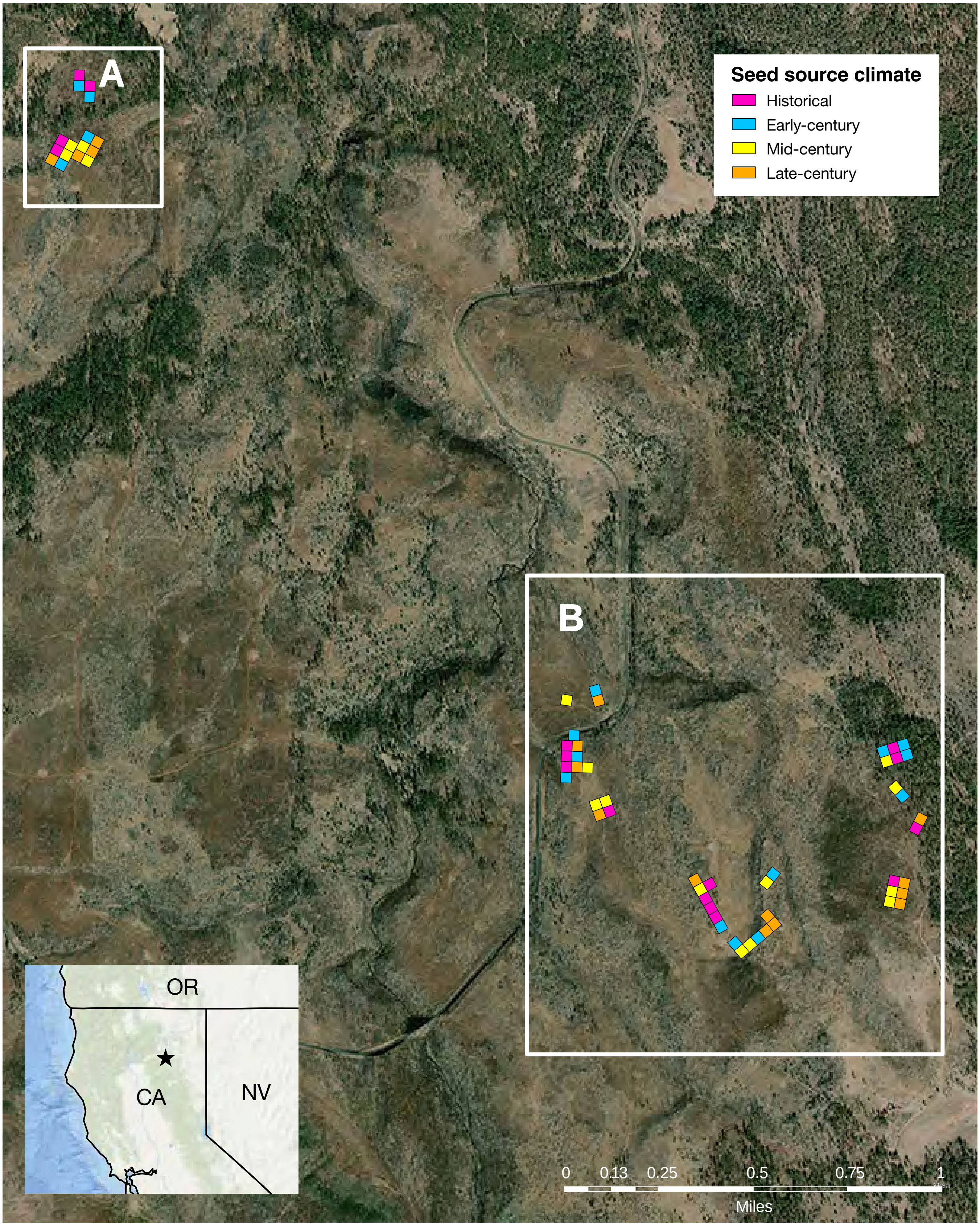

Figure A1.1—Bald Fire site with tentative experimental treatment plot layout. White boxes labeled A and B show the extent of maps in figures A1.2 and A1.3, respectively.

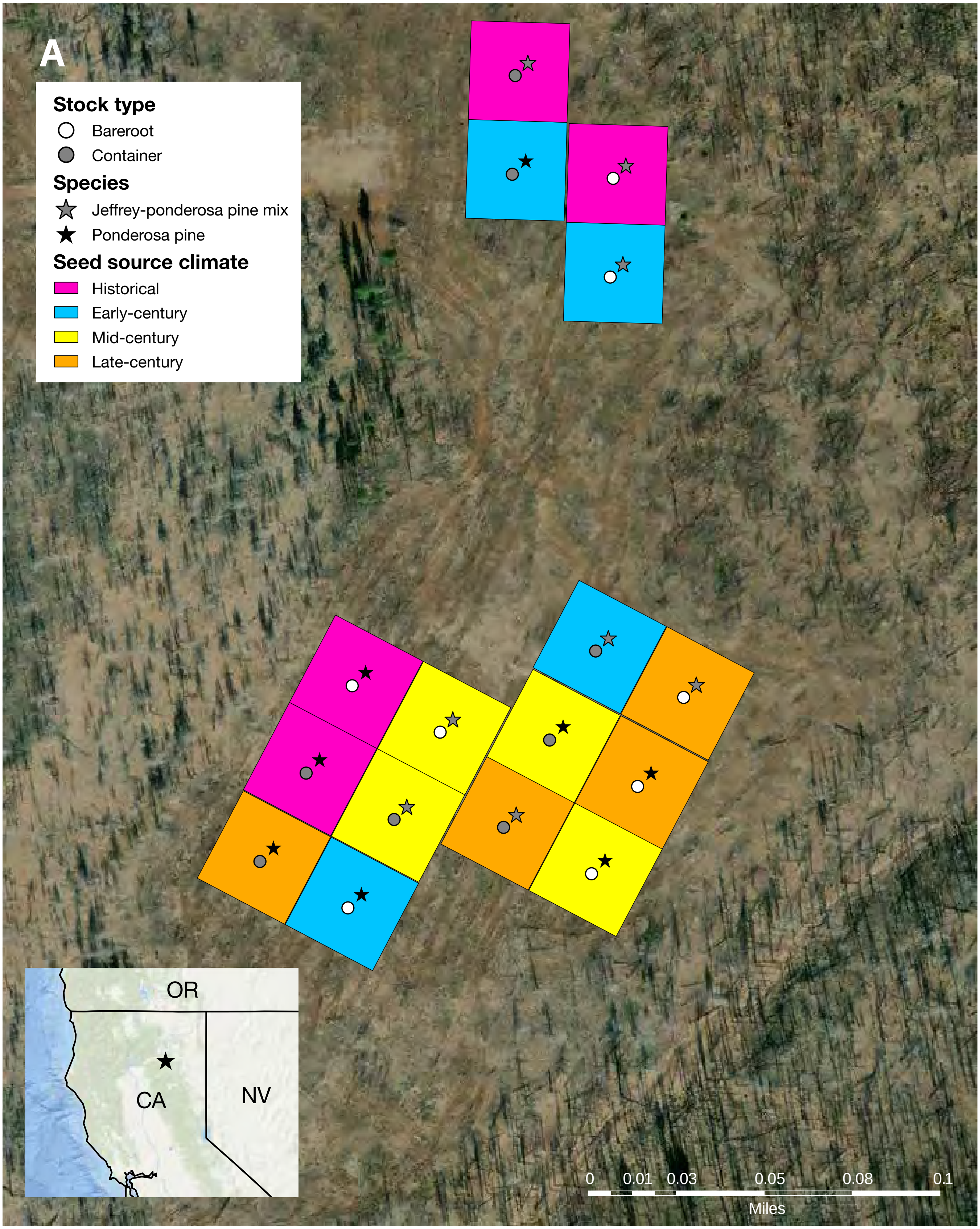

Figure A1.2—Bald Fire site with tentative layout of 16 experimental treatment plots. This is a zoomed-in view of box A in figure A1.1.

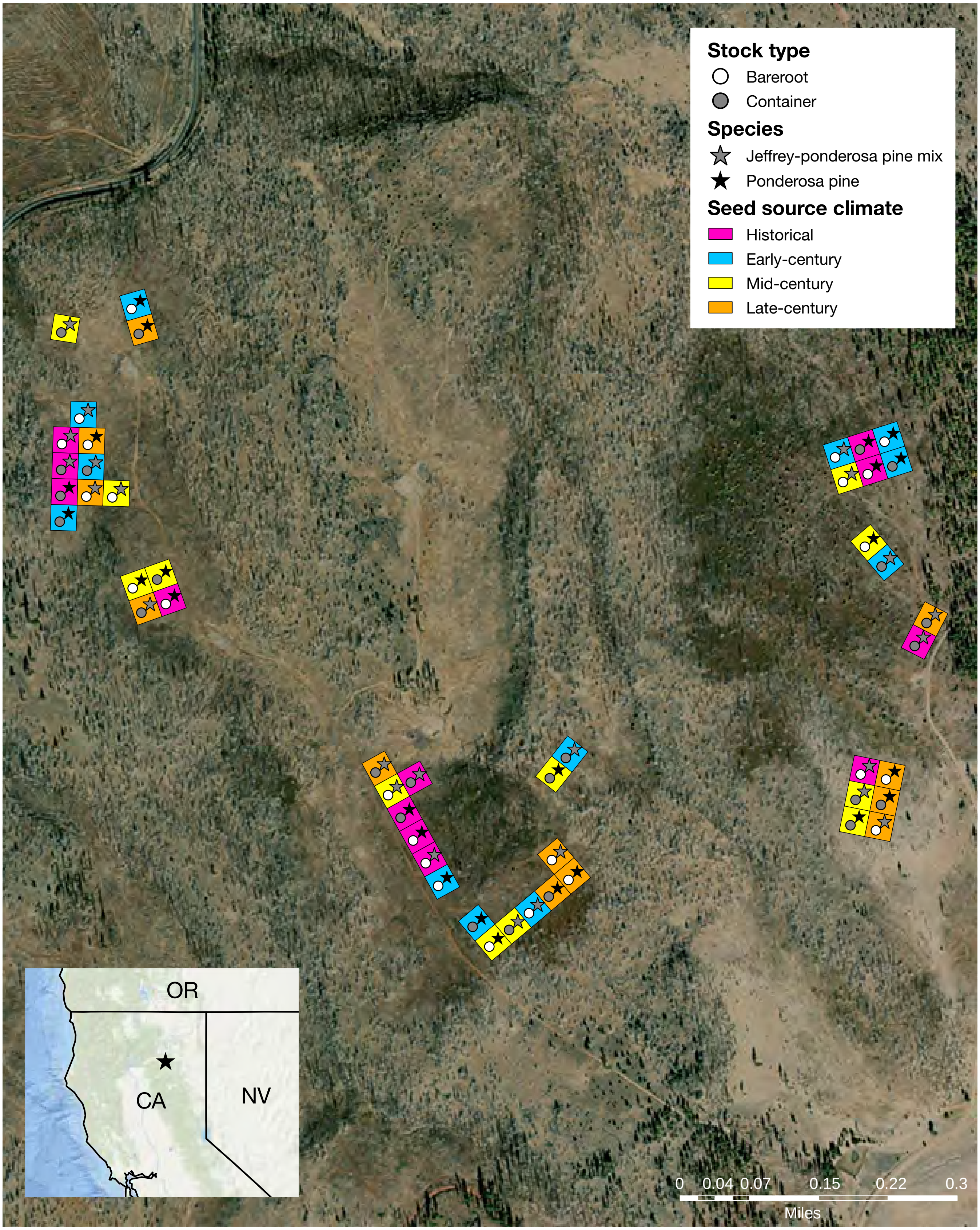

Figure A1.3—Bald Fire site with tentative layout of 48 experimental treatment plots. This is a zoomed-in view of box B in figure A1.1.

Berry Brush Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 39.654899°, −121.347157°; Plumas National Forest, Feather River Ranger District (nearest town: Brush Creek, California)

SITE CHARACTERISTICS: The site is at an elevation of 3,000 ft and faces SW with gentle slopes of <10 percent (fig. A1.4). The soils are fine-loamy, mixed, mesic Ultic Haploxeralfs. The mean annual temperature is 13.3 °C (coldest month 5.6 °C, warmest month 23.3 °C), and mean annual precipitation is 1692 mm (24 mm as snow).

SITE HISTORY: The site burned in the 2020 North Complex fire. Pre-fire stands consisted of a mix of ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), incense cedar (*Calocedrus decurrens*), white fir (*Abies concolor*), sugar pine (*Pinus lambertiana*), California black oak (*Quercus kelloggii*), Pacific madrone (*Arbutus menziesii*), tanoak (*Notholithocarpus densiflorus*), and Pacific dogwood (*Cornus nuttallii*).

PLANTED SPECIES: Douglas-fir

PRE-PLANTING SITE CONDITIONS: The land manager logged this area as part of a roadside salvage project in summer 2023. The treatment included removal of most woody biomass from the site with smaller woody detritus chipped and scattered. Prior to salvage, sprouting shrubs and hardwoods were waist height.

PLANTING DATE: Planned for spring 2025

SITE PREPARATION: Salvage reduced competing vegetation and scarified the soil. The site preparation crew applied herbicide (backpack spraying of a tank mix of glyphosate and triclopyr) in spring 2024.

EXPERIMENTAL DESIGN: Salvage was not as extensive as hoped, and due to space constraints we used a completely randomized design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Climate-Adapted Seed Tool (Reforestation Tools, n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Lassen and Plumas National Forests	3,000–3,500	4.54	167.1
Early-century (2011–2040)	Lassen and Plumas National Forests	2,500–3,000	5.34	193.0
Mid-century (2041–2070)	Lassen and Plumas National Forests	2,000–2,500	6.24	230.7
Late-century (2071–2100)	Lassen and Plumas National Forests	1,500–2,000	6.93	266.9

SILVICULTURAL TREATMENTS: Two species composition treatments: 100 percent planted Douglas-fir at 200 trees per ac versus a mixture of planted Douglas-fir at 160 trees per ac and 20 retained hardwood sprout clumps (genets) per ac sprout mix. Retained hardwoods were evenly spaced, with a species retention preference (in declining order) for California black oak, Pacific madrone, Pacific dogwood, and tanoak.

PLANTING DENSITY: Operational crews planted 160–200 trees per ac depending on treatment, anticipating that vigorous shrub competition will reduce survival even after control with herbicide.

SEEDLING STOCK TYPE: 1-year-old containerized stock

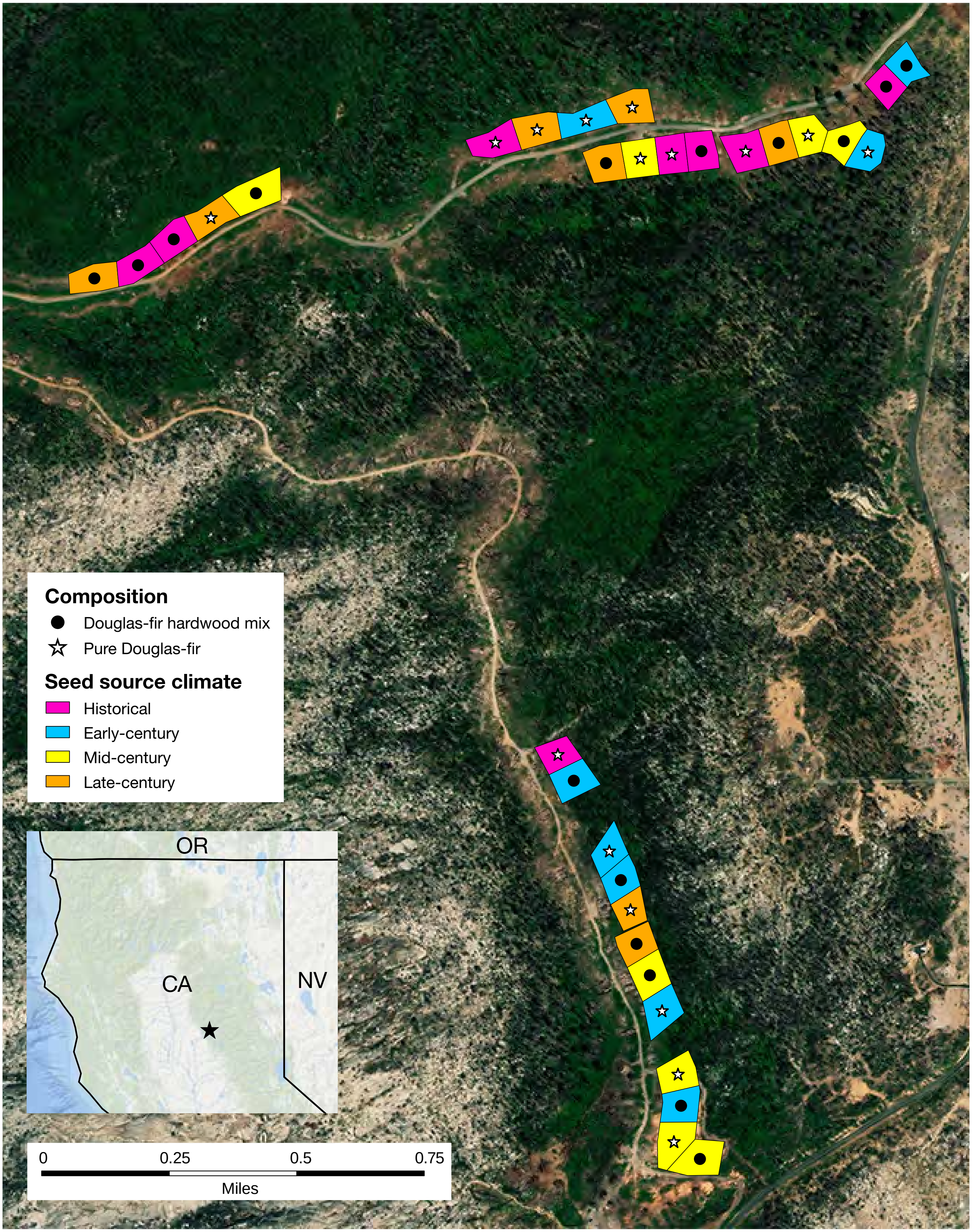

Figure A1.4—Berry Brush site with layout of 32 experimental treatment plots.

Burney Mountain Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 40.777414°, −121.583174°; Lassen National Forest, Hat Creek Ranger District (nearest town: Hat Creek, California)

SITE CHARACTERISTICS: The site is split into four blocks at an elevation of 4,750 ft on flat or minimally sloping (<5 percent slope) terrain (figs. A1.5, A1.6, A1.7). The soils of this young volcanic landscape are a mix of ashy, frigid Typic Vitrixerands and medial-skeletal frigid Ultic Haploxerands. One block is surrounded by old lava flows on three sides. The mean annual temperature is 9.4 °C (coldest month 1.1 °C, warmest month 13.9 °C), and mean annual precipitation is 1360 mm (129 mm as snow).

SITE HISTORY: The site, originally east-side mixed conifers, burned in the 2015 Eiler Fire. Pre-fire vegetation included a mixture of Douglas-fir (*Pseudotsuga menziesii*), Jeffrey pine (*Pinus jeffreyi*), sugar pine (*Pinus lambertiana*), Sierra lodgepole pine (*Pinus contorta* var. *murrayana*), and white fir (*Abies concolor*). Lands are a checkerboard of Forest Service and private ownership, with Sierra Pacific Industries lands adjacent to the experimental site.

PLANTED SPECIES: Douglas-fir

PRE-PLANTING SITE CONDITIONS: The site represented a mixture of recently salvaged and unsalvaged lands prior to 2023. By 2023, all four experimental blocks had been completely salvaged, with two blocks receiving prior herbicide treatment targeting shrubs. These blocks had been subject to mostly failed previous plantings prior to the recent adoption of herbicides. Scattered pockets of surviving planted pines and natural regeneration of lodgepole pine were present but avoided during plot layout.

PLANTING DATE: Planned for spring 2025

SITE PREPARATION: The site preparation crew backpack sprayed with a tank mix of Imazapyr (Polaris SP) and glyphosate (RoundUp Custom/RoundUp Pro Concentrate) herbicide with MSO surfactant and HiLite blue dye in late August–early September 2023, targeting green shrubs.

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We will use the Climate-Adapted Seed Tool (Reforestation Tools, n.d.) to choose four seed sources for planting.

SILVICULTURAL TREATMENTS: Four treatments: two stock types (bareroot versus containerized) and two species mixtures (100 percent Douglas-fir versus a 50:50 mix of Douglas-fir and Jeffrey pine)

PLANTING DENSITY: Operational contract crews will plant 250 trees per ac for a target established density of 125 trees per ac, acknowledging historically poor survival at this site.

SEEDLING STOCK TYPE: 1-year-old containerized stock and 1-0 bareroot stock

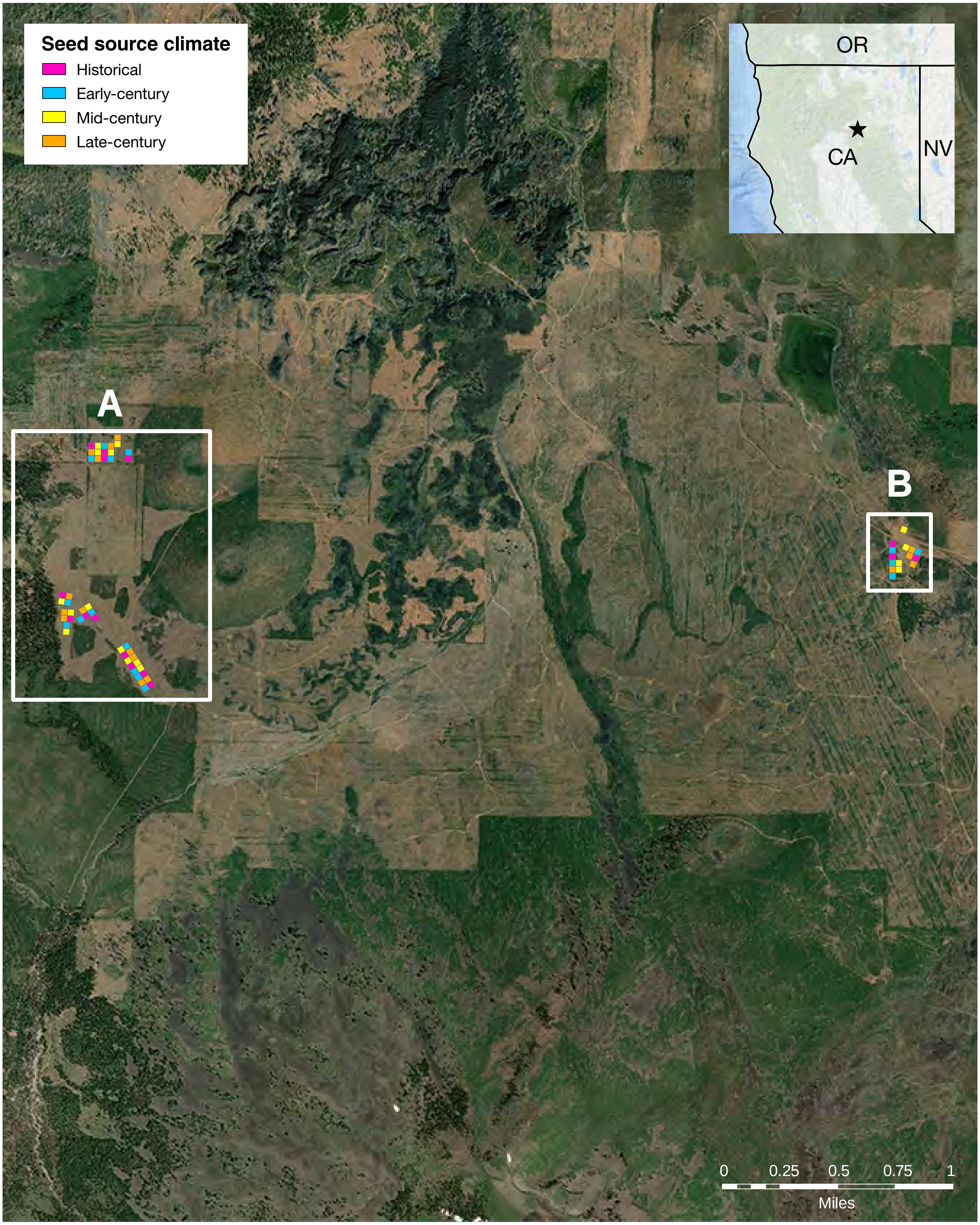

Figure A1.5—Burney Mountain site with tentative experimental treatment plot layout, zoomed out view of full site. White boxes labeled A and B show the extent of maps in figures A1.6 and A1.7, respectively.

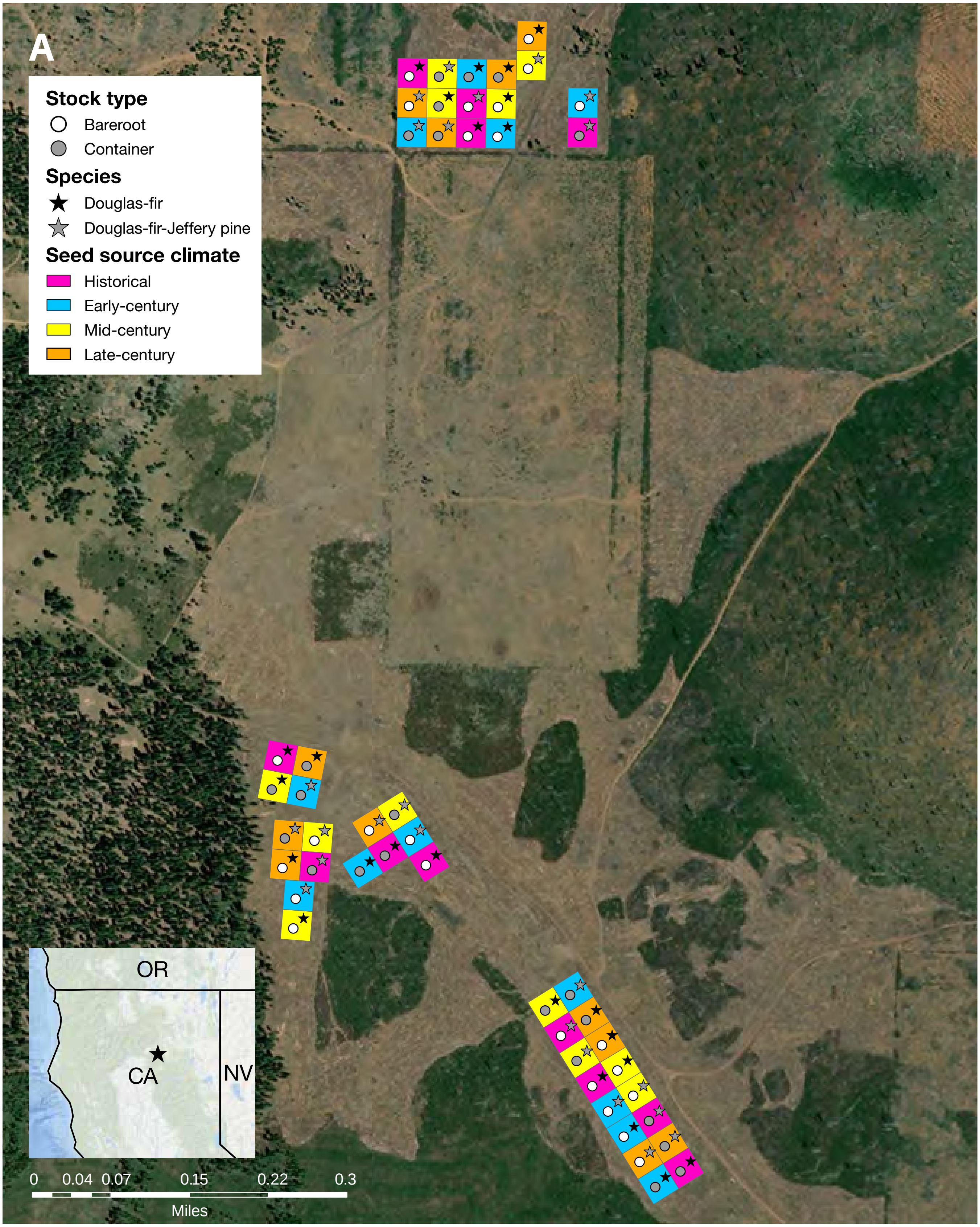

Figure A1.6—Burney Mountain site with tentative layout of 48 experimental treatment plots. This is a zoomed-in view of box A in figure A1.5.

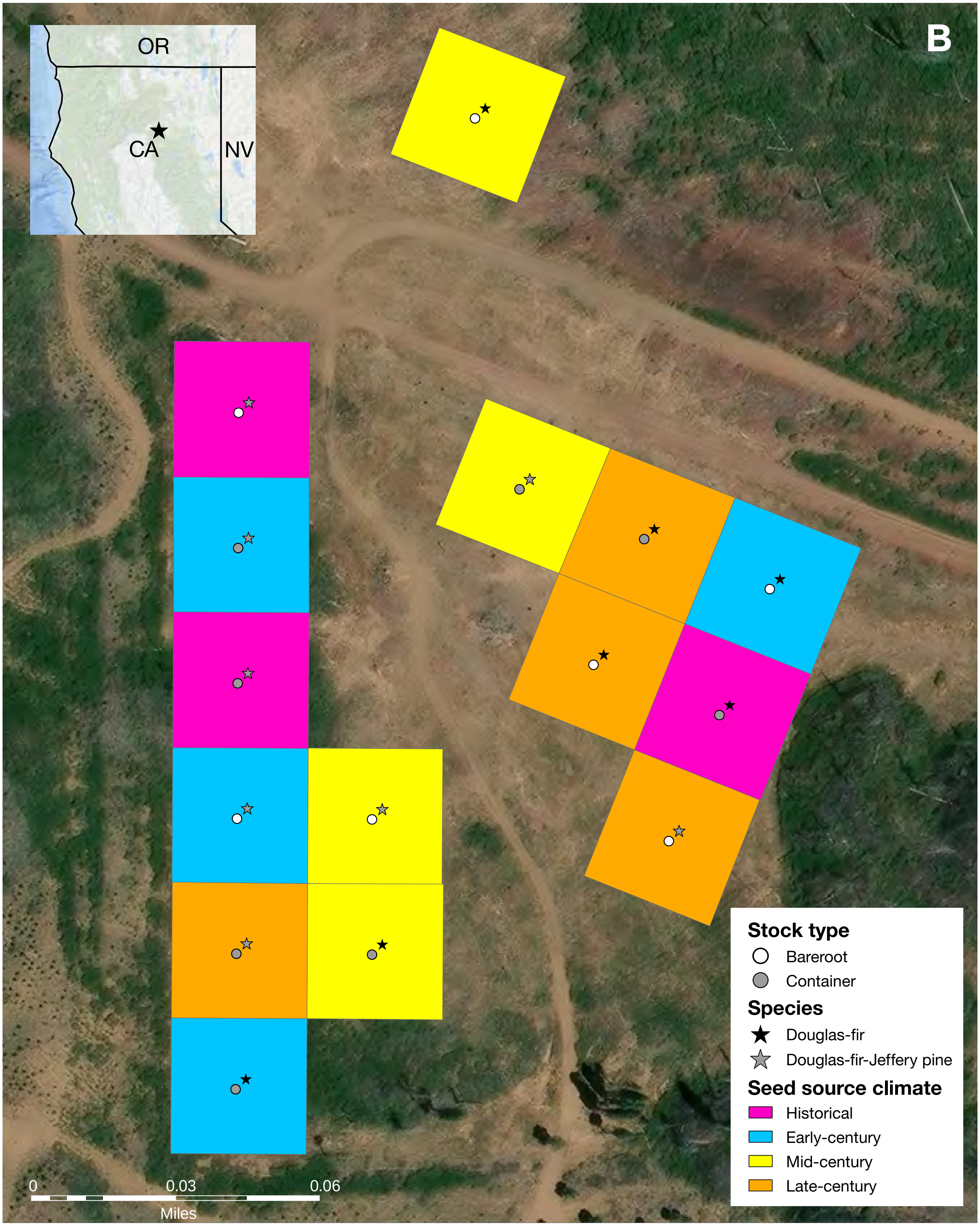

Figure A1.7—Burney Mountain site with tentative layout of 16 experimental treatment plots. This is a zoomed-in view of box B in figure A1.5.

Burnt Creek Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 43.318631°, −122.869955°;Umpqua National Forest, North Umpqua Ranger District (nearest town: Glide, Oregon)

SITE CHARACTERISTICS: The site is on an exposed, S-SW-facing, 5–15 percent slope at an elevation of 2,800 ft (fig. A1.8). The mean annual temperature is 10.6 °C (coldest month 3.3 °C, warmest month 18.9 °C), and the mean annual precipitation is 1871 mm (64 mm as snow).

SITE HISTORY: This site was a primarily Douglas-fir (*Pseudotsuga menziesii*) stand that was commercially thinned in 1992. The site burned with 100 percent tree mortality in the Archie Creek Fire, one of the 2020 Labor Day fires.

PLANTED SPECIES: Douglas-fir

PRE-PLANTING SITE CONDITIONS: This site experienced 100 percent tree mortality and was salvage harvested in 2022. Despite no expected recruitment in the area due to the high-severity burn, there has been a surprising response from the Douglas-fir seed bank, and some natural regeneration is now likely.

PLANTING DATE: Planned for spring 2025

SITE PREPARATION: Salvage harvest

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation FEET	Mean coldest month temperature DEGREES CELSIUS	Summer heat moisture index UNITLESS
Historical (1961–1990)	Umpqua National Forest	2,000–3,000	2.74	69.3
Early-century (2011–2040)	Siuslaw National Forest	<1,000	4.95	59.7
Mid-century (2041–2070)	Siskiyou National Forest	500–2,000	4.83	86.2
Late-century (2071–2100)	Humboldt County, CA	2,000–2,500	7.00	113.0

SILVICULTURAL TREATMENTS: Three different seedling stock types (see below)

PLANTING DENSITY: Operational contract crews will plant 200 trees per ac.

SEEDLING STOCK TYPE: 2-year stock: 2-0 bareroot; 1-year stock: Styro-8 plugs, Q-plugs (Q+1)

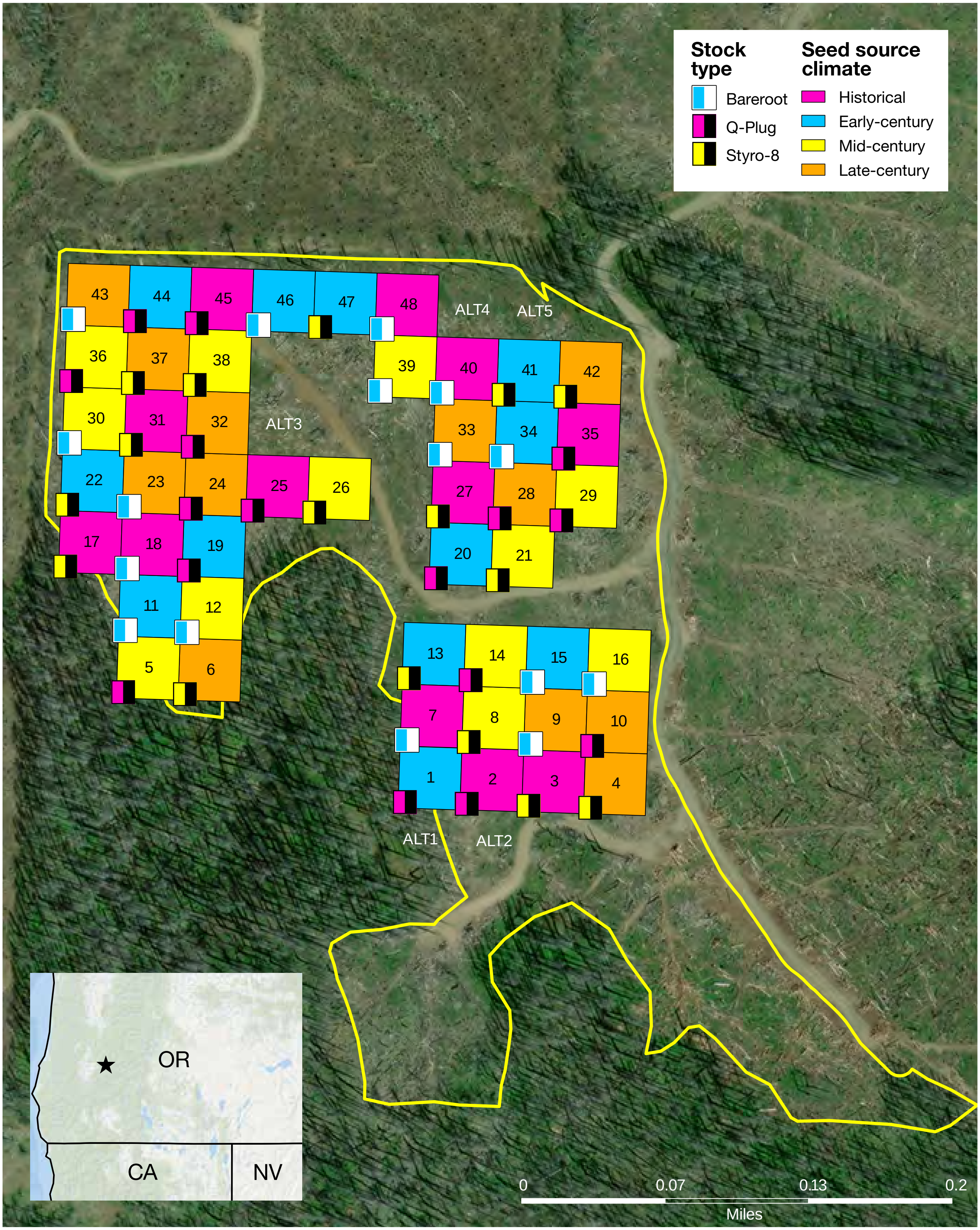

Figure A1.8—Burnt Creek site with tentative layout of 48 experimental treatment plots.

Caldor Fire Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 38.6293254°, −120.4099775°; Eldorado National Forest, Placerville Ranger District (nearest town: Pollock Pines, California)

SITE CHARACTERISTICS: The site is at an elevation of 5,400 ft and faces SW, with a slope of 17–27 percent (fig. A1.9). The soils are moderately deep, well-drained, gravelly sandy loams formed in material weathered from andesitic mudflows. The mean annual temperature is 10.0 °C (coldest month 1.7 °C, warmest month 20.0 °C), and mean annual precipitation is 1309 mm (99 mm as snow).

SITE HISTORY: The site burned in the 2021 Caldor Fire.

PLANTED SPECIES: Douglas-fir (*Pseudotsuga menziesii*)

PLANTING DATE: Spring 2023

SITE PREPARATION: None

EXPERIMENTAL DESIGN: Completely randomized design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Climate-Adapted Seed Tool (Reforestation Tools, n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Eldorado National Forest	4,500–5,000	3.11	188.0
Early-century (2011–2040)	Eldorado National Forest	4,000–4,500	3.99	209.1
Mid-century (2041–2070)	Eldorado National Forest	3,000–3,500	5.26	276.3
Late-century (2071–2100)	Eldorado National Forest	2,500–3,000	5.89	313.1

SILVICULTURAL TREATMENTS: None

PLANTING DENSITY: Operational contract crews planted 300 trees per ac.

SEEDLING STOCK TYPE: Containerized (Styro 6 for the historical, early-century, and late-century seed sources, Styro 91 for the mid-century seed source)

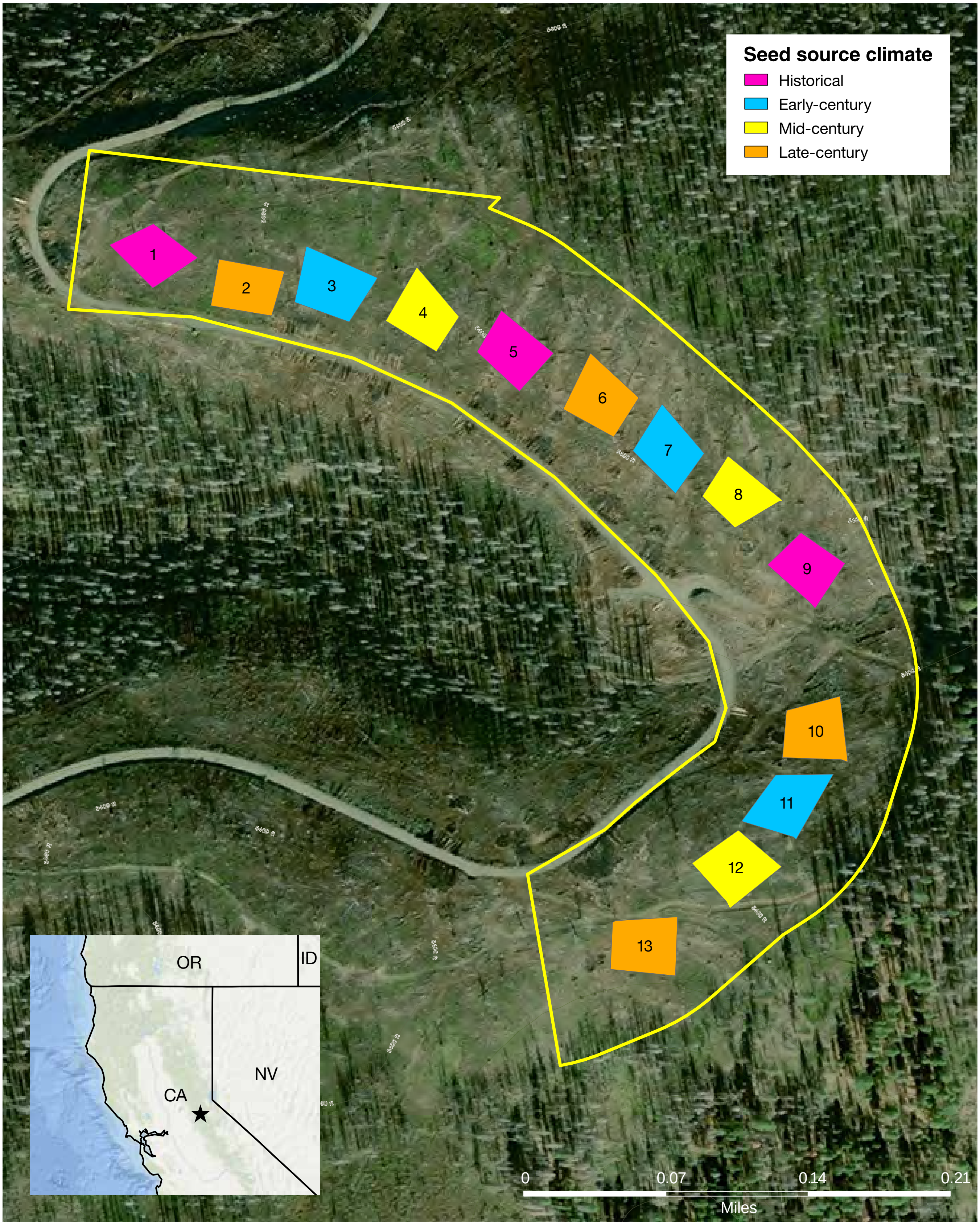

Figure A1.9—Caldor Fire site with layout of 13 experimental treatment plots.

Carlton Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 48.337896°, −119.903164°; Okanogan-Wenatchee National Forest, Methow Valley Ranger District (nearest town: Twisp, Washington)

SITE CHARACTERISTICS: The site is at an elevation of 3,700 ft and faces S-SE, with a gentle slope of about 1 percent (fig. A1.10). The soil is very deep, well-drained, ashy, sandy loam derived from outwash mixed with minor amounts of volcanic ash and loess. The mean annual temperature is 5.0 °C (coldest month −6.1 °C, warmest month 16.7 °C), and mean annual precipitation is 445 mm (167 mm as snow).

SITE HISTORY: The site burned with high severity as part of the Carlton Complex fire in the summer of 2014. Before the fire, the stand was dominated by ponderosa pine (*Pinus ponderosa*), with likely minor components of Douglas-fir (*Pseudotsuga menziesii*), western larch (*Larix occidentalis*), and Engelmann spruce (*Picea engelmannii*).

PLANTED SPECIES: Ponderosa pine

PLANTING DATE: Fall 2021

SITE PREPARATION: The site was salvage logged prior to planting.

PRE-PLANTING SITE CONDITIONS: Given the high-severity burn and salvage harvest, the site had virtually no remaining canopy and very minimal vegetation at the time of planting. Scattered shrubs, graminoids, and naturally regenerating pine seedlings were present at the site.

EXPERIMENTAL DESIGN: Randomized complete block design with four replications per assisted migration treatment by silvicultural treatment combination applied to 1-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation FEET	Mean coldest month temperature DEGREES CELSIUS	Summer heat moisture index UNITLESS
Historical (1961–1990)	Okanogan National Forest	3,000–4,000	–5.72	123.4
Early-century (2011–2040)	Wenatchee National Forest	3,000–3,500	–4.12	172.2
Mid-century (2041–2070)	Wenatchee National Forest	<4,000	–3.03	139.7
Late-century (2071–2100)	Deschutes National Forest	3,500–4,000	–0.96	141.2

SILVICULTURAL TREATMENTS: None tested. Shade cards were installed next to each seedling.

PLANTING DENSITY: Operational contract crews planted 150 trees per ac.

SEEDLING STOCK TYPE: 1-0 bareroot seedlings.

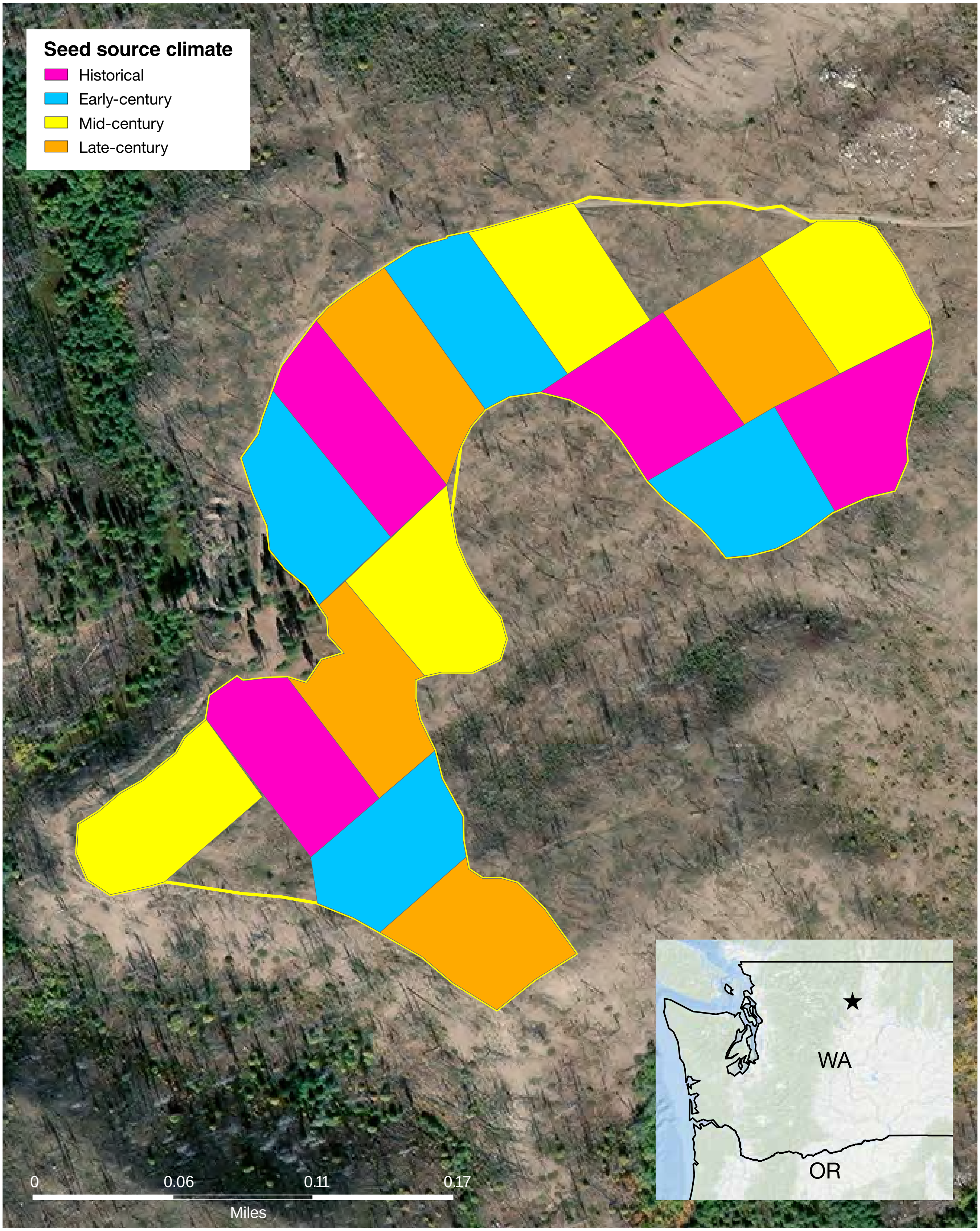

Figure A1.10—Carlton site with layout of 16 experimental treatment plots.

Cedar Cub Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 48.4308°, −120.2827°; Okanogan-Wenatchee National Forest, Chelan Ranger District (nearest town: Winthrop, Washington)

SITE CHARACTERISTICS: The site is at an elevation of 4,100 ft and faces SE-S-SW, with a moderate slope of 21–36 percent (fig. A1.11). The site is fairly rocky, and the soils are shallow to deep ashy loams formed in colluvium, residuum and glacial till from schist, gneiss, rhyodacite, and quartz latite, with minor amounts of volcanic ash and loess. The mean annual temperature is 5.6 °C (coldest month −4.4 °C, warmest month 16.1 °C), and mean annual precipitation is 632 mm (263 mm as snow).

SITE HISTORY: The site burned in the 2021 Cedar Creek Fire.

PLANTED SPECIES: Ponderosa pine (*Pinus ponderosa*)

PRE-PLANTING SITE CONDITIONS: Since the fire burned with high intensity in this area, there are many standing dead trees and no live trees. There are scattered downed trees throughout the site, but the ground is largely clear of woody debris. Ground cover is largely herbaceous, with dense pockets of Canada thistle (*Cirsium arvense*) and a very small amount of natural ponderosa pine regeneration. A skid trail runs through the site, but we avoided it during planting.

PLANTING DATE: Spring 2024

SITE PREPARATION: None

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Okanogan National Forest	3,000–4,000	–5.72	123.4
Early-century (2011–2040)	Wenatchee National Forest	<4,000	–3.03	139.7
Mid-century (2041–2070)	Gifford Pinchot National Forest	2,000–2,500	–1.31	231.4
Late-century (2071–2100)	Deschutes National Forest	3,500–4,000	–0.96	141.2

SILVICULTURAL TREATMENTS: Three different planting densities (see below)

PLANTING DENSITY: Operational crews planted 150, 200, and 250 trees per ac.

SEEDLING STOCK TYPE: Styro 10 (large, containerized stock)

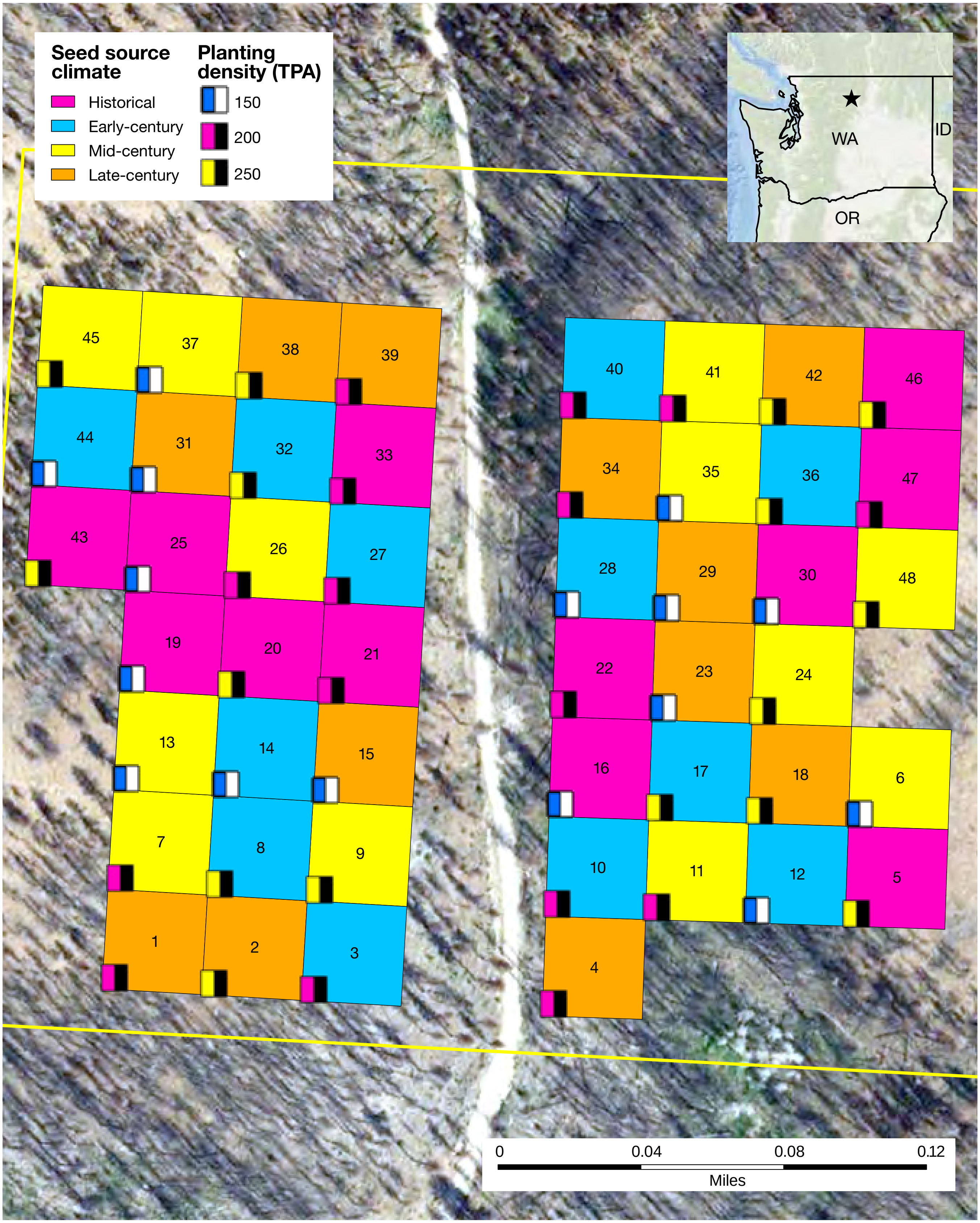

Figure A1.11—Cedar Cub site with layout of 48 experimental treatment plots. TPA = trees per acre.

Detroit (Two Adjacent Sites)

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 44.734439°, –122.171184° and 44.7369°, –122.1659°; Willamette National Forest, Detroit Ranger District (nearest town: Detroit, Oregon)

SITE CHARACTERISTICS: The sites are directly adjacent to the Detroit Ranger Station, at a mean elevation of 1,800 ft, and face SW with a moderate slope of 10–27 percent (fig. A1.12). The soils are deep, somewhat well-drained, gravelly cobbly loam formed from colluvium and slide deposits derived from igneous rock mixed with volcanic ash. The mean annual temperature is 9.4 °C (coldest month 1.7 °C, warmest month 17.8 °C), and mean annual precipitation is 2081 mm (134 mm as snow).

SITE HISTORY: The sites burned during the 2020 Beachie Creek Fire (part of the 2020 Labor Day fires)

PLANTED SPECIES: Douglas-fir (*Pseudotsuga menziesii*)

PRE-PLANTING SITE CONDITIONS: At the time of planting, the salvaged site had no remaining overstory, a few stumps, minor woody debris and little vegetation, with a ground cover of mostly California blackberry (*Rubus ursinus*) and common ladyfern (*Athyrium filix-femina*). The non-salvaged site had a significant amount of standing and down dead trees and woody debris, with California blackberry and common ladyfern ground cover. Both sites had some natural Douglas-fir regeneration.

PLANTING DATE: Spring 2023

SITE PREPARATION: One of the sites was salvage harvested and the other had no site preparation (fig. A1.12).

EXPERIMENTAL DESIGN: Randomized complete block design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting for both sites:

Climate period	Seed source characteristics			
	Seed origin	Elevation FEET	Mean coldest month temperature DEGREES CELSIUS	Summer heat moisture index UNITLESS
Historical (1961–1990)	Willamette National Forest	1,000–2,000	2.06	53.9
Early-century (2011–2040)	Willamette National Forest	1,000–2,000	3.29	79.0
Mid-century (2041–2070)	Siuslaw National Forest	1,000–2,000	4.53	62.2
Late-century (2071–2100)	Six Rivers National Forest	500–1,000	5.76	75.4

SILVICULTURAL TREATMENTS: None

PLANTING DENSITY: Operational contract crews planted 200 trees per ac.

SEEDLING STOCK TYPE: Containerized

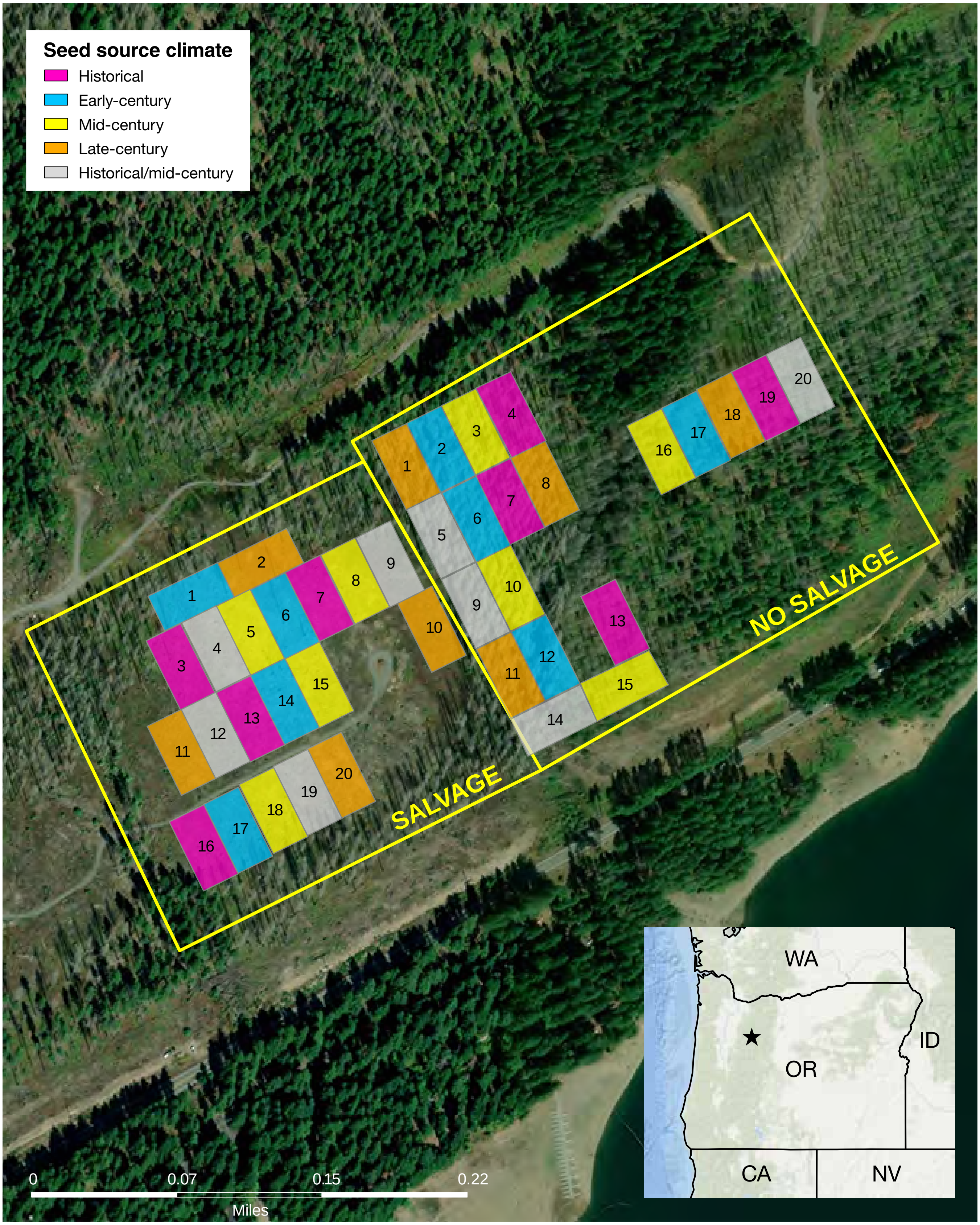

Figure A1.12—Detroit sites with layout of experimental treatment plots for the salvaged and the nonsalvaged sites. Post-fire imagery is not yet available.

Falls Creek Site

OWNERSHIP: U.S. Department of the Interior, Bureau of Land Management (BLM)

LOCATION: 44.945793°, −122.524416°; NW Oregon District (nearest town: Silverton, Oregon)

SITE CHARACTERISTICS: The site is at an elevation of 2,500 ft and faces S-SW with a moderate slope of approximately 18 percent (fig. A1.13). The soils are deep, well-drained, gravelly loams formed in colluvium from andesite, breccias, tuffs, and volcanic ash, and silty loams formed in loess and glacial till from igneous and metamorphic bedrock. The mean annual temperature is 8.3 °C (coldest month 2.2 °C, warmest month 15.6 °C), and mean annual precipitation is 2071 mm (124 mm as snow).

SITE HISTORY: The site, originally a predominantly Douglas-fir (*Pseudotsuga menziesii*) stand, underwent a thinning in 2012 and a regeneration harvest in 2022.

PLANTED SPECIES: Douglas-fir

PRE-PLANTING SITE CONDITIONS: The site has extensive woody debris throughout, including large, scattered slash piles. Clumps of large live trees are scattered throughout the site as well. We placed experimental plots to avoid these clumps and debris as much as possible, but they were unavoidable in some areas. Understory regeneration was very minimal, with no visible natural conifer regeneration.

PLANTING DATE: Spring 2024

SITE PREPARATION: None

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation FEET	Mean coldest month temperature DEGREES CELSIUS	Summer heat moisture index UNITLESS
Historical (1961–1990)	BLM—Molalla area	600–2,400	2.78	54.4
Early-century (2011–2040)	BLM—Santiam area	800–2,600	2.72	51.7
Mid-century (2041–2070)	BLM—Alsea area	900–2,300	4.15	72.1
Late-century (2071–2100)	BLM—Coquille 16 area	<1,600	6.36	80.6

SILVICULTURAL TREATMENTS: Vegetation control by herbicide application with four treatment variations (two different radii of treatment, one application versus two applications)

PLANTING DENSITY: Operational contract crews planted 250 trees per ac.

SEEDLING STOCK TYPE: Styro 515 containerized stock

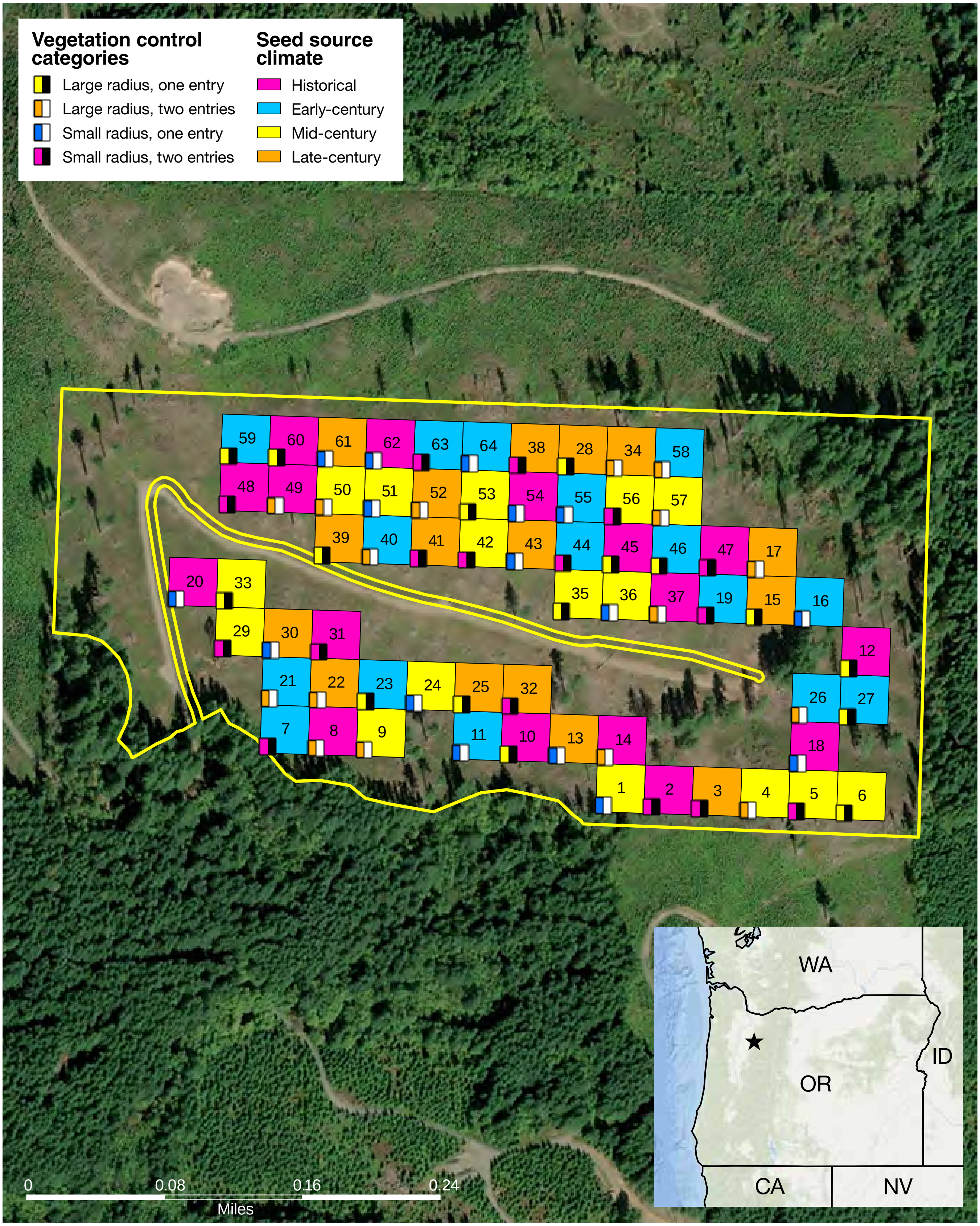

Figure A1.13—Falls Creek site with layout of 64 experimental treatment plots. Post-fire imagery is not yet available.

Fuego Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 42.6334407°, −121.4256785°; Fremont-Winema National Forest, Bly Ranger District (nearest town: Sprague River, Oregon)

SITE CHARACTERISTICS: The site is at an elevation of 5,800 ft and faces N-NE-E, with a moderate slope of 10–27 percent (fig. A1.14). The soils are excessively drained, gravelly loamy coarse sands formed in residuum from pumice and volcanic ash. The mean annual temperature is 5.6 °C (coldest month −2.8 °C, warmest month 15.6 °C), and mean annual precipitation is 715 mm (237 mm as snow).

SITE HISTORY: The site was originally a mixed-conifer stand that was heavily logged 60 to 70 years ago. It burned with high severity (more than 90-percent tree mortality) in the 2021 Bootleg Fire.

PLANTED SPECIES: Ponderosa pine (*Pinus ponderosa*)

PRE-PLANTING SITE CONDITIONS: There should be little remaining overstory and slash after the site preparation treatment. Trees greater than 22 inches and trees less than 9 inches diameter at breast height (DBH) will not be removed, so there will be remaining snags and downed woody debris in these size classes. Natural regeneration is expected to be low due to high tree mortality; however, the site is adjacent to areas that experienced lower mortality, so some natural conifer regeneration is possible.

PLANTING DATE: Planned for spring 2026

SITE PREPARATION: Site preparation will include removal of dead trees 9 to 22 inches DBH with retention of 5 to 10 tons per ac of woody material and coarse woody debris.

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Fremont-Winema National Forest	5,500–6,000	−2.50	129.1
Early-century (2011–2040)	Modoc National Forest	5,500–6,000	−1.37	144.6
Mid-century (2041–2070)	Shasta-Trinity National Forest	3,500–4,000	0.60	151.0
Late-century (2071–2100)	Stanislaus National Forest	4,000–4,500	3.90	266.8

SILVICULTURAL TREATMENTS: Two different seedling stock types (see below)

PLANTING DENSITY: Operational contract crews will plant 222 trees per ac.

SEEDLING STOCK TYPE: 2-0 bareroot and 1-year-old containerized seedlings

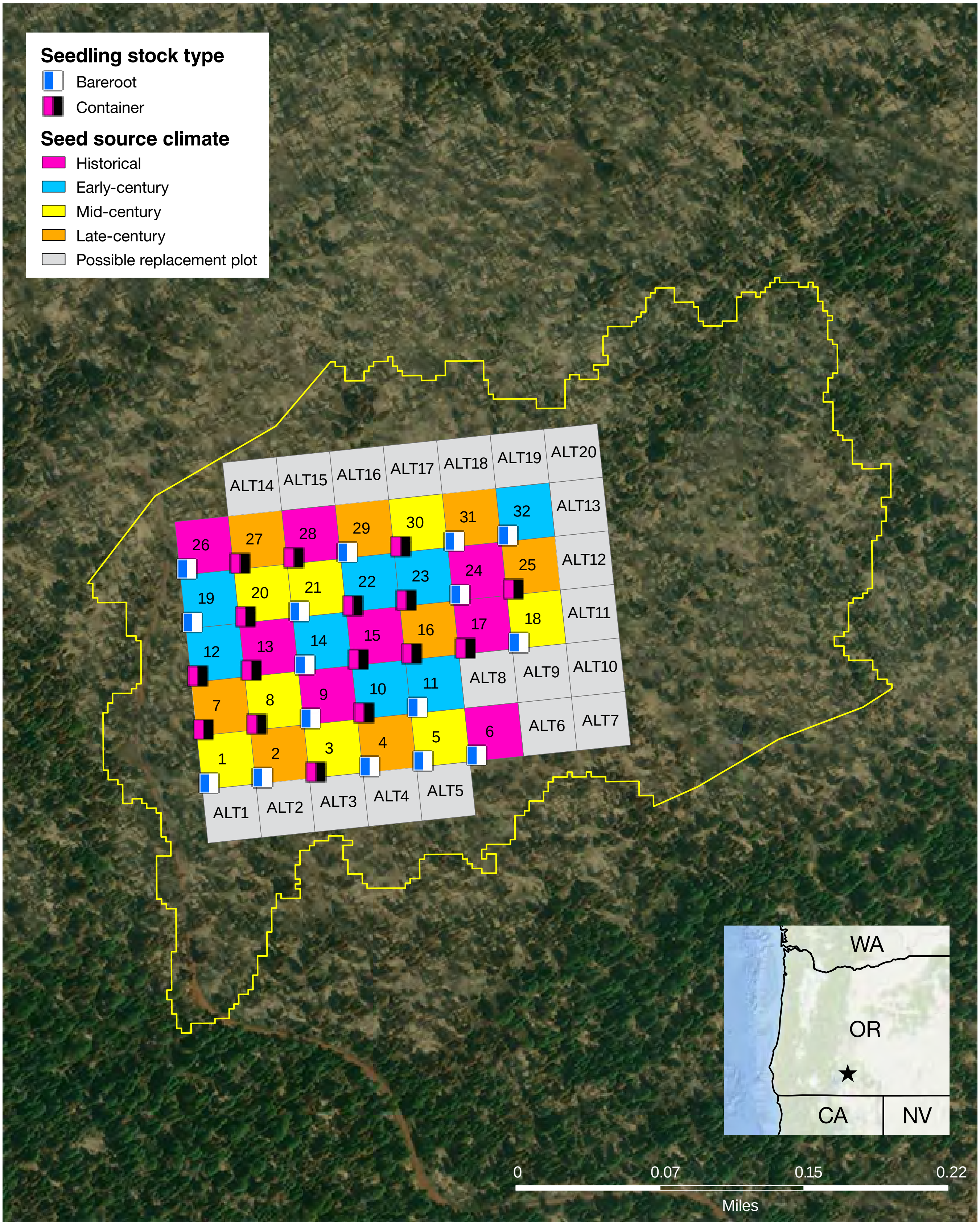

Figure A1.14—Fuego site with tentative layout of 32 experimental treatment plots and 20 possible replacement plots.

Gawley Panther Sites 1 and 2

OWNERSHIP: Oregon Department of Forestry (ODF)

LOCATION: 44.9111801°, −122.4038170° and 44.92689°, −122.36660°; nearest town: Elkhorn, Oregon

SITE CHARACTERISTICS: The sites are at an elevation of 4,000 ft (S-facing) (fig. A1.15) and 2,400 ft (N-facing) (fig. A1.16), both with a slope of 18–29 percent. The soils are deep, well-drained, gravelly loams formed in colluvium weathered from andesite rocks mixed with volcanic ash. The mean annual temperature is 7.2 °C (coldest month 1.1 °C, warmest month 14.4 °C), and mean annual precipitation is 2465 mm (254 mm as snow).

SITE HISTORY: Before burning in the 2020 Beachie Creek Fire, these sites were a mixed Douglas-fir (*Pseudotsuga menziesii*)/noble fir (*Abies procera*) stand with some mountain (*Tsuga mertensiana*) and western hemlock (*Tsuga heterophylla*) and a very small hardwood component. Management history records for this area unfortunately burned during the same fire, but the stand was likely 40–60 years old, having been planted after an initial harvest and then commercially thinned 10–15 years before it burned.

PLANTED SPECIES: Douglas-fir

PRE-PLANTING SITE CONDITIONS: Since the sites were salvage harvested, they are almost entirely clear except for a few live trees and snags in some areas. Woody debris covers about half of the area within the sites, with moderate-sized burn piles scattered throughout both sites. Natural regeneration includes some ferns and rhododendron, as well as a very small amount of noble fir and Douglas-fir.

PLANTING DATE: Spring 2024

SITE PREPARATION: Salvage harvest and baseline herbicide spray in 2023

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	ODF—North Cascades area	>2,750	1.00	37.9
Early-century (2011–2040)	ODF—Nehalem area	<2,750	3.17	47.2
Mid-century (2041–2070)	ODF— Burnt Woods area	<2,000	3.61	97.9
Late-century (2071–2100)	ODF—South Central Coast area	<1,500	5.04	67.6

SILVICULTURAL TREATMENTS: Four treatments: two different planting densities (see below) and herbicide spray versus no herbicide control

PLANTING DENSITY: Operational contract crews planted 436 (standard operating density) and 303 trees per ac.

SEEDLING STOCK TYPE: 515 containerized seedlings

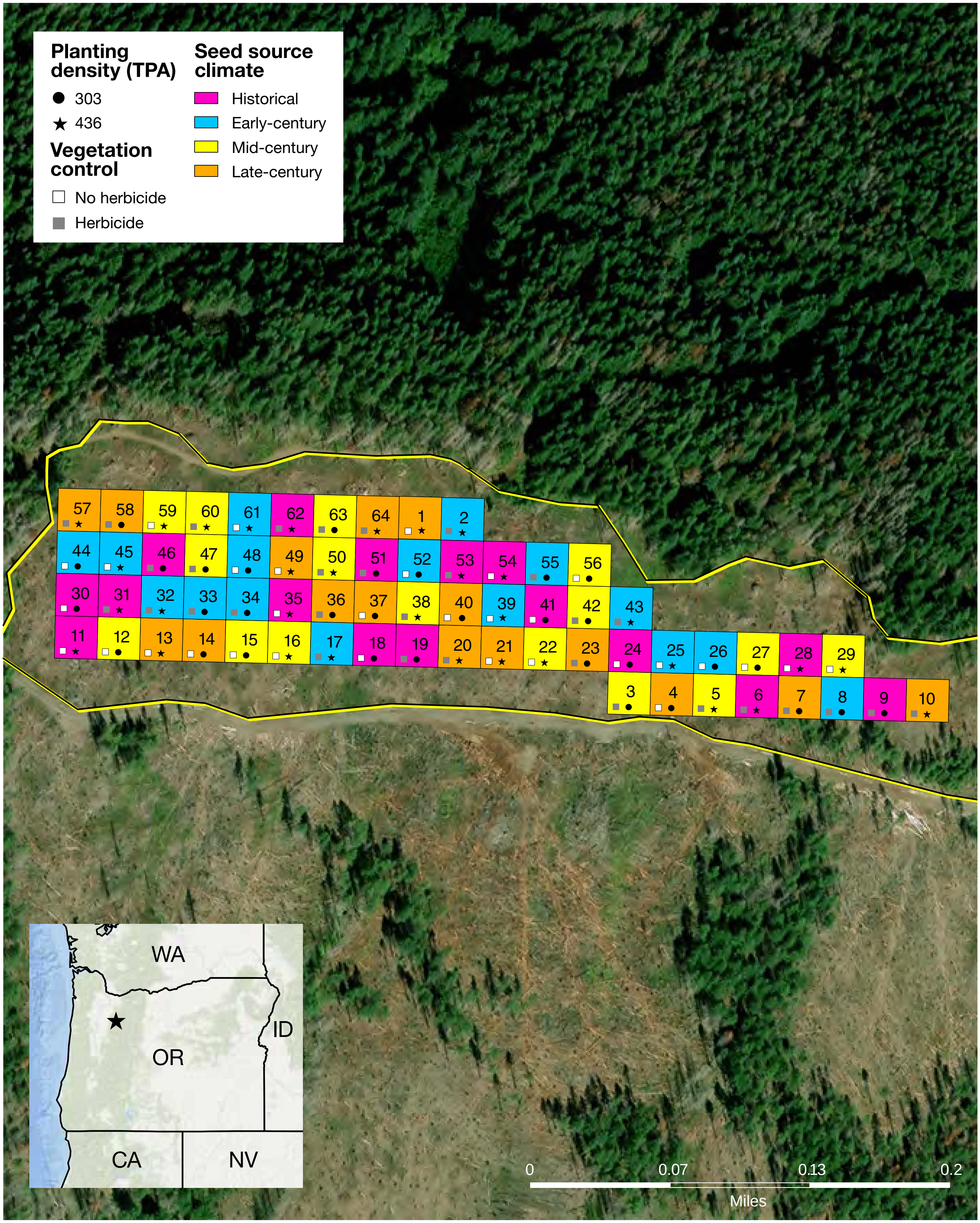

Figure A1.15—Gawley Panther 1 (S-facing) site with layout of 64 experimental treatment plots. Post-fire imagery is not yet available. TPA = trees per acre.

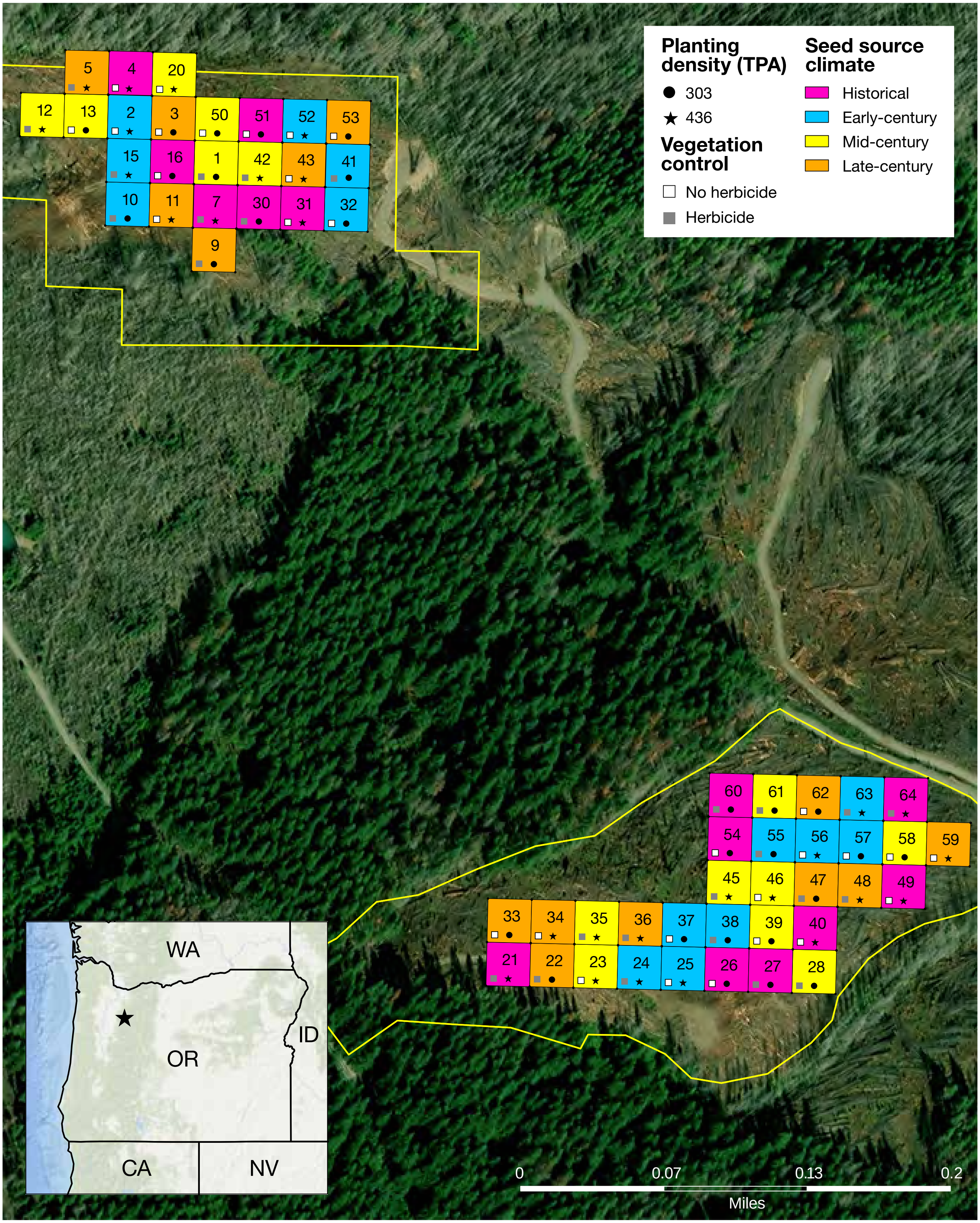

Figure A1.16—Gawley Panther 2 (N-facing) site map with layout of 56 experimental treatment plots. Post-fire imagery is not yet available. TPA = trees per acre.

Government 40 Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 39.612901°, −121.201150°; Plumas National Forest, Feather River Ranger District (nearest town: Lumpkin, California)

SITE CHARACTERISTICS: The site is at an elevation of 3,800 ft and faces SW with slopes of generally <10 percent (fig. A1.17). The soils are fine-loamy, mixed, active, mesic Typic Haploxerults. Mean annual temperature is 12.8 °C (coldest month 5.0 °C, warmest month 22.2 °C), and mean annual precipitation is 1829 mm (34 mm as snow). Potential site productivity is high with a Dunning site class of II and ponderosa pine site index of 110 (base age 50) assessed nearby.

SITE HISTORY: The site, originally a west-side mixed-conifer-hardwood forest, burned in the 2020 North Complex fire. Stands consisted of a mixture of ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), incense cedar (*Calocedrus decurrens*), white fir (*Abies concolor*), sugar pine (*Pinus lambertiana*), California black oak (*Quercus kelloggii*), Pacific madrone (*Arbutus menziesii*), and tanoak (*Notholithocarpus densiflorus*). The site was a small inholding of mature forest surrounded by intensively managed private lands (Sierra-Pacific Industries).

PLANTED SPECIES: Ponderosa pine

PRE-PLANTING SITE CONDITIONS: The site was salvaged in two stages because the first logger avoided unmerchantable salvage: large, high-value snags were removed by summer 2023, with cleanup of slash, lower value large trees, and small-diameter snags in spring 2024.

PLANTING DATE: Planned for spring 2025

SITE PREPARATION: Mastication of shrubs and woody debris in spring 2024, followed by spraying shrubs with a mixture of glyphosate and triclopyr herbicides.

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Climate-Adapted Seed Tool (Reforestation Tools, n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Tahoe, Eldorado, and Plumas National Forests	3,000–3,500	5.04	217.1
Early-century (2011–2040)	Plumas and Lassen National Forests	2,000–2,500	6.24	230.7
Mid-century (2041–2070)	Tahoe, Eldorado, and Plumas National Forests	2,500–3,000	5.49	232.7
Late-century (2071–2100)	Shasta National Forest	1,000–1,500	6.06	196.1

SILVICULTURAL TREATMENTS: Four treatments: planting arrangement (uniform versus cluster planting) crossed with vegetation control (triclopyr-glyphosate herbicide versus no herbicide). The cluster planting treatment will consist of planting four trees at 6-foot spacing, with 28 ft between the centers of each cluster.

PLANTING DENSITY: Operational contract crews will plant 222 trees per ac.

SEEDLING STOCK TYPE: 1-year-old containerized stock

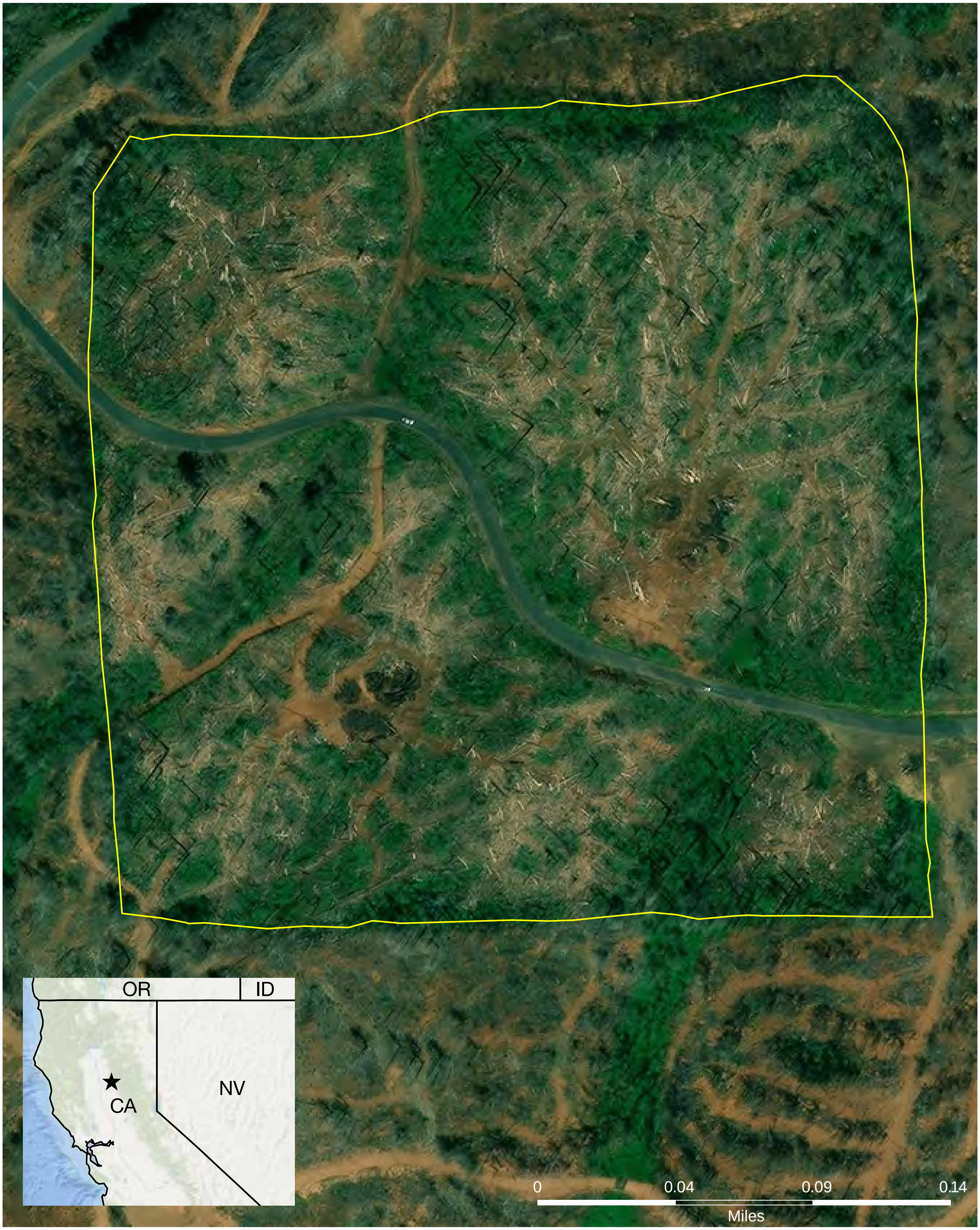

Figure A1.17—Government 40 site. Plot layout is not yet complete for this site. Post-fire imagery is not yet available.

Hammerhorn Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 39.948239°, −122.989712°; Mendocino National Forest, Upper Lake Ranger District (nearest town: Reeves Place, California)

SITE CHARACTERISTICS: The site is adjacent to Hammerhorn Lake at an elevation of 3,500 ft and faces S-SW with a slope of 14–27 percent (fig. A1.18). The soils are moderately deep, well-drained, and derived from residuum from sandstone and shale. The mean annual temperature is 11.7 °C (coldest month 3.9 °C, warmest month 21.7 °C), and mean annual precipitation is 1301 mm (42 mm as snow).

SITE HISTORY: The plant community at the site was originally Sierra mixed conifer, mostly Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*), with small components of sugar pine (*Pinus lambertiana*) and incense cedar (*Calocedrus decurrens*). The area was harvested for timber as recently as 1980 and likely once or twice before then. This site burned in the 2020 August Complex fire.

PLANTED SPECIES: Douglas-fir

PRE-PLANTING SITE CONDITIONS: No remaining overstory, minimal understory vegetation.

PLANTING DATE: Spring 2024

SITE PREPARATION: None—this site was completely cleared in the fire.

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Climate-Adapted Seed Tool (Reforestation Tools, n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Mendocino and Trinity National Forests	3,000–3,500	4.19	197.9
Early-century (2011–2040)	Eldorado National Forest	3,500–4,000	4.58	243.4
Mid-century (2041–2070)	Tahoe National Forest	2,500–3,000	5.49	232.7
Late-century (2071–2100)	Plumas and Lassen National Forests	2,000–2,500	6.24	230.7

SILVICULTURAL TREATMENTS: Two treatments: uniform versus cluster planting. The cluster planting treatment consisted of planting groups of 3–4 trees at approximately 3-ft spacing, with approximately 30 ft between clusters.

PLANTING DENSITY: Operational contract crews planted 200 trees per ac.

SEEDLING STOCK TYPE: Styro 10D (large, containerized stock)

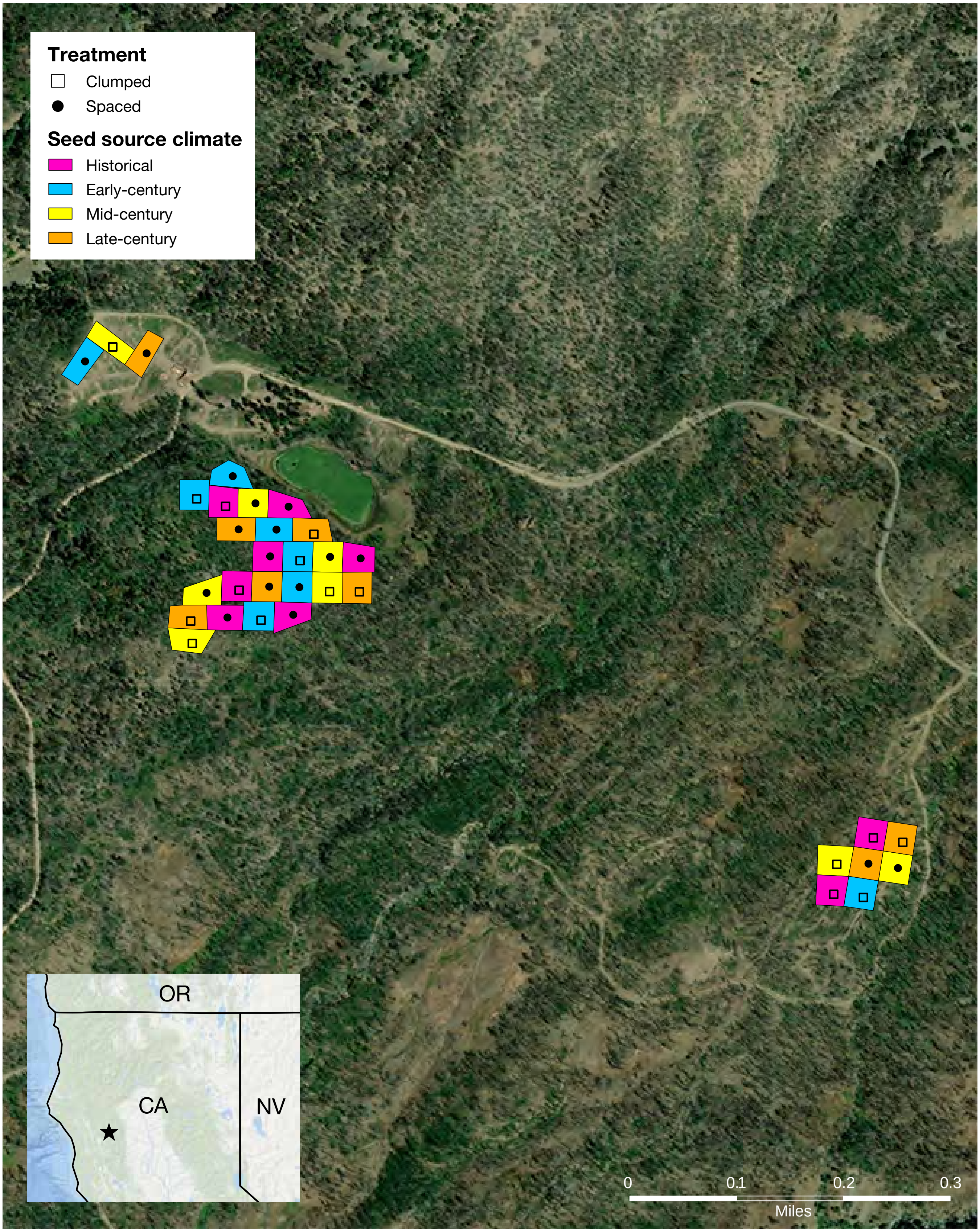

Figure A1.18—Hammerhorn site with layout of 33 experimental treatment plots.

Happy Camp (Two Sites)

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 41.887266°, −123.403204°; Klamath National Forest, Happy Camp Ranger District (nearest town: Happy Camp, California)

SITE CHARACTERISTICS: The sites are at an elevation of 2,500 ft on generally flat terrain (fig. A1.19). The soils are clayey, oxidic, mesic Xeric Haplohumults. The mean annual temperature is 11.7 °C (coldest month 3.3 °C, warmest month 21.7 °C), and mean annual precipitation is 1679 mm (65 mm as snow).

SITE HISTORY: The sites are in an area that has been administered by the Forest Service Pacific Southwest Region genetics program for tree planting and research purposes for about 50 years. Specifically, the sites are in the former location of the sugar pine blister rust resistance trials, a fenced area that burned with high severity in the 2020 Slater Fire, leaving virtually no trees.

PLANTED SPECIES: Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*)

PLANTING DATE: Spring 2024

SITE PREPARATION: Since the sites are on a very well-maintained facility and burned with high severity, site preparation was not necessary.

EXPERIMENTAL DESIGN: The mixture of stockable and unstockable plots and salvage conditions made blocking prohibitively complex. Therefore, we used a completely randomized design with four replications per assisted migration treatment per species. Species were randomly assigned to adjacent plots, but we classify each species as a separate site.

ASSISTED MIGRATION TREATMENTS: We used the Climate-Adapted Seed Tool (Reforestation Tools, n.d.) to choose four seed sources for planting for each species:

Climate period	Douglas-fir seed source characteristics			
	Seed origin	Elevation FEET	Mean coldest month temperature DEGREES CELSIUS	Summer heat moisture index UNITLESS
Historical (1961–1990)	Klamath National Forest	2,000–2,500	3.61	163.4
Early-century (2011–2040)	Lassen National Forest	2,500–3,000	3.14	195.8
Mid-century (2041–2070)	Tahoe National Forest	2,500–3,000	5.49	232.7
Late-century (2071–2100)	Plumas and Lassen National Forests	1,500–2,000	6.93	266.9

Climate period	Ponderosa pine seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Klamath National Forest	2,000–2,500	3.61	163.4
Early-century (2011–2040)	Klamath National Forest	1,500–2,000	3.95	198.3
Mid-century (2041–2070)	Tahoe National Forest	2,500–3,000	5.49	232.7
Late-century (2071–2100)	Shasta National Forest	1,000–1,500	6.06	196.1

SILVICULTURAL TREATMENTS: None. Each plot had a 50 percent mix of the two seedling stock types used (see below). Because of space limitations, Douglas-fir was planted into 0.33-ac plots while ponderosa pine was planted into the standard 0.5-ac plots. Monitoring of both species will take place on the standard 0.25-ac measurement plots.

PLANTING DENSITY: Operational contract crews planted 200 trees per ac.

SEEDLING STOCK TYPE: 50 percent containerized and 50 percent 1-0 bareroot seedlings.

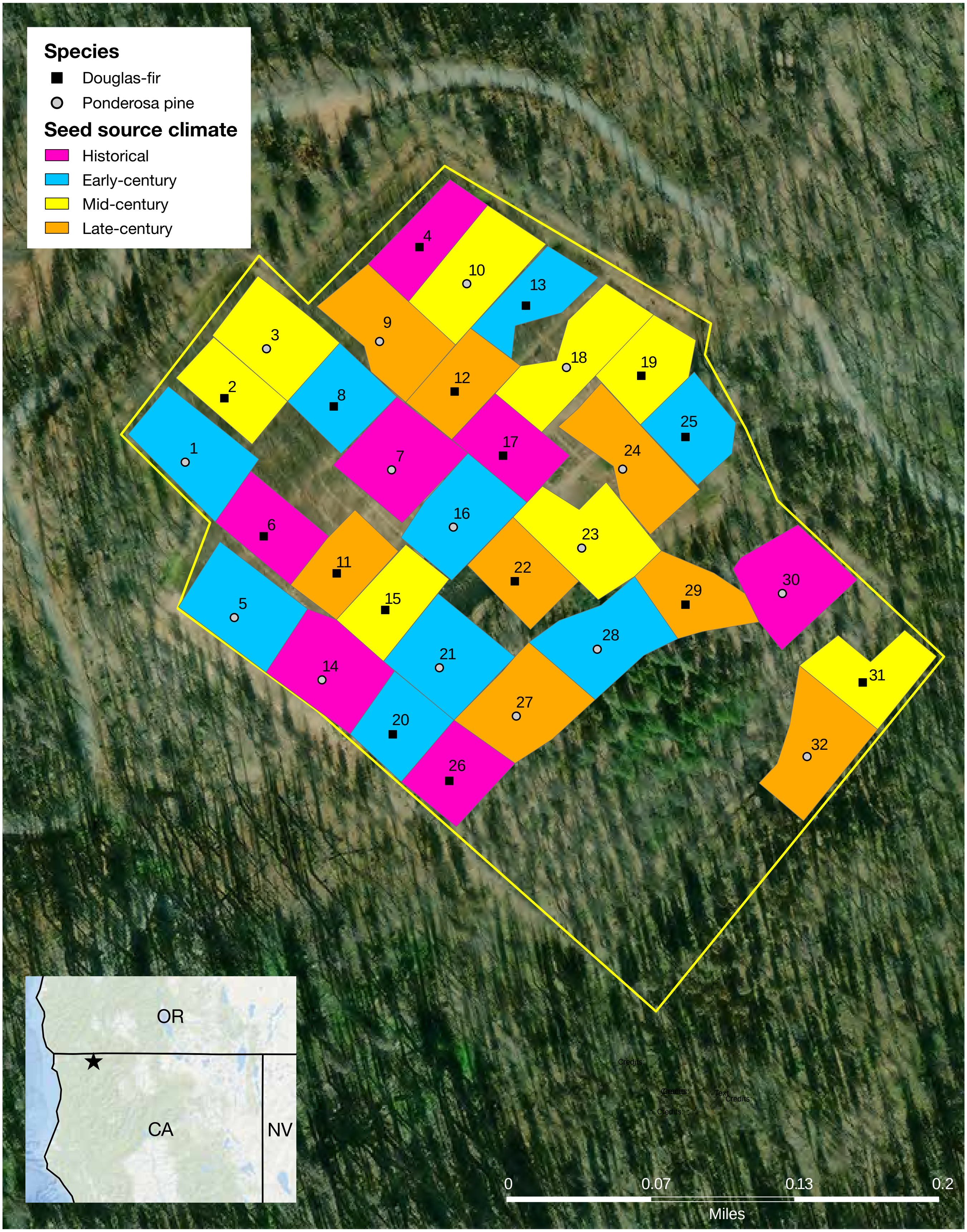

Figure A1.19—Happy Camp sites with layout of 32 experimental treatment plots.

Hidden Road Site

OWNERSHIP: Washington Department of Natural Resources (WDNR)

LOCATION: 47.9478°, −117.7336°; nearest town: Ford, Washington

SITE CHARACTERISTICS: The site is on a 5–25 percent S-SW slope at 2,000 ft (fig. A1.20). The soils are shallow to moderately deep, well-drained, ashy loam derived from loess and volcanic ash over granite colluvium and residuum with abundant cobbles and a few exposed rocky slabs. Mean annual temperature is 8.3 °C (coldest month −3.9 °C, warmest month 20.6 °C), and mean annual precipitation is 490 mm (102 mm as snow).

SITE HISTORY: This site was initially harvested in 1917 and salvage logged in 1995. In 2014, the Highway 231 Fire burned a small portion of the site. The site was harvested again in 2020 as a partial overstory removal with a goal of uneven-aged management, already having an understory of greater than 100 small trees per ac. However, the 2021 Ford Corkscrew Fire burned overstory and understory with high intensity at the site.

PLANTED SPECIES: Ponderosa pine (*Pinus ponderosa*)

PRE-PLANTING SITE CONDITIONS: Some dead overstory trees with minimal understory vegetation, largely grasses and common mullein (*Verbascum thapsus*) in addition to a small amount of natural pine regeneration in some areas. A skid trail runs through the site, but it was avoided for planting.

PLANTING DATE: Spring 2024

SITE PREPARATION: Baseline herbicide 1 year before planting.

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	WDNR (local)	1,000–2,000	−4.02	190.4
Early-century (2011–2040)	Deschutes National Forest	4,000–4,500	−1.91	162.8
Mid-century (2041–2070)	Deschutes National Forest	3,500–4,000	−0.96	141.2
Late-century (2071–2100)	Rogue River National Forest	2,000–3,000	1.25	104.4

SILVICULTURAL TREATMENTS: Three different stock types (see below)

PLANTING DENSITY: Operational contract crews planted 300 trees per ac.

SEEDLING STOCK TYPE: Containerized (Styro 5/6, Styro 10, Ellepot)

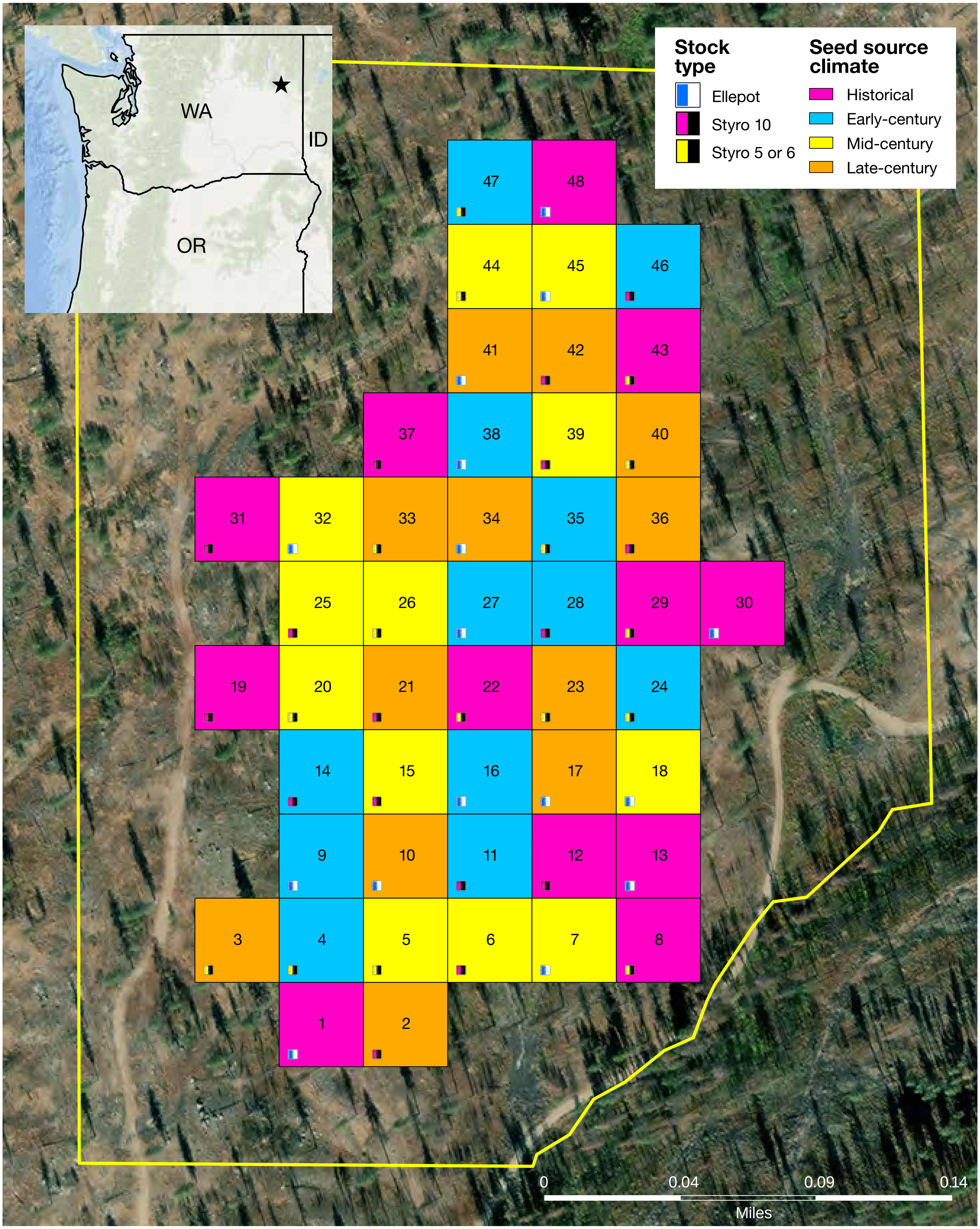

Figure A1.20—Hidden Road site with layout of 48 experimental treatment plots.

Hillockburn Springs Site

OWNERSHIP: U.S. Department of the Interior, Bureau of Land Management (BLM)

LOCATION: 45.199954°, −122.233391°; NW Oregon District (nearest town: Dodge, Oregon)

SITE CHARACTERISTICS: The site is at 1,600 ft elevation and faces N-NE, with a slope of 27–47 percent (fig. A1.21). The soils are moderately deep, well-drained, cobbly loams formed from mixed volcanic parent materials such as tuff-breccia and andesite. The mean annual temperature is 9.4 °C (coldest month 2.8 °C, warmest month 17.2 °C), and mean annual precipitation is 1751 mm (76 mm as snow).

SITE HISTORY: The site was originally a mixed clear-cut/thinned 50-year-old Douglas-fir stand before burning in the 2014 36 Pit Fire. After the fire, the site was salvage harvested and planted with Douglas-fir (*Pseudotsuga menziesii*) and western redcedar (*Thuja plicata*) at 200 trees per ac each. In 2020, the site burned again during the 2020 Riverside Fire.

PLANTED SPECIES: Douglas-fir

PRE-PLANTING SITE CONDITIONS: The site is largely clear of overstory, with some standing dead and live trees in certain areas. After mechanical removal, the ground was fairly clear of woody debris and shrubs.

PLANTING DATE: Spring 2024

SITE PREPARATION: Mechanical woody debris and shrub removal

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation FEET	Mean coldest month temperature DEGREES CELSIUS	Summer heat moisture index UNITLESS
Historical (1961–1990)	BLM—Molalla area	600–2,400	2.78	54.4
Early-century (2011–2040)	BLM—McKenzie area	800–2,700	3.50	74.4
Mid-century (2041–2070)	BLM—Swisshome/ Mapleton area	800–2,500	4.32	71.3
Late-century (2071–2100)	BLM—Coquille 16 area	<1,600	6.36	80.6

SILVICULTURAL TREATMENTS: Herbicide application with four treatment variations (two different radii of treatment, one application versus two applications)

PLANTING DENSITY: Operational contract crews planted 250 trees per ac.

SEEDLING STOCK TYPE: Styro 515 containerized stock

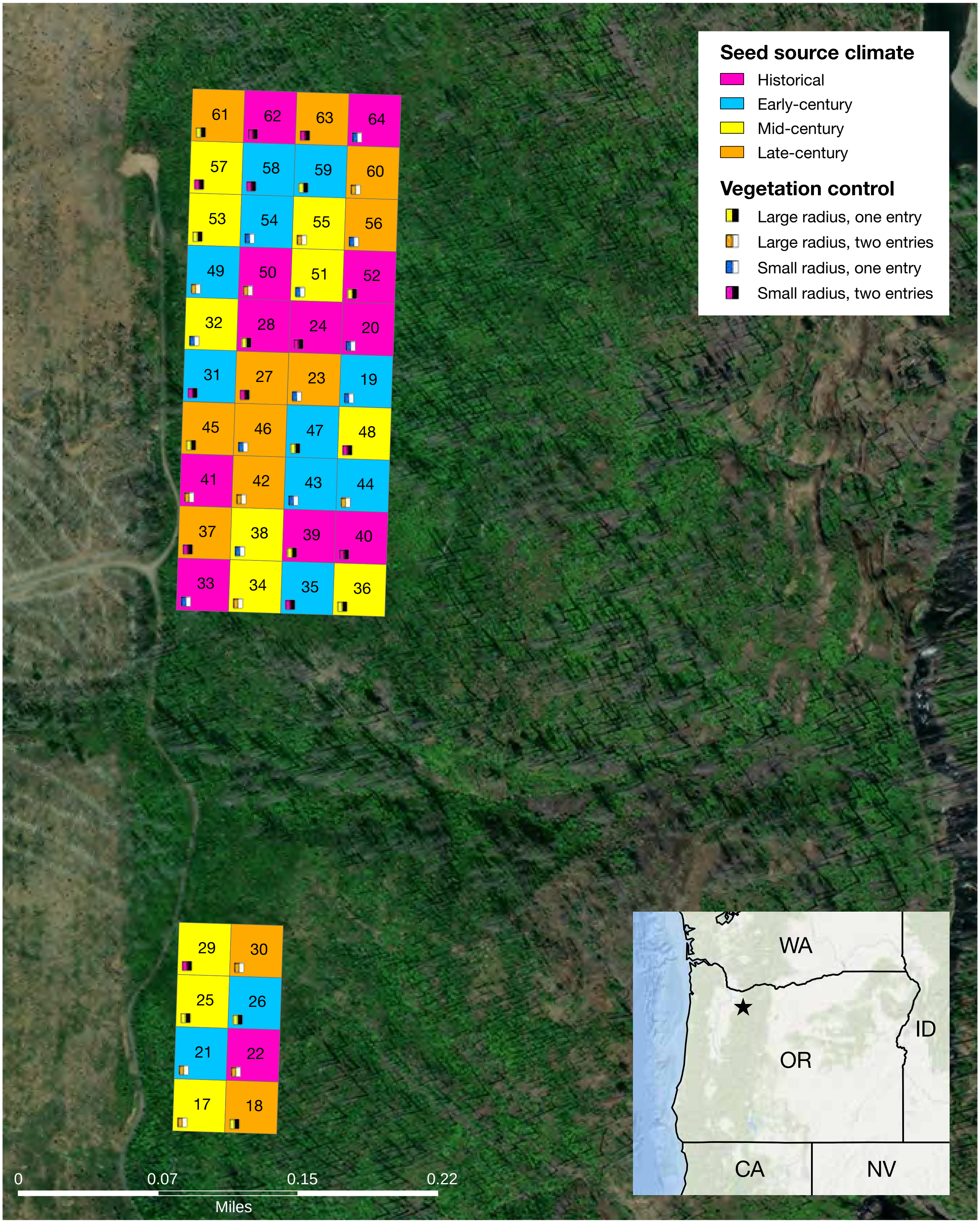

Figure A1.21—Hillockburn Springs site with layout of 64 experimental treatment plots. Post-fire imagery is not yet available.

Huck Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 42.6030260°, −121.1764720°; Fremont-Winema National Forest, Bly Ranger District (nearest town: Beatty, Oregon)

SITE CHARACTERISTICS: The site is nearly flat and at an elevation of 5,300 ft (fig. A1.22). The mean annual temperature is 6.7 °C (coldest month −2.2 °C, warmest month 16.7 °C), and mean annual precipitation is 544 mm (138 mm as snow).

SITE HISTORY: The site was originally a Ponderosa Pine/bitterbrush/needlegrass and White fir/ceanothus-manzanita stand that was part of the Huck Sale area awarded in 2021. However, the site burned in the Bootleg Fire in the summer of 2021, and it was not cut until late October or November, 2021, following the hazard tree/site preparation prescription.

PLANTED SPECIES: Ponderosa pine (*Pinus ponderosa*)

PRE-PLANTING SITE CONDITIONS: The area was logged using normal ground-based logging methods, so slash is minimal as needed for erosion control. Most of the area burned with high tree mortality, so natural regeneration will likely be low. Although a skid trail runs through the site, it will be avoided for planting.

PLANTING DATE: Planned for spring 2026

SITE PREPARATION: Salvage harvest

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Fremont-Winema National Forest	5,000–6,000	–2.60	141.3
Early-century (2011–2040)	Klamath and Shasta-Trinity National Forests	5,000–5,500	–0.95	159.8
Mid-century (2041–2070)	Lassen and Plumas National Forests	4,500–5,000	0.54	186.0
Late-century (2071–2100)	Stanislaus National Forest	5,000–5,500	2.83	243.5

SILVICULTURAL TREATMENTS: Two different seedling stock types (see below)

PLANTING DENSITY: Operational contract crews will plant 222 trees per ac.

SEEDLING STOCK TYPE: 2-0 bareroot and 1-year-old containerized seedlings

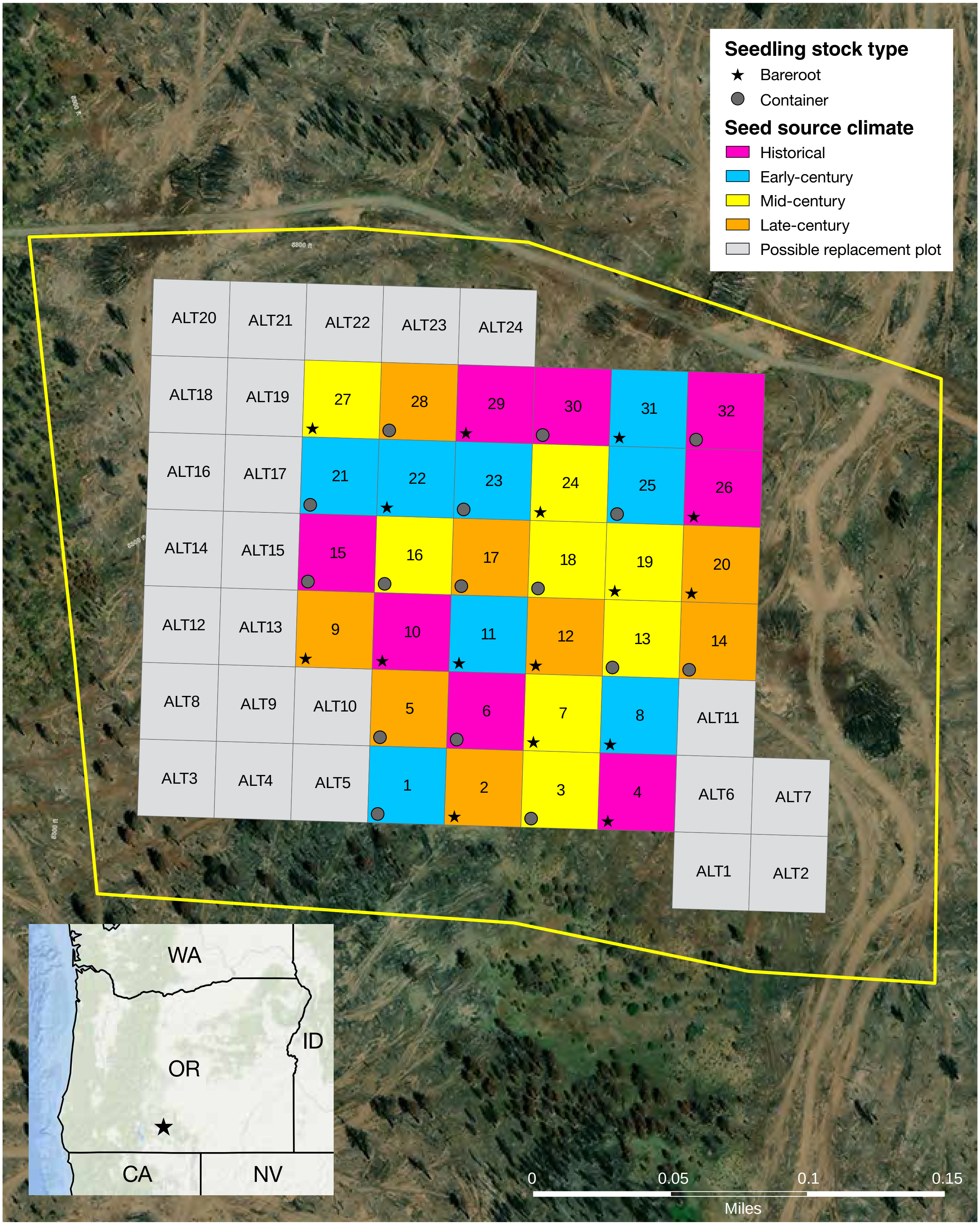

Figure A1.22—Huck site with tentative layout of 32 experimental treatment plots and 24 possible replacement plots.

Keller Ridge Site

OWNERSHIP: Confederated Tribes of the Colville Reservation

LOCATION: 48.18155°, −118.78951°; nearest town: Keller, Washington

SITE CHARACTERISTICS: The site is on a ridgetop at an elevation of 3,600 ft, with a slope of 18–36 percent on all sides (fig. A1.23). The soils are deep, well-drained loams formed in colluvium and residuum from granitic rock, with a thin mantle of volcanic ash and loess. The mean annual temperature is 6.1 °C (coldest month −5.6 °C, warmest month 17.8 °C), and mean annual precipitation is 409 mm (117 mm as snow).

SITE HISTORY: The site was a mixed western larch/ponderosa pine stand that was part of a regeneration with reserves cut in 2019 due to excessive dwarf mistletoe. The site was excavator piled/scarified and the piles were burned in 2020. In the spring of 2021, the site was planted with 30 percent western larch (*Larix occidentalis*) and 70 percent ponderosa pine (*Pinus ponderosa*) at 300 trees per ac. The site was then burned through by the Chuweah Creek Fire in the summer of 2021.

PLANTED SPECIES: Western larch

PRE-PLANTING SITE CONDITIONS: There are scattered live overstory and pole-size ponderosa pine, Douglas-fir (*Pseudotsuga menziesii*), and western larch trees across the site, at a density of 3 trees per ac. The fire killed most planted seedlings and very few planted or natural seedlings are present. Grass has fully reoccupied the site and brush is starting to come back in the shallow draws.

PLANTING DATE: Planned for spring 2025

SITE PREPARATION: Excavator piling with a follow-up vegetation control treatment (mechanical or chemical, to be determined)

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.3-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Wallowa-Whitman National Forest	5,500–6,000	−5.78	65.2
Early-century (2011–2040)	Ochoco National Forest	5,800–6,500	−3.73	93.7
Mid-century (2041–2070)	Wallowa-Whitman National Forest	<4,500	−2.24	98.5
Late-century (2071–2100)	Deschutes National Forest	4,000–4,500	−1.36	126.8

SILVICULTURAL TREATMENTS: Two different stock types (see below) and vegetation control versus no vegetation control

PLANTING DENSITY: Operational contract crews will plant 300 trees per ac.

SEEDLING STOCK TYPE: Containerized stock (Styro 10, Styro 2A[211A])

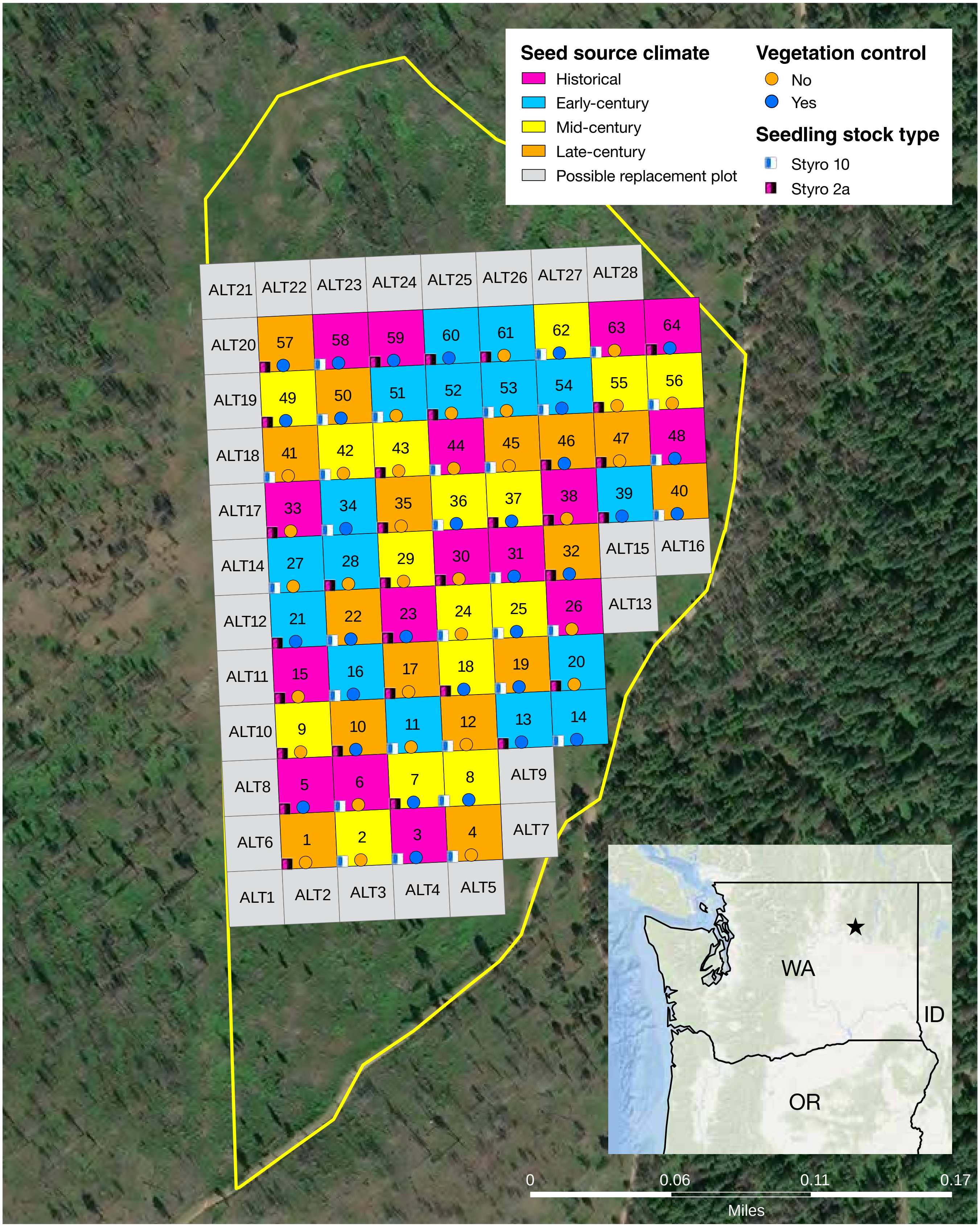

Figure A1.23—Keller Ridge site with tentative layout of 64 experimental treatment plots and 28 possible replacement plots. Post-fire imagery is not yet available.

Letts Lake Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 39.304202°, −122.706676°; Mendocino National Forest, Grindstone Ranger District (nearest town: Fouts Springs, California)

SITE CHARACTERISTICS: The site is on a ridge at an elevation of 4,500 ft, facing S-SW on one side and N-NE on the other, with moderate to steep slopes of 45–80 percent (fig. A1.24). The soils are shallow to deep, gravelly loams formed in alluvium and colluvium from metamorphosed igneous, sedimentary, metasedimentary, and metavolcanic rocks. The mean annual temperature is 11.7 °C (coldest month 3.9 °C, warmest month 22.2 °C), and mean annual precipitation is 1317 mm (49 mm as snow).

SITE HISTORY: This site, next to a lake and a high-use campground, burned in the 2018 Ranch Fire. Prior to the fire, the stand was Coast Range mixed conifers with active maintenance because of its campground proximity. This area is also part of a larger research initiative and hosts many other research projects.

PLANTED SPECIES: Douglas-fir (*Pseudotsuga menziesii*)

PRE-PLANTING SITE CONDITIONS: After snag removal, the site was clear of trees, with some remaining stumps.

PLANTING DATE: Spring 2024

SITE PREPARATION: All dead trees were removed from the site prior to planting.

EXPERIMENTAL DESIGN: Completely randomized design with four replications per assisted migration treatment applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Climate-Adapted Seed Tool (Reforestation Tools, n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	CA Seed Zone 372 (Mendocino National Forest)	4,500–5,000	3.27	333.7
Early-century (2011–2040)	CA Seed Zone 372 (Mendocino National Forest)	3,500–4,000	4.97	388.7
Mid-century (2041–2070)	CA Seed Zone 302 (Klamath National Forest)	500–1,000	5.05	139.1
Late-century (2071–2100)	CA Seed Zone 521 (Shasta National Forest)	1,000–1,500	6.06	196.1

SILVICULTURAL TREATMENTS: None

PLANTING DENSITY: Operational contract crews planted 176 trees per ac.

SEEDLING STOCK TYPE: Styro 10D (large, containerized stock)

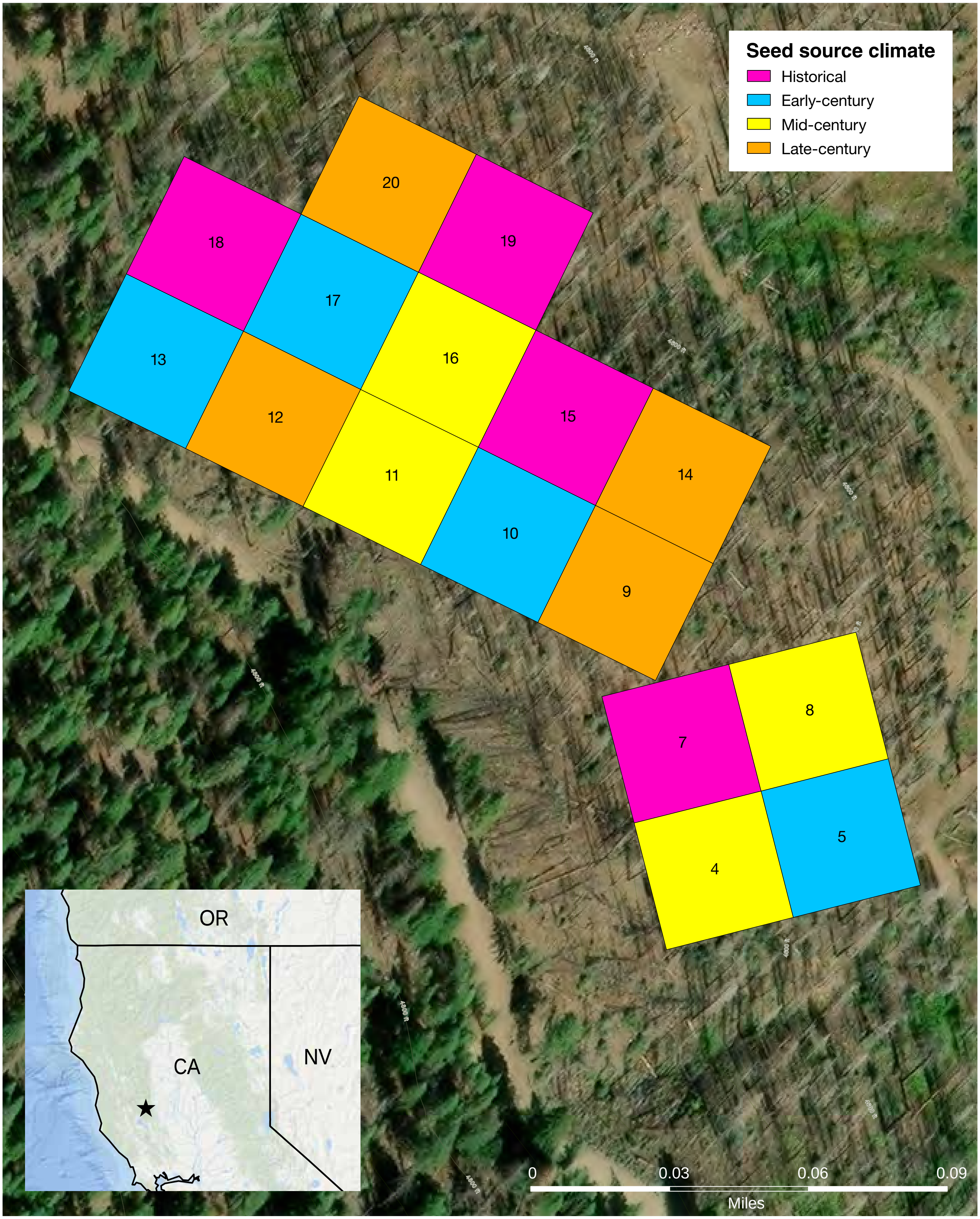

Figure A1.24—Letts Lake site with layout of 16 experimental treatment plots.

Lickety Split Site

OWNERSHIP: U.S. Department of the Interior, Bureau of Land Management (BLM)

LOCATION: 42.14443°, −122.92365°; Medford District (nearest town: Medford, Oregon)

SITE CHARACTERISTICS: The site is at an elevation of 2,600 ft and faces N-NE, with a slope of 47–84 percent (fig. A1.25). The soils are moderately deep, well-drained, gravelly/silt loams that formed in colluvium weathered from altered sedimentary, metamorphic, and extrusive igneous rocks. The mean annual temperature is 10.0 °C (coldest month 1.1 °C, warmest month 19.4 °C), and mean annual precipitation is 640 mm (43 mm as snow).

SITE HISTORY: The site was a stand dominated by Douglas-fir (*Pseudotsuga menziesii*), with minor components of ponderosa pine (*Pinus ponderosa*), Pacific madrone (*Arbutus menziesii*), California black oak (*Quercus kelloggii*), and Oregon white oak (*Q. garryana*). Drought and flat-headed fir borer killed 99 percent of the mature Douglas-fir overstory in the several years before planting.

PLANTED SPECIES: Douglas-fir

PLANTING DATE: Planned for spring 2025

SITE PREPARATION: Salvage harvest followed by mechanical removal of Douglas-fir regeneration and hardwood shrubs.

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.4-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	BLM—Jacksonville area	1,500–3,000	2.50	186.5
Early-century (2011–2040)	Klamath National Forest	3,500–4,000	1.59	200.3
Mid-century (2041–2070)	Shasta-Trinity and Mendocino National Forests	4,500–5,000	4.14	324.2
Late-century (2071–2100)	Lassen, Plumas, and Tahoe National Forests	2,500–3,000	4.95	212.5

SILVICULTURAL TREATMENTS: 3 mechanical vegetation control treatments: No grubbing, grubbing one-year post-planting, grubbing two years post-planting.

PLANTING DENSITY: Operational contract crews will plant 435 trees per ac.

SEEDLING STOCK TYPE: Containerized (Styro 8/415C)

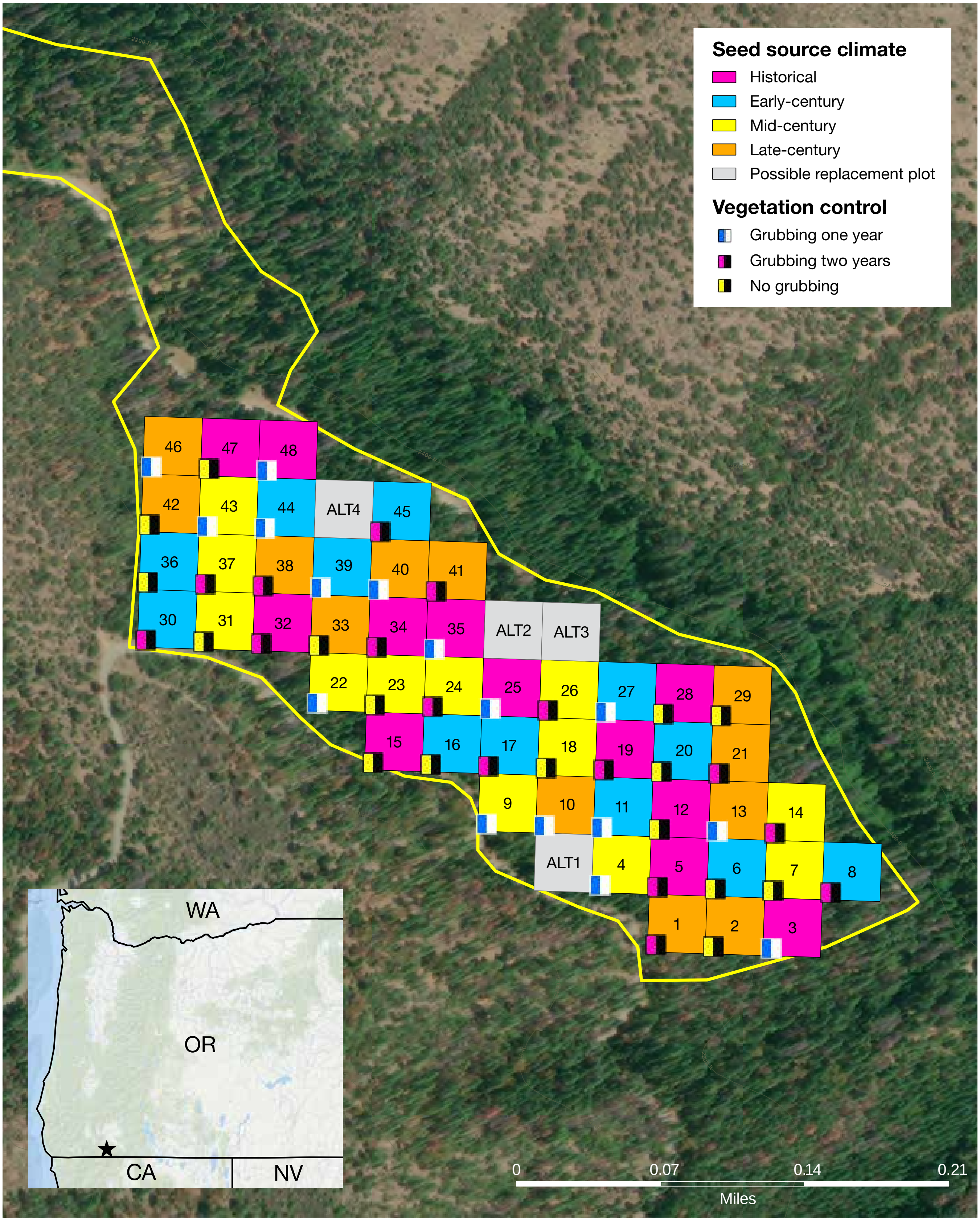

Figure A1.25—Lickety Split site with tentative layout of 48 experimental treatment plots and 4 possible replacement plots. Post-disturbance imagery is not yet available.

Magalia Site

OWNERSHIP: U.S. Department of the Interior, Bureau of Land Management (BLM)

LOCATION: 39.811754°, −121.610472°; Northern California District (in the town of Magalia, CA)

SITE CHARACTERISTICS: The site is at an elevation of 2,200 ft and faces SE with gentle slopes of <15 percent (fig. A1.26). The soils are fine, mixed, semiactive, mesic Andic Haploxeralfs. The mean annual temperature is 14.4 °C (coldest month 6.7 °C, warmest month 23.9 °C) and mean annual precipitation is 1480 mm (15 mm as snow).

SITE HISTORY: The site is a city park managed by the BLM in the town of Magalia in a high-visibility area. The stand was a low-elevation ponderosa pine stand before burning in the 2018 Camp Fire.

PLANTED SPECIES: Ponderosa pine (*Pinus ponderosa*)

PLANTING DATE: Spring 2024

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Climate-Adapted Seed Tool (Reforestation Tools, n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Lassen National Forest	2,000–2,500	6.01	226.1
Early-century (2011–2040)	Shasta National Forest	1,500–2,000	5.16	165.9
Mid-century (2041–2070)	Sierra National Forest	2,000–2,500	6.65	622.6
Late-century (2071–2100)	Shasta National Forest	1,000–1,500	5.88	189.8

SILVICULTURAL TREATMENTS: Two different seedling stock types (see below)

PLANTING DENSITY: Operational contract crews planted 302 trees per ac.

SEEDLING STOCK TYPE: Half containerized, half bareroot stock

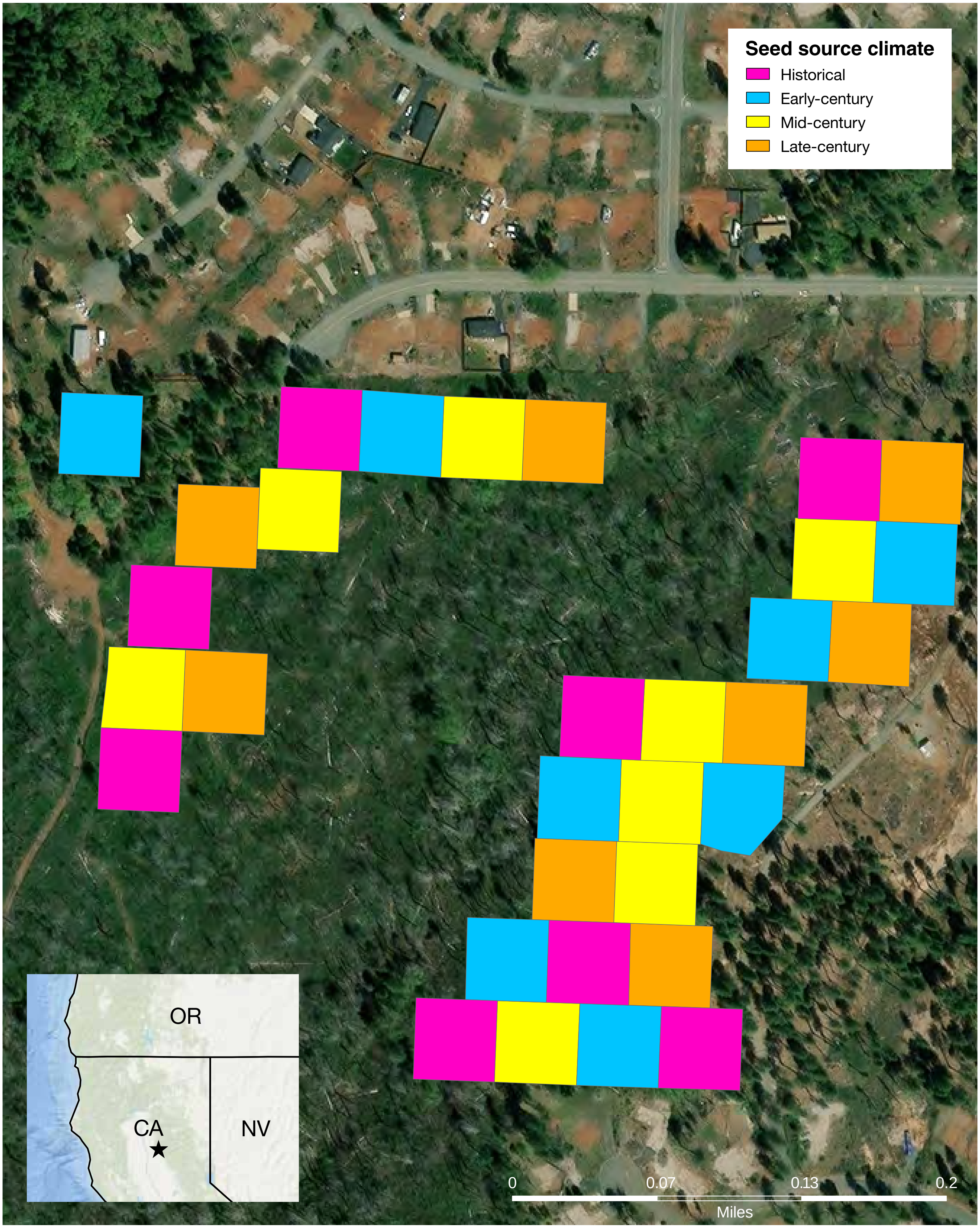

Figure A1.26—Magalia site with layout of 16 experimental treatment plots. Post-fire imagery is not yet available.

McKenzie Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 44.174591°, −122.249124°; Willamette National Forest, McKenzie River Ranger District (nearest town: Rainbow, Oregon)

SITE CHARACTERISTICS: The site sits on a 15–40 percent, S-SE slope at 1,800 ft of elevation (fig. A1.27). The soils are deep, well-drained, stony/gravelly loams derived from colluvium and residuum from basalt and sandstone. The mean annual temperature is 10.0 °C (coldest month 2.2 °C, warmest month 18.3 °C), and mean annual precipitation is 1830 mm (93 mm as snow).

SITE HISTORY: This site was a second-growth Douglas-fir (*Pseudotsuga menziesii*) stand that was previously clearcut and regenerated sometime around 1955, followed by a commercial thinning and some associated fuels treatments around 2010–2012. The Holiday Farm Fire burned the site in 2020 and killed most trees. The stand was then salvaged in 2021 followed by pile burning in 2022.

PLANTED SPECIES: Ponderosa pine (*Pinus ponderosa*)

PRE-PLANTING SITE CONDITIONS: The site was covered in moderate to dense understory, including fireweed (*Chamerion angustifolium*), blackberry (*Rubus* sp.), and vine maple (*Acer circinatum*), as well as some light woody debris and scattered heavy log piles. One small group of standing dead and live Douglas-fir trees remained on the higher end of the site, and there was a small number of scattered natural Douglas-fir regenerations.

PLANTING DATE: Spring 2023

SITE PREPARATION: The site was salvage harvested post-fire, 2 years before planting.

EXPERIMENTAL DESIGN: Randomized complete block design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Mt. Hood National Forest	1,000–2,000	2.38	64.9
Early-century (2011–2040)	Willamette National Forest	1,000–2,000	3.29	79.0
Mid-century (2041–2070)	Siuslaw National Forest	500–2,000	4.83	86.2
Late-century (2071–2100)	Six Rivers National Forest	0–500	6.41	76.7

SILVICULTURAL TREATMENTS: None

PLANTING DENSITY: Operational contract crews planted 200 trees per ac.

SEEDLING STOCK TYPE: Containerized

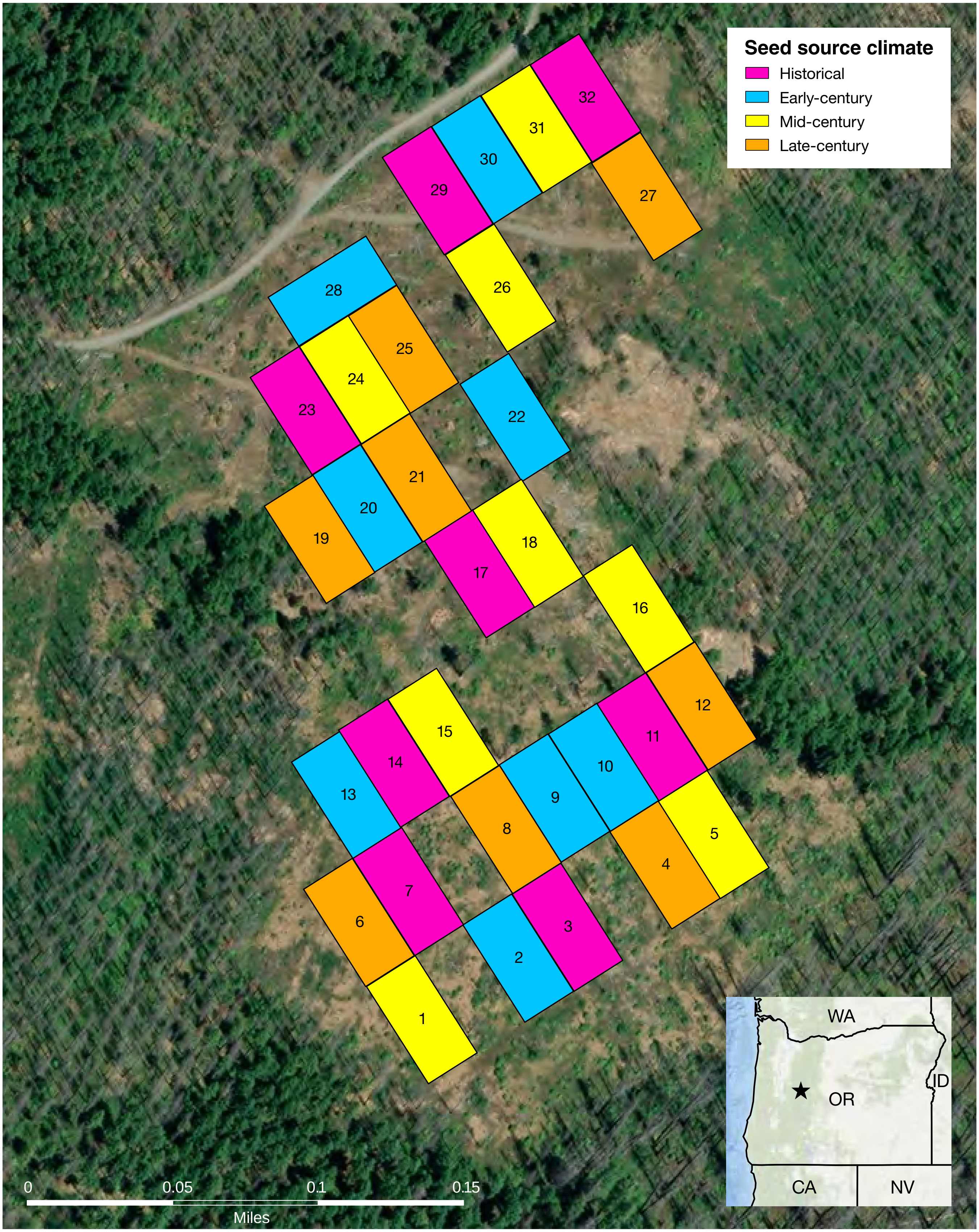

Figure A1.27—McKenzie site with layout of 32 experimental treatment plots. Post-fire imagery is not yet available.

Pettijohn Site

OWNERSHIP: Washington Department of Natural Resources

LOCATION: 48.74034°, −119.10075°; nearest town: Tonasket, Washington

SITE CHARACTERISTICS: The site is on a 5–15 percent S-SE slope at 4,200 ft of elevation (fig. A1.28). The soils are soft and shallow, ashy loamy andisols derived from volcanic ash over glacial till, with exposed rocky slabs. The mean annual temperature is 4.4 °C (coldest month −7.2 °C, warmest month 15.6 °C), and the mean annual precipitation is 494 mm (209 mm as snow).

SITE HISTORY: The first entry into this parcel was a variable density thinning in 1993 as part of the 4 Forties timber sale, followed by a fuels reduction treatment in 2014 and a shelterwood removal treatment in 2021 that left healthy ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*), and Douglas-fir (*Pseudotsuga menziesii*). The site then burned with high intensity in the 2021 Walker Creek Fire.

PLANTED SPECIES: Ponderosa pine

PRE-PLANTING SITE CONDITIONS: The site has some dead overstory trees. The sparse vegetation that survived the spray treatment includes fireweed (*Chamerion angustifolium*) and Saskatoon serviceberry (*Amelanchier alnifolia*), as well as a small amount of natural pine regeneration.

PLANTING DATE: Spring 2024

SITE PREPARATION: Baseline herbicide spray 1 year before planting.

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Okanogan National Forest	4,000–5,000	–7.12	85.4
Early-century (2011–2040)	Wenatchee National Forest	2,500–3,000	–5.51	166.4
Mid-century (2041–2070)	Wallowa-Whitman National Forest	4,000–4,500	–4.05	123.5
Late-century (2071–2100)	Wallowa-Whitman National Forest	4,000–4,500	–2.24	98.5

SILVICULTURAL TREATMENTS: Three different seedling stock types (see below)

PLANTING DENSITY: Operational contract crews planted 300 trees per ac.

SEEDLING STOCK TYPE: Containerized (Styro 5/6, Styro 10, Ellepot)

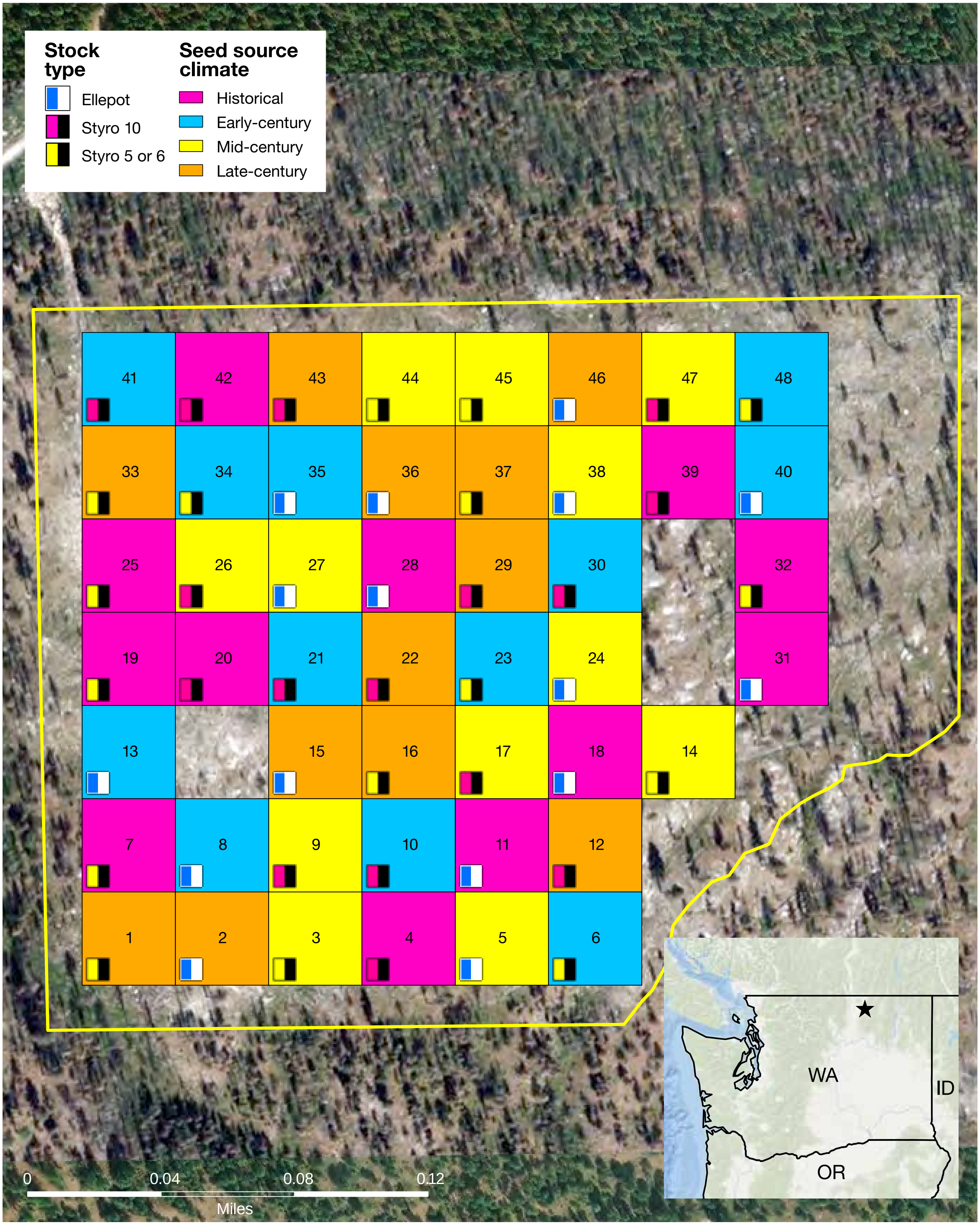

Figure A1.28—Pettijohn site with layout of 48 experimental treatment plots.

Riverside Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 45.15443°, −122.288315°; Mt. Hood National Forest, Clackamas River Ranger District (nearest town: Estacada, Oregon)

SITE CHARACTERISTICS: The site sits on a 10–30 percent NE-SE slope at 2,600 ft of elevation (fig. A1.29). The soils are deep, well drained silt loams formed from thin loess over glacial till or colluvium. Mean annual temperature is 7.8 °C (coldest month 1.7 °C, warmest month 15.0 °C), and mean annual precipitation is 2297 mm (185 mm as snow).

SITE HISTORY: The site was composed of a mixed-conifer forest prior to being clearcut and replanted with Douglas-fir (*Pseudotsuga menziesii*) in the 1960s. A commercial variable density thinning prescription was being executed at the site in the summer of 2020 when it burned with high severity in the Riverside Fire.

PLANTED SPECIES: Douglas-fir

PRE-PLANTING SITE CONDITIONS: Since wildfire reached the unit while it was being commercially thinned, some logs that had been cut but not yet removed remained on site after the fire, partially burned. One year post-fire, virtually no live trees remained in the overstory and there was little understory regeneration. However, there are some nearby areas with live conifer trees that are a potential seed source for natural regeneration. A skid trail runs through the site, but it was avoided for planting.

PLANTING DATE: Spring 2023

SITE PREPARATION: None

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation FEET	Mean coldest month temperature DEGREES CELSIUS	Summer heat moisture index UNITLESS
Historical (1961–1990)	Mt. Hood National Forest	1,500–2,000	2.02	50.0
Early-century (2011–2040)	Willamette National Forest	1,000–1,500	2.80	55.2
Mid-century (2041–2070)	Siuslaw National Forest	500–1,500	3.69	39.0
Late-century (2071–2100)	Siskiyou National Forest	1,500–2,000	5.20	53.7

SILVICULTURAL TREATMENTS: Two different planting densities (see below)

PLANTING DENSITY: Operational contract crews planted 200 and 250 trees per ac.

SEEDLING STOCK TYPE: Containerized

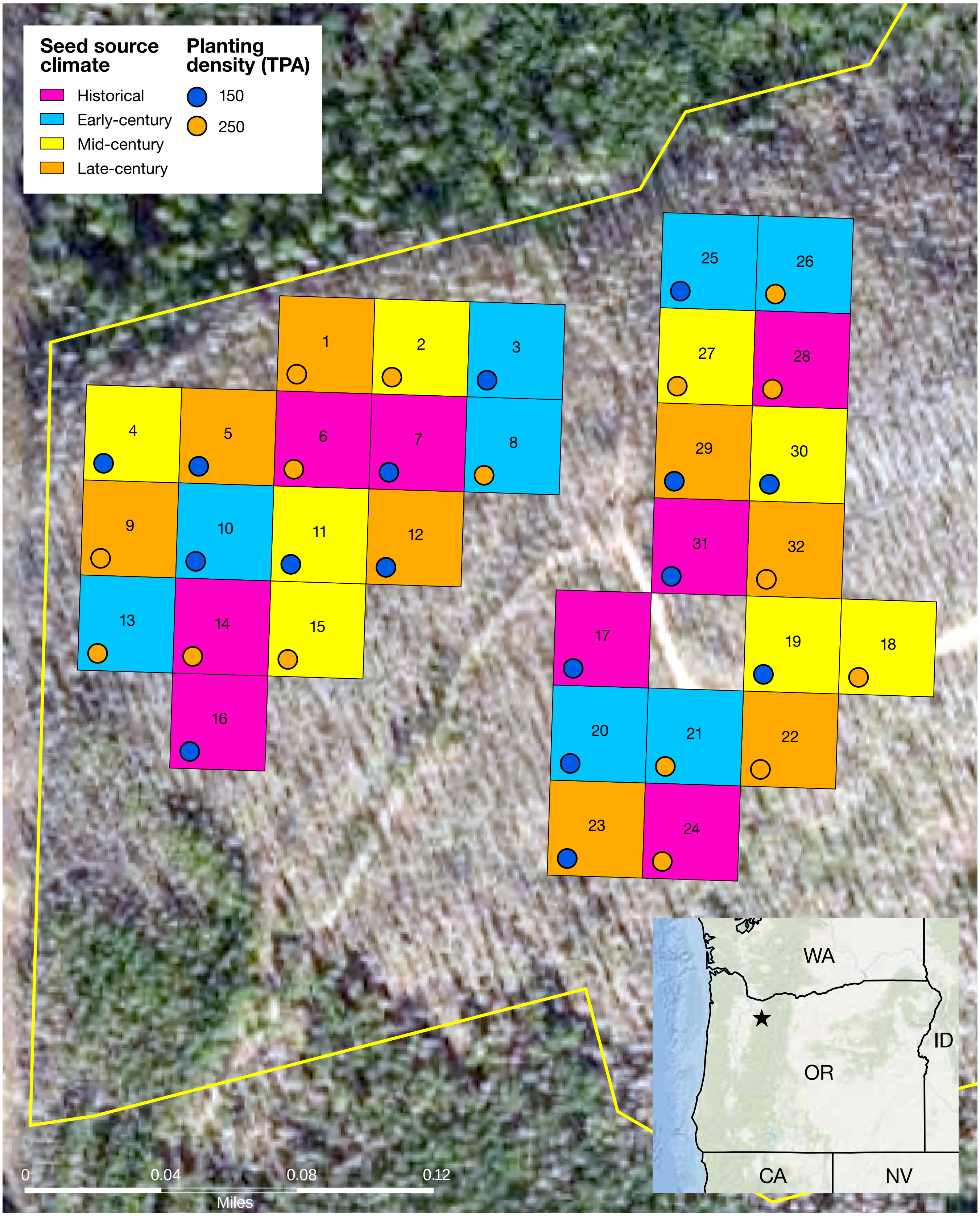

Figure A1.29—Riverside site with layout of 32 experimental treatment plots. TPA = trees per acre.

Rosland Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 43.694874°, −121.434611°; Deschutes National Forest, Bend-Fort Rock Ranger District (nearest town: La Pine, Oregon)

SITE CHARACTERISTICS: The site is almost flat and at 4,300 ft of elevation (fig. A1.30). The soils are excessively drained, loamy sands formed from a moderately thick layer of pumice and volcanic ash over residual soil on basaltic lavas and outwashed sands. The mean annual temperature is 6.7 °C (coldest month −2.2 °C, warmest month 16.1 °C), and the mean annual precipitation is 508 mm (121 mm as snow).

SITE HISTORY: The site was a predominantly black bark ponderosa pine stand that was part of a stand improvement cut during the 1999 Prairie timber sale. The Rosland Road Fire burned the site with high severity in July of 2020, killing most of the trees and all the understory vegetation, but leaving the soil relatively intact.

PLANTED SPECIES: Ponderosa pine (*Pinus ponderosa*)

PRE-PLANTING SITE CONDITIONS: After the salvage harvest and fuels reduction, the site will have virtually no remaining canopy, and the soil will be cleared of large woody debris. Some understory regeneration is expected.

PLANTING DATE: Planned for spring 2026

SITE PREPARATION: The site area will receive a salvage harvest and fuels removal. The slash will be machine-piled and then burned.

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Deschutes National Forest	4,000–4,500	−1.91	162.8
Early-century (2011–2040)	Mt. Hood National Forest	2,000–3,000	−1.16	203.5
Mid-century (2041–2070)	Rogue River National Forest	4,000–5,000	1.69	126.0
Late-century (2071–2100)	Umpqua National Forest	<3,500	2.54	78.1

SILVICULTURAL TREATMENTS: Four vegetation control treatments: two radii of treatment around seedlings, one versus two entry times

PLANTING DENSITY: Operational contract crews will plant 165 trees per ac.

SEEDLING STOCK TYPE: Containerized (Q-plugs+1.5)

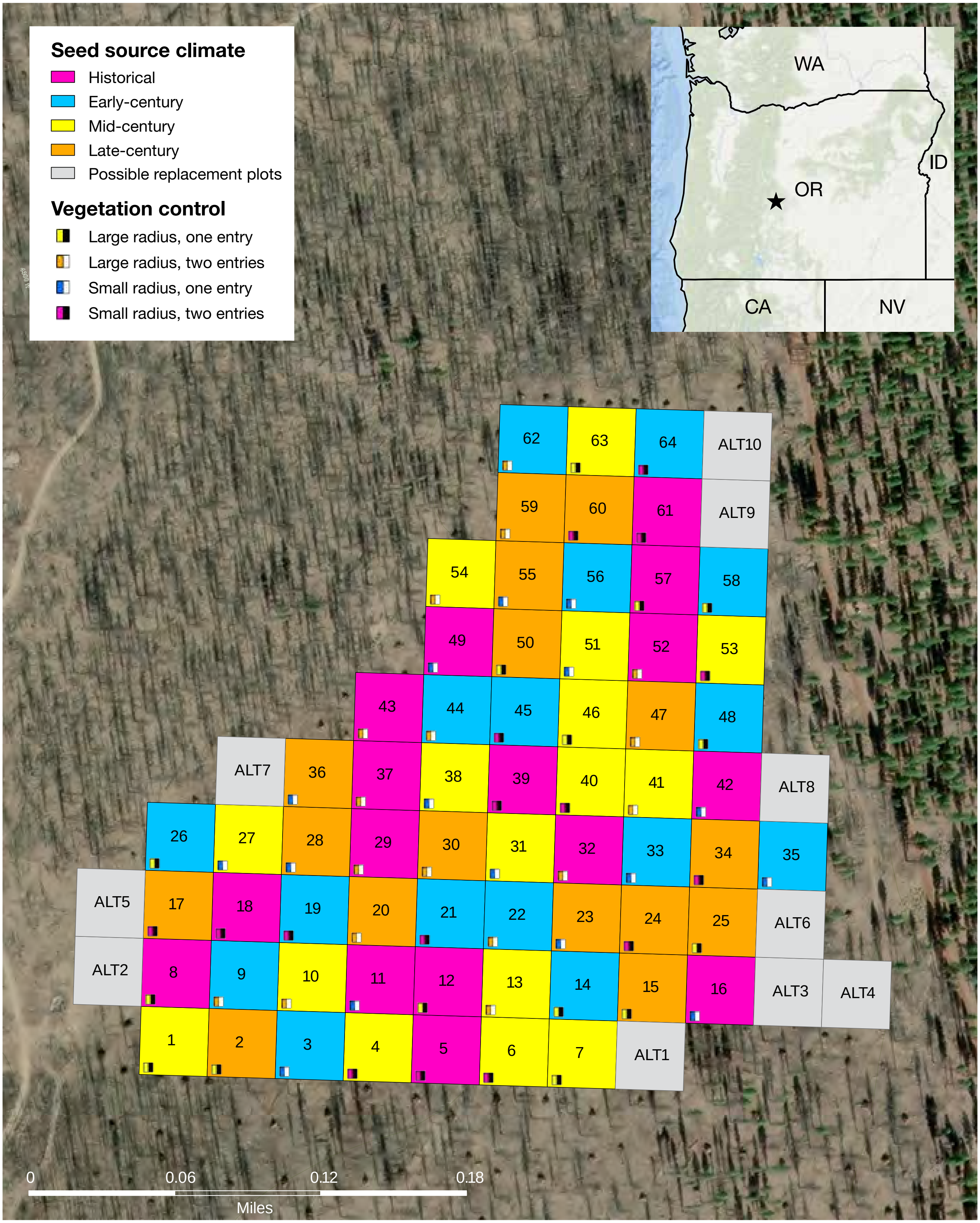

Figure A1.30—Rosland site with tentative layout of 64 experimental treatment plots and 10 possible replacement plots.

Schneider Spring Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 46.889089°, −121.134570°; Okanogan-Wenatchee National Forest, Cle Elum Ranger District (nearest town: Cliffdell, Washington)

SITE CHARACTERISTICS: The site is on a gentle 5–12 percent, N-NE-E facing slope at 4,500 ft of elevation (fig. A1.31). The soils are very deep, well-drained, ashy, sandy loams formed in colluvium from basalt or andesite, with a mantle of volcanic ash. The mean annual temperature is 4.4 °C (coldest month −3.9 °C, warmest month 14.4 °C), and mean annual precipitation is 1477 mm (616 mm as snow).

SITE HISTORY: The site burned in the 2021 Schneider Springs Fire.

PLANTED SPECIES: Ponderosa pine (*Pinus ponderosa*)

PRE-PLANTING SITE CONDITIONS: The site had some small dead standing trees in patches. The understory had sparse vegetation, including grasses and fireweed (*Chamerion angustifolium*), and virtually no natural conifer regeneration.

PLANTING DATE: Spring 2024

SITE PREPARATION: None

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Wenatchee National Forest	>4,000	–3.98	87.0
Early-century (2011–2040)	Gifford Pinchot National Forest	2,500–3,000	–1.30	92.0
Mid-century (2041–2070)	Deschutes National Forest	3,500–4,000	–0.96	141.2
Late-century (2071–2100)	Rogue River National Forest	5,000–6,000	0.75	115.8

SILVICULTURAL TREATMENTS: Three different planting densities (see below)

PLANTING DENSITY: Operational contract crews planted 150, 200, and 250 trees per ac.

SEEDLING STOCK TYPE: Styro 10 (large, containerized stock)

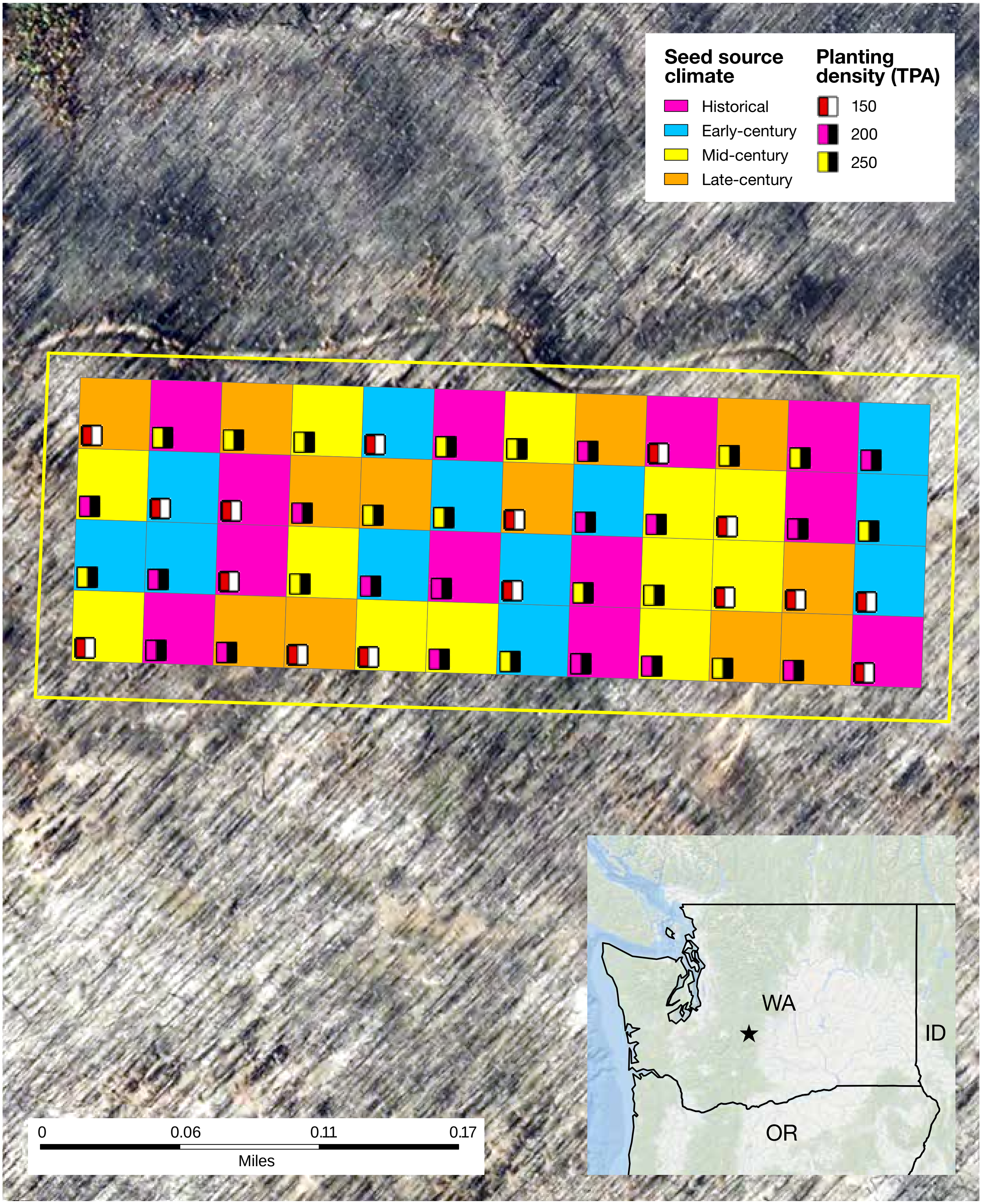

Figure A1.31—Schneider Spring site with layout of 48 experimental treatment plots. TPA = trees per acre.

Sugar Pine Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 42.922441°, −122.661168°; Umpqua National Forest, Tiller Ranger District (nearest town: Tiller, Oregon)

SITE CHARACTERISTICS: The site is at an elevation of 4,100 ft and faces NW, with a gentle slope of 9–18 percent (fig. A1.32). The mean annual temperature is 8.3 °C (coldest month 1.1 °C, warmest month 17.8 °C), and mean annual precipitation is 1369 mm (128 mm as snow).

SITE HISTORY: The site burned with high severity in the 2018 Columbus Fire, with nearly 100 percent tree mortality. Before it was selected as a research area, the site was planned for an operational planting of about 80 percent Douglas-fir (*Pseudotsuga menziesii*), with minor components of sugar pine (*Pinus lambertiana*) and ponderosa pine (*Pinus ponderosa*), as sugar pine rarely grows in pure stands.

PLANTED SPECIES: Sugar pine

PRE-PLANTING SITE CONDITIONS: Even 5 years post-fire, there was little natural regeneration by the time of planting. Large, downed logs and debris covered a large portion of the site, as well as clusters of Pacific rhododendron (*Rhododendron macrophyllum*).

PLANTING DATE: Spring 2022

SITE PREPARATION: None. Seedlings were planted interspersed with slash and other regenerating vegetation.

EXPERIMENTAL DESIGN: Randomized complete block design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Rogue River National Forest	2,500–4,000	2.06	113.4
Early-century (2011–2040)	Siskiyou National Forest	<2,500	3.49	151.3
Mid-century (2041–2070)	Siskiyou National Forest	2,500–4,000	3.86	83.1
Late-century (2071–2100)	Eldorado National Forest	2,500–3,000	5.89	313.1

SILVICULTURAL TREATMENTS: None

PLANTING DENSITY: Operational contract crews planted 200 trees per ac.

SEEDLING STOCK TYPE: 1-0 containerized stock

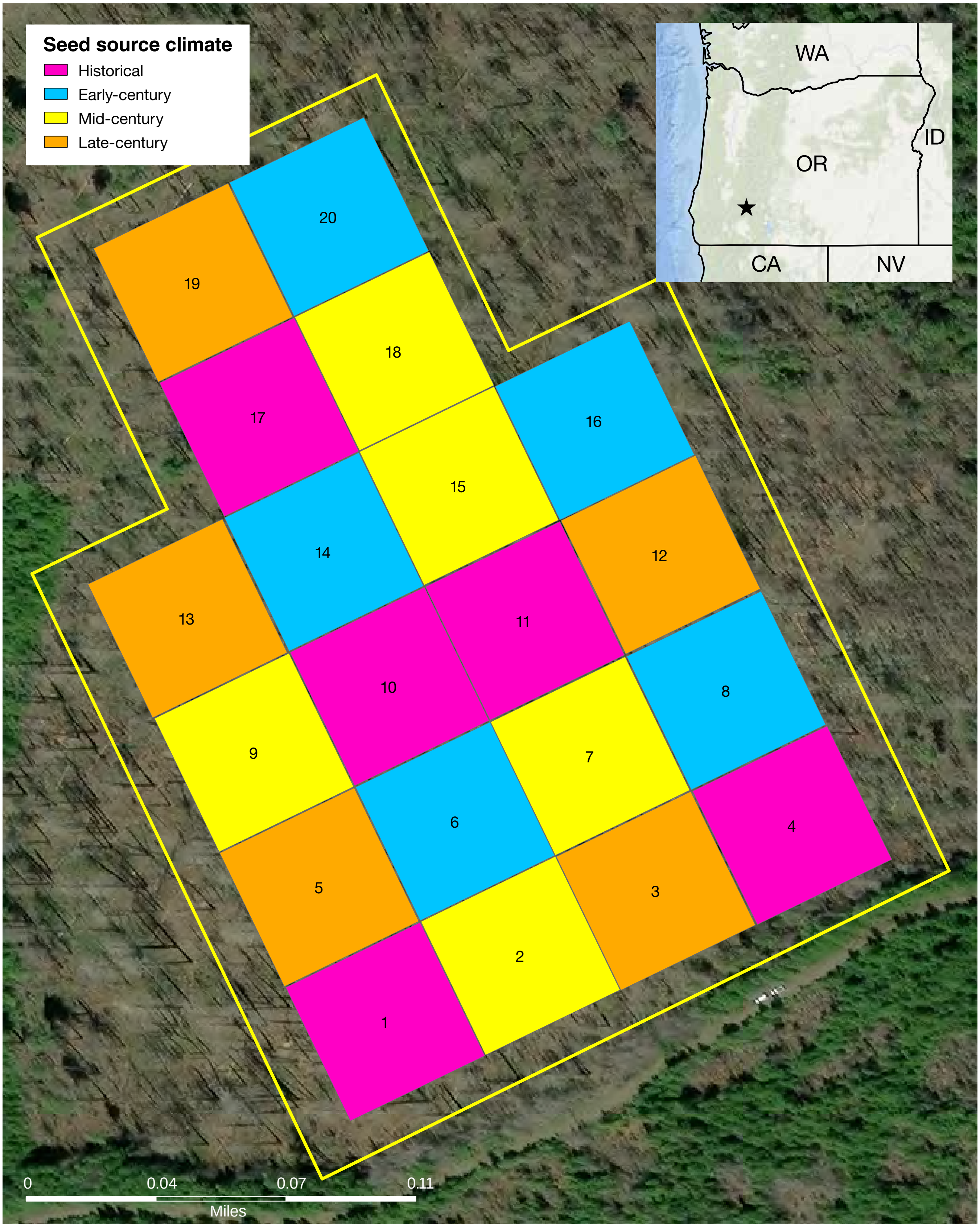

Figure A1.32—Sugar Pine site with layout of 20 experimental treatment plots.

Summit Trail Site

OWNERSHIP: Confederated Tribes of the Colville Reservation

LOCATION: 48.3041410°, −118.5096361°; nearest town: Keller, Washington

SITE CHARACTERISTICS: The site is at an elevation of 4,900 ft and faces W-SW, with a gentle slope of 10–27 percent (fig. A1.33). The soils are very deep, well-drained, silt loams formed in colluvium and residuum from granitic rock, with a mantle of volcanic ash. The mean annual temperature is 5.0 °C (coldest month −6.7 °C, warmest month 16.7 °C), and mean annual precipitation is 605 mm (218 mm as snow).

SITE HISTORY: The site burned in the 2021 Summit Trail Fire.

PLANTED SPECIES: Western larch (*Larix occidentalis*)

PLANTING DATE: Planned for spring 2025

SITE PREPARATION: Excavator piling with a follow-up vegetation control treatment (mechanical or chemical, to be determined). A skid trail runs through the site, but it will be avoided for planting.

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.3-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Colville National Forest	4,000–4,500	–5.95	64.8
Early-century (2011–2040)	Malheur National Forest	4,500–5,500	–4.76	128.4
Mid-century (2041–2070)	Umatilla National Forest	5,000–5,500	–3.23	77.9
Late-century (2071–2100)	Deschutes National Forest	4,000–4,500	–1.36	126.8

SILVICULTURAL TREATMENTS: Two different stock types (see below) and vegetation control versus no vegetation control

PLANTING DENSITY: Operational contract crews will plant 300 trees per ac.

SEEDLING STOCK TYPE: Containerized stock (Styro 10, Styro 2A[211A])

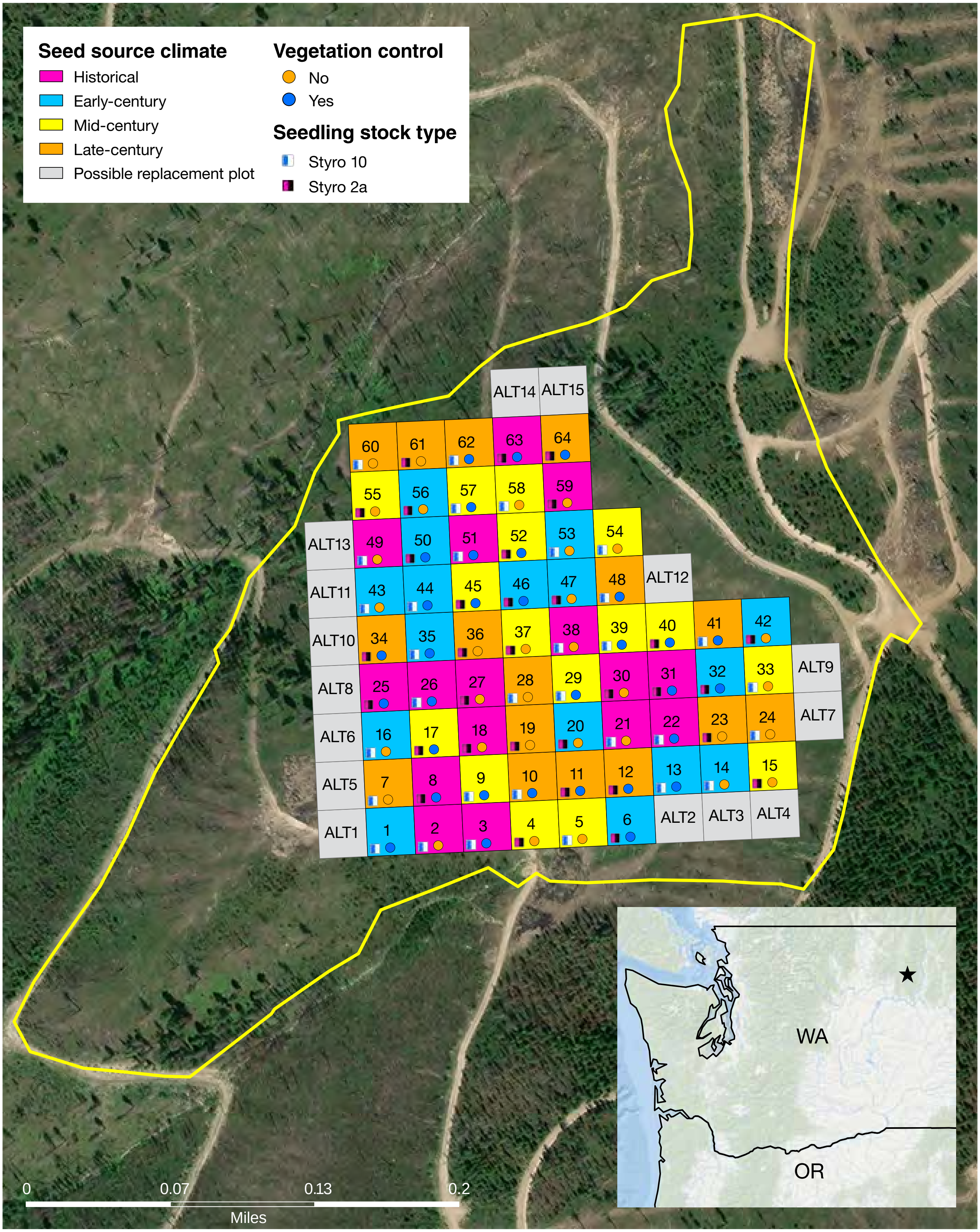

Figure A1.33—Summit Trail site with tentative layout of 64 experimental treatment plots and 15 possible replacement plots.

Tamarack (Three Sites)

OWNERSHIP: U.S. Department of the Interior, Bureau of Land Management

LOCATION: 38.747841°, −119.784595°; Carson City District (nearest town: Markleeville, California)

SITE CHARACTERISTICS: The sites are at an elevation of 5,600 ft and generally face E with gentle slopes of <10 percent (figs. A1.34, A1.35, A1.36). The soils are loamy-skeletal, mixed, superactive, frigid Typic Argixerolls. The mean annual temperature is 8.3 °C (coldest month −0.6 °C, warmest month 18.9 °C), and mean annual precipitation is 563 mm (84 mm as snow). The sites occupy an ecotone between high-elevation mixed conifers: Jeffrey pine (*Pinus jeffreyi*), incense cedar (*Calocedrus decurrens*) and white fir (*Abies concolor*); and woodland species: singleleaf pinyon (*Pinus monophylla*) and western juniper (*Juniperus occidentalis*).

SITE HISTORY: The sites burned in the 2021 Tamarack Fire with salvage subsequently completed along a 400-foot buffer adjacent to an important access road to the local airstrip. The planted area was a mixture of salvaged and unsalvaged land due to a deficit of stockable, salvaged areas.

PLANTED SPECIES: Ponderosa pine (*Pinus ponderosa*), incense cedar, Jeffrey pine

PRE-PLANTING SITE CONDITIONS: Following salvage, sites had recovered a mixture of forbs and shrubs such as ceanothus (*Ceanothus* sp.) and sagebrush (*Artemisia* sp.).

PLANTING DATE: Spring 2024

SITE PREPARATION: Sites were prepared with mechanical brush control localized around seedlings at the time of planting.

EXPERIMENTAL DESIGN: Completely randomized design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots. Species were also randomly assigned to plots, but we classify each species as a separate site.

ASSISTED MIGRATION TREATMENTS: We used the Climate-Adapted Seed Tool (Reforestation Tools, n.d.) to choose four seed sources for planting for each species:

Climate period	Ponderosa pine seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Lassen National Forest	3,500–4,000	0.93	232.8
Early-century (2011–2040)	Shasta-Trinity National Forest	2,500–3,000	2.80	224.6
Mid-century (2041–2070)	Klamath National Forest	1,500–2,000	2.67	275.6
Late-century (2071–2100)	Sierra National Forest	2,000–2,500	6.76	633.6

Climate period	Jeffrey pine seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Toiyabe National Forest	5,500–6,000	–1.00	169.9
Early-century (2011–2040)	Klamath National Forest	3,000–3,500	1.38	259.3
Mid-century (2041–2070)	Klamath National Forest	1,500–2,000	2.67	275.6
Late-century (2071–2100)	Sierra National Forest	2,000–2,500	6.76	633.6

Climate period	Incense cedar seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Lassen National Forest	4,000–4,500	0.30	197.0
Early-century (2011–2040)	Klamath National Forest	2,500–3,000	1.41	328.4
Mid-century (2041–2070)	Eldorado National Forest	2,500–3,000	5.89	313.1
Late-century (2071–2100)	San Bernardino National Forest	3,500–4,000	6.75	379.7

SILVICULTURAL TREATMENTS: Two stock types: bareroot versus containerized stock. Species are also compared (consistently with containerized seedlings because of shortages) in single-species, mixed provenance plantings against single-provenance, single-species plots.

PLANTING DENSITY: Operational contract crews planted 302 trees per ac, anticipating lower survival due to less effective mechanical brush control and arid conditions.

SEEDLING STOCK TYPE: Half containerized, half bareroot stock, forming the main experimental factor.

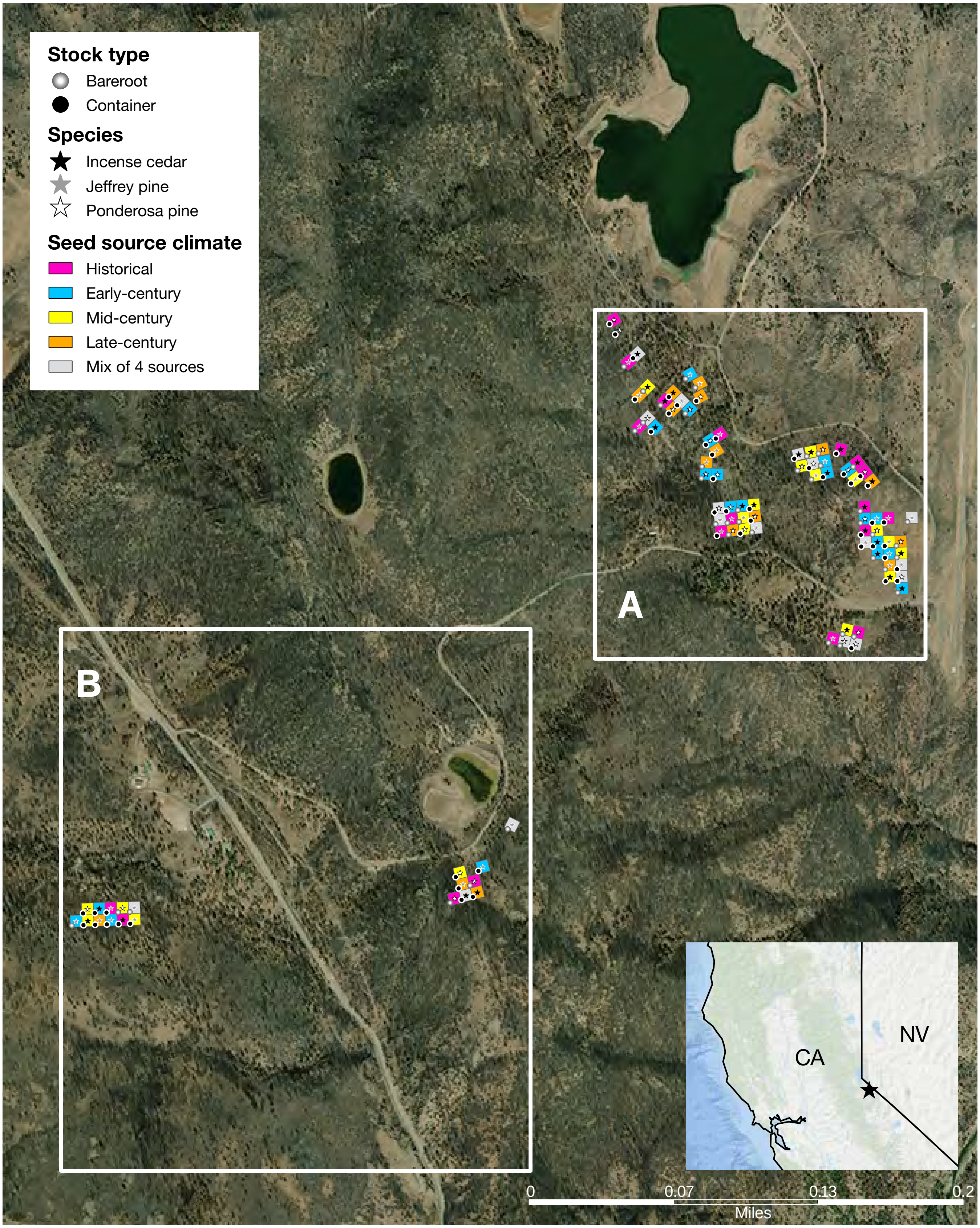

Figure A1.34—Tamarack site with experimental treatment plot layout. White boxes labeled A and B show the extent of maps in figures A1.35 and A1.36, respectively.

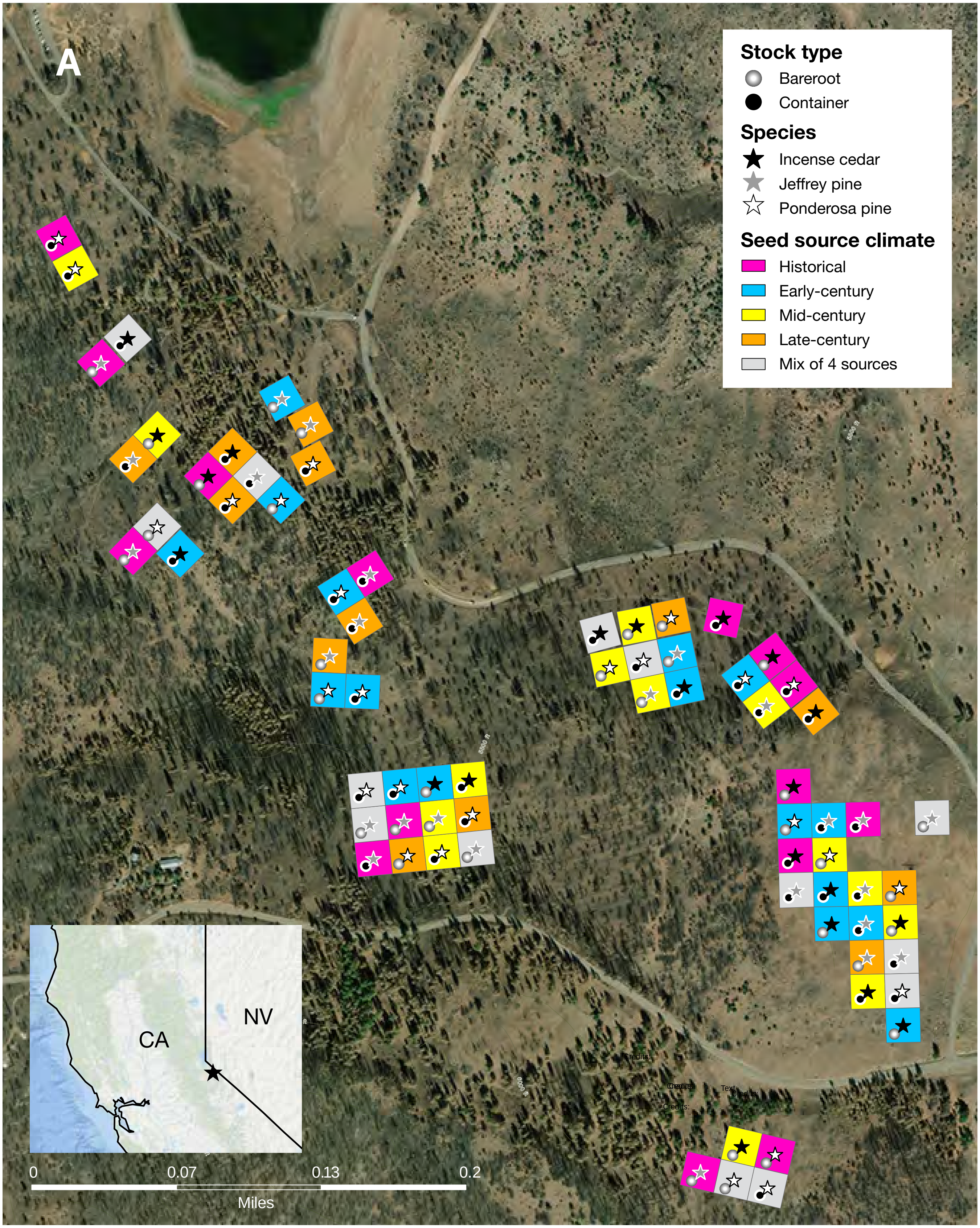

Figure A1.35—Tamarack site with layout of 73 experimental treatment plots. This is a zoomed-in view of box A in figure A1.34.

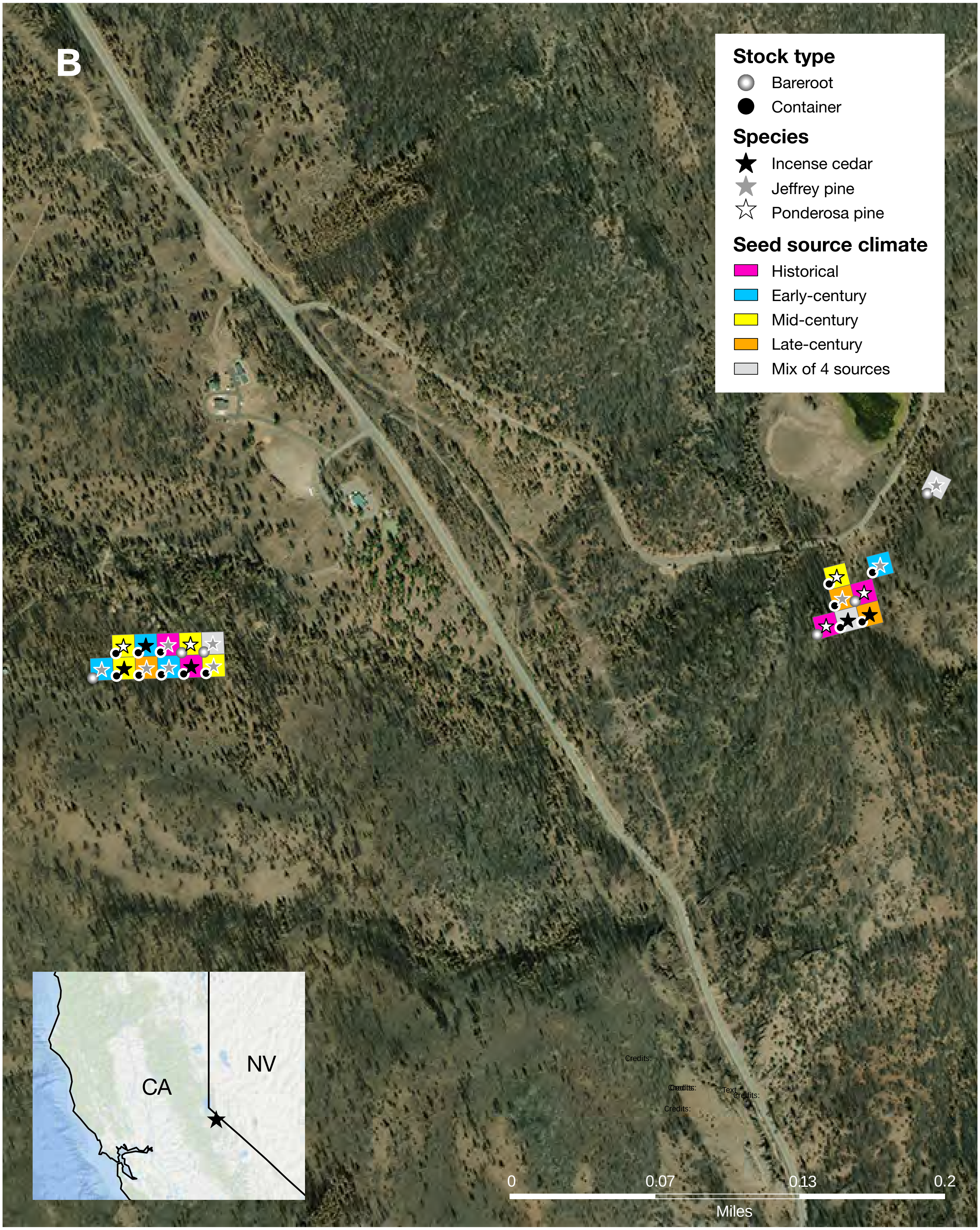

Figure A1.36—Tamarack site with layout of 19 experimental treatment plots. This is a zoomed-in view of box B in figure A1.34.

White River Site

OWNERSHIP: U.S. Department of Agriculture, Forest Service

LOCATION: 45.145696°, −121.526664°; Mt. Hood National Forest, Barlow Ranger District (nearest town: Maupin, Oregon)

SITE CHARACTERISTICS: The site is on a 10–25 percent, N-NW slope at 3,100 ft elevation (fig. A1.37). The soils are deep coarse silt loams derived from glacial till mixed with volcanic ash. The mean annual temperature is 7.2 °C (coldest month −1.7 °C, warmest month 16.7 °C), and mean annual precipitation is 751 mm (148 mm as snow).

SITE HISTORY: Part of the unit was clearcut in 1979 and planted in 1984 with ponderosa pine (*Pinus ponderosa*) at 440 trees per ac. The site was commercially thinned around the same time in the areas that were not clear cut. The site burned with high severity (nearly 100 percent tree mortality) during the 2020 White River Fire.

PLANTED SPECIES: Ponderosa pine

PRE-PLANTING SITE CONDITIONS: The site experienced nearly 100 percent mortality of trees in the overstory. Snags are a mix of 12–15-inch diameter at breast height ponderosa pine and larger Douglas-fir (*Pseudotsuga menziesii*). At time of planting, some trees were down because of breakage. Slash recruitment is expected to increase as overstory snags decay and fall. Little to no natural regeneration of conifer species has been noted to date. Some herbaceous plant regeneration has occurred, largely blackberry (*Rubus* sp.) and thistle.

PLANTING DATE: Spring 2023

SITE PREPARATION: None

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Mt. Hood National Forest	2,000–3,000	−1.16	203.5
Early-century (2011–2040)	Deschutes National Forest	3,500–4,000	−0.96	141.2
Mid-century (2041–2070)	Umpqua National Forest	3,500–4,500	1.19	70.0
Late-century (2071–2100)	Rogue River National Forest	2,000–3,000	2.63	160.1

SILVICULTURAL TREATMENTS: Three different planting densities (see below)

PLANTING DENSITY: Operational contract crews planted 150, 200, and 250 trees per ac.

SEEDLING STOCK TYPE: Containerized (Styro 7.9, 91/130)

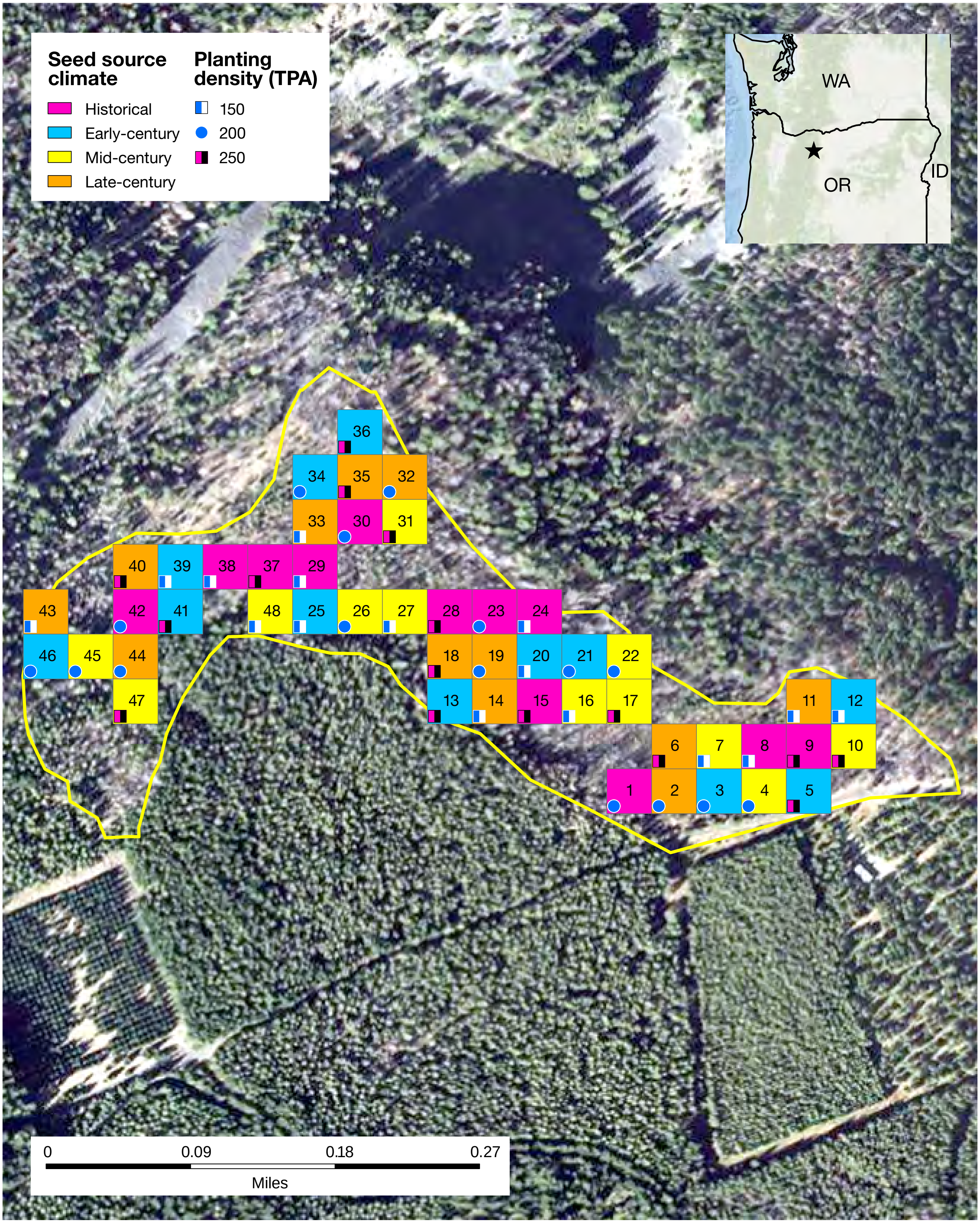

Figure A1.37—White River site with layout of 48 experimental treatment plots. TPA = trees per acre.

Whitmore Fire Site

OWNERSHIP: Confederated Tribes of the Colville Reservation

LOCATION: 48.24849°, −119.20866°; nearest town: Nespelem, Washington

SITE CHARACTERISTICS: The site is on a ridgetop at an elevation of 2,700 ft and faces S-SW/N-NE, with a gentle slope of 5–14 percent (fig. A1.38). The soils are moderately deep, well-drained loams formed in mixed volcanic ash over glacial till. The mean annual temperature is 7.2 °C (coldest month −5.0 °C, warmest month 19.4 °C), and mean annual precipitation is 354 mm (93 mm as snow).

SITE HISTORY: The site burned in the 2021 Whitmore Fire.

PLANTED SPECIES: Ponderosa pine (*Pinus ponderosa*)

PLANTING DATE: Planned for spring 2025

SITE PREPARATION: Excavator piling with a follow-up vegetation control treatment (mechanical or chemical, to be determined)

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Okanogan-Wenatchee National Forest	4,000–4,500	–5.25	105.0
Early-century (2011–2040)	Umatilla National Forest	3,500–4,000	–3.14	99.7
Mid-century (2041–2070)	Deschutes National Forest	4,000–5,000	–1.79	108.8
Late-century (2071–2100)	Mt. Hood National Forest	1,000–2,000	–0.55	287.3

SILVICULTURAL TREATMENTS: Three different stock types (see below)

PLANTING DENSITY: Operational contract crews will plant 300 trees per ac.

SEEDLING STOCK TYPE: Containerized stock (Styro 6, Styro 10, Ellepot)

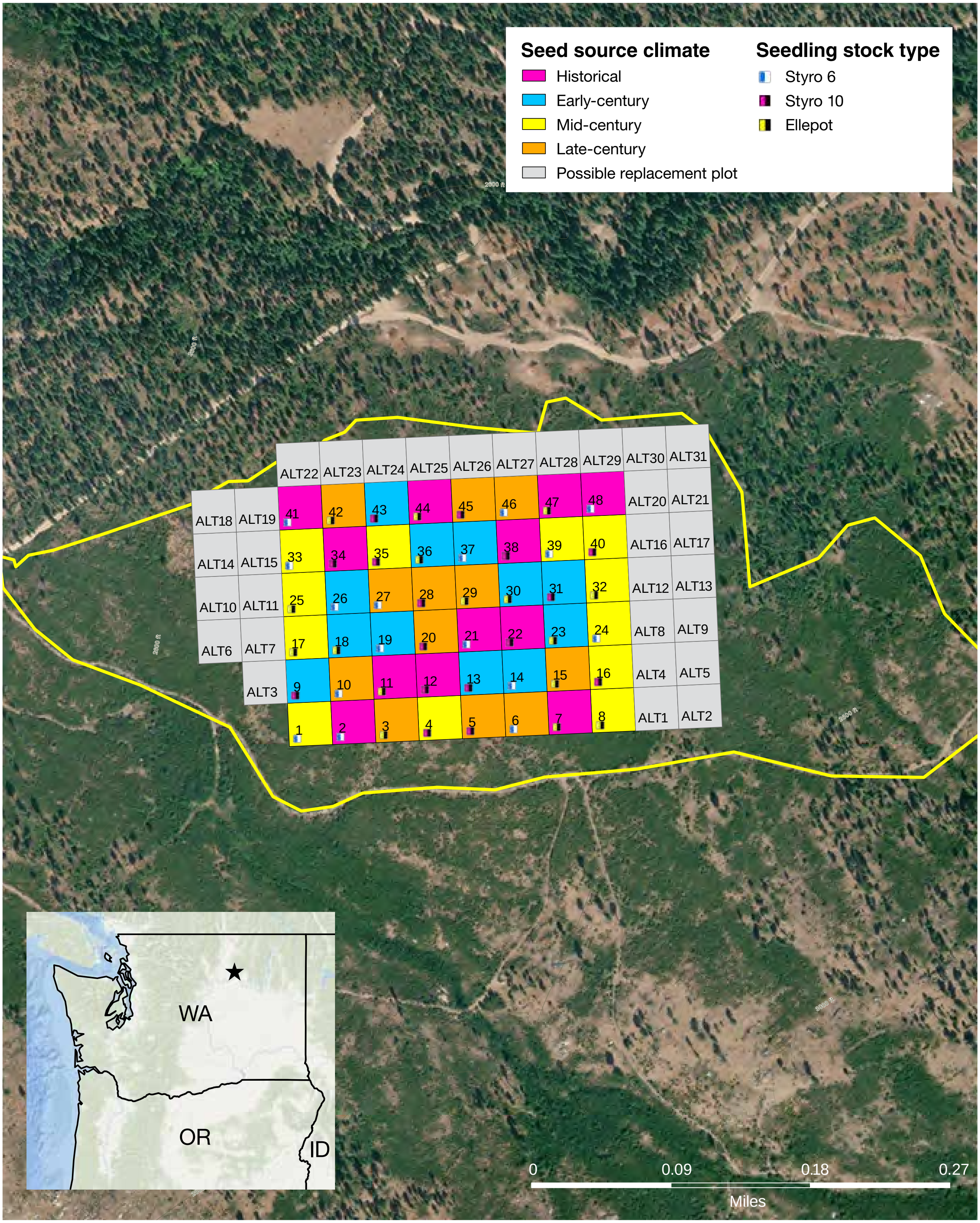

Figure A1.38—Whitmore Fire site with tentative layout of 48 experimental treatment plots.

Winterfelled Site

OWNERSHIP: Oregon Department of Forestry

LOCATION: 44.7022143°, −122.3797775°; nearest town: Mill City, Oregon

SITE CHARACTERISTICS: The site is S-facing and at an elevation of 2,400 ft with a slope of 18–46 percent (fig. A1.39). The soils are deep, well-drained, gravelly loams formed in colluvium and residuum from tuffaceous sandstone, siltstone, and basalt. The mean annual temperature is 8.3 °C (coldest month 2.2 °C, warmest month 16.1 °C), and mean annual precipitation is 2225 mm (135 mm as snow).

SITE HISTORY: The site was harvested in 2023.

PLANTED SPECIES: Douglas-fir (*Pseudotsuga menziesii*)

PLANTING DATE: Spring 2024

EXPERIMENTAL DESIGN: Randomized complete block factorial design with four replications per assisted migration treatment by silvicultural treatment combination applied to 0.5-ac plots.

ASSISTED MIGRATION TREATMENTS: We used the Seedlot Selection Tool (USDA FS et al., n.d.) to choose four seed sources for planting:

Climate period	Seed source characteristics			
	Seed origin	Elevation (FEET)	Mean coldest month temperature (DEGREES CELSIUS)	Summer heat moisture index (UNITLESS)
Historical (1961–1990)	Bureau of Land Management (BLM)—Molalla area	2,700–4,000	0.87	34.2
Early-century (2011–2040)	BLM—McKenzie area	2,700–4,000	2.85	67.1
Mid-century (2041–2070)	BLM—McKenzie area	800–2,700	3.50	74.4
Late-century (2071–2100)	BLM—Coquille 16 area	<1,600	6.36	80.6

SILVICULTURAL TREATMENTS: Three herbicide application treatments: No spray, one application, two applications

PLANTING DENSITY: Operational contract crews planted 300 trees per ac.

SEEDLING STOCK TYPE: Containerized stock (Styro 515).

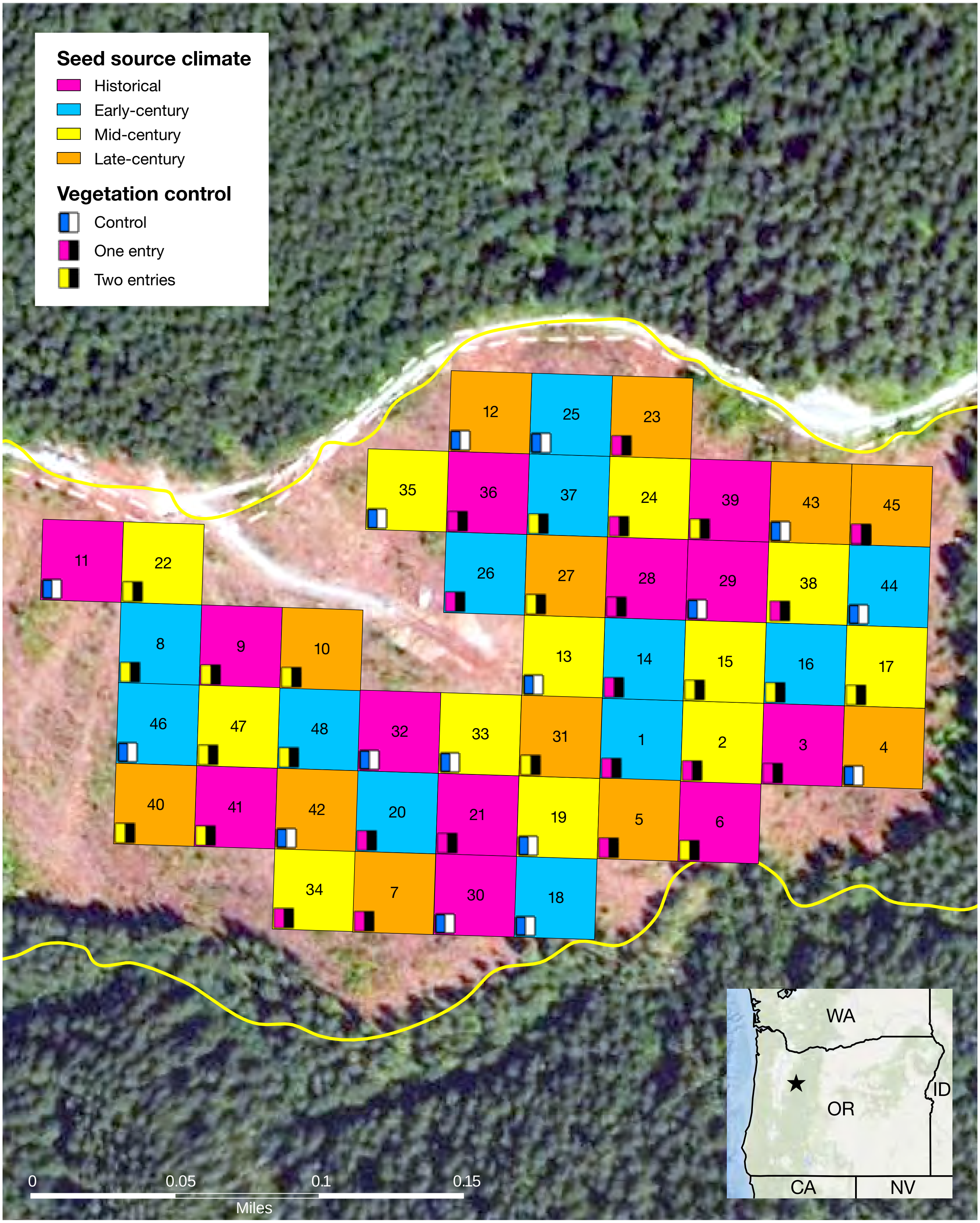

Figure A1.39—Winterfelled site with layout of 48 experimental treatment plots.

APPENDIX 2

Scientific and Common Names of Plants Referenced in this Study

Life form	Scientific name	Authority	Common name
Tree	*Abies concolor*	(Gord. & Glend.) Lindl. ex Hildebr.	White fir
Tree	*Abies procera*	Rehder	Noble fir
Tree	*Arbutus menziesii*	Pursh	Pacific madrone
Tree	*Calocedrus decurrens*	(Torr.) Florin	Incense cedar
Tree	*Cornus nuttallii*	Audubon ex Torr. & A. Gray	Pacific dogwood
Tree	*Juniperus occidentalis*	Hook.	Western juniper
Tree	*Larix occidentalis*	Nutt.	Western larch
Tree	*Notholithocarpus densiflorus*	(Hook. & Arn.) P.S. Manos, C.H. Cannon, & S.H. Oh	Tanoak
Tree	*Picea engelmannii*	Parry ex Engelm.	Engelmann spruce
Tree	*Pinus contorta* var. *murrayana*	(Balf.) Engelm.	Sierra lodgepole pine
Tree	*Pinus jeffreyi*	Balf.	Jeffrey pine
Tree	*Pinus lambertiana*	Douglas	Sugar pine
Tree	*Pinus monophylla*	Torr. & Frém.	Singleleaf pinyon
Tree	*Pinus ponderosa*	Lawson & C. Lawson	Ponderosa pine
Tree	*Pseudotsuga menziesii*	(Mirb.) Franco	Douglas-fir
Tree	*Quercus garryana*	Douglas ex Hook	Oregon white oak
Tree	*Quercus kelloggii*	Newberry	California black oak
Tree	*Thuja plicata*	Donn ex D. Don	Western redcedar
Tree	*Tsuga heterophylla*	(Raf.) Sarg.	Western hemlock
Tree	*Tsuga mertensiana*	(Bong.) Carrière	Mountain hemlock
Shrub	*Acer circinatum*	Pursh	Vine maple
Shrub	*Amelanchier alnifolia*	(Nutt.) Nutt. ex M. Roem.	Saskatoon serviceberry
Shrub	*Artemisia* sp.	L.	Sagebrush
Shrub	*Ceanothus* sp.	L.	Ceanothus
Shrub	*Rhododendron macrophyllum*	D. Don ex G. Don	Pacific rhododendron
Shrub	*Rubus* sp.	L.	Blackberry
Shrub	*Rubus ursinus*	Cham. & Schltdl.	California blackberry
Forb	*Athyrium filix-femina*	(L.) Roth	Common ladyfern
Forb	*Chamerion angustifolium*	(L.) Holub	Fireweed
Forb	*Cirsium arvense*	(L.) Scop.	Canada thistle
Forb	*Verbascum thapsus*	L.	Common mullein

Glossary

1-0—A 1-year-old bareroot seedling that was not transplanted at the nursery.

2-0—A 2-year-old bareroot seedling that was not transplanted at the nursery.

bareroot—A seedling stock type that is separated from the soil in which it is grown before packaging and delivery. Seedling roots are fully exposed when planting into the ground. Bareroot seedlings are denoted by X-Y, where X is the number of years grown in the seedbed after sowing and Y is the number of additional years grown after transplanting (usually to a bed with lower seedling density to allow for greater growth and size). For example, a 2-2 is a 4-year-old seedling that was grown after transplanting for 2 years.

block—As used for this project, a block refers to the element of a randomized complete block design used to group experimental units to control for variability not explained by the treatment. Where we used this design, we randomly assigned each unique treatment combination to one plot per block for four replications of a treatment combination per site. A block contains 4–16 plots.

containerized—A seedling stock type that is packaged and delivered in the plug of soil in which it was grown. Seedling plugs are typically grown in a Styroblock cell and then packaged, and the entire plug (soil and seedling) is planted directly into the ground.

Ellepot—A type of containerized seedling that is grown in soil media surrounded by paper (compared to being grown in a Styroblock).

grubbing—The practice of removing vegetation and surficial soil around a seedling after planting to provide favorable planting conditions.

plot—As used for this project, a plot refers to the unit of area within a site to which the assisted migration and silvicultural treatments were applied.

Q-plugs—A type of seedling that is initially grown in a container and then transplanted to a bed to produce large vigorous seedlings in a shorter time.

shade cards—Rectangular cards made out of plastic, wood, or other durable material that are placed on the southern side of a tree seedling to provide shade in exposed conditions.

site—As used for this project, a site refers to an area in which a set of assisted migration and silvicultural treatments are evaluated. When a randomized complete block design is used at a site, the site contains four blocks. A site contains 13–64 plots.

Styro—Abbreviated name for Styroblock. Styroblocks are cubes of Styrofoam containing a grid of cell cavities in which tree seedlings are grown. Styroblocks come in various configurations with cavities of different volumes denoted by number (e.g., Styro-8 is a container with cells that are 3.8 cm in diameter and 15.2 cm deep with volume of 130 cm^3 (approximately 8 cubic inches).

summer heat moisture index—A unitless measure of moisture stress that integrates the temperature of the warmest month and summer precipitation. This measure is a default climate variable in the Seedlot Selection Tool (USDA FS et al., n.d.).

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