

Washington State Reforestation Needs, Capacity, and Carbon Markets Assessment



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Executive Summary

The Pacific Northwest faces an escalating and complex challenge in reforesting and expanding its forests, driven by intensifying wildfires, ongoing timber harvest, and carbon sequestration considerations. In response, the presiding Washington State Commissioner of Public Lands in 2023 set an ambitious goal to reforest 1 million acres across the state by 2040. To achieve this, the Washington Department of Natural Resources (DNR) secured legislative funding in the 2023 Operating Budget to develop internal expertise and conduct comprehensive assessments of reforestation needs, current capacity, and expansion potential along the supply chain. American Forests was contracted by Washington DNR to develop these assessments. The resulting "Washington State Reforestation Needs, Capacity, and Carbon Markets Assessment" provides pertinent information by analyzing the current reforestation needs, future projected reforestation needs, barriers and opportunities to scale reforestation projects, extent of potential afforestation, and carbon market considerations. This assessment also provides strategic opportunities and recommendations to increase and improve reforestation efforts.

Current and Projected Reforestation Need Assessment

Washington State faces a growing reforestation need from timber harvest and high-severity wildfires, currently estimated together at 983,275 acres. Washington State's reforestation needs are projected to rise sharply, particularly in fire-prone Eastern Washington, where demand could increase by over 500% by the 2060s. Western Washington's needs, primarily driven by timber harvest, are expected to remain stable but could also increase depending on market demand and wildfire behavior. To meet this growing reforestation need, strategic planning for adequate seed supply, workforce capacity, and reforestation infrastructure is recommended, along with climate-informed forestry planning to increase forest resilience, ecological integrity, and carbon sequestration.

Nursery Capacity, Limitations, and Recommendations

Nurseries in Oregon and Washington report an annual seedling capacity of 162.75 to 284.75 million seedlings, operating near maximum utilization, especially for container stock units. The majority of seedlings grown are Douglas Fir, Ponderosa Pine, and Western Red Cedar. While latent expansion capacity exists, it is largely constrained by uncertain future demand, infrastructure limitations, labor availability, and inconsistent ordering patterns mostly driven by short-term agreements lasting one to two years. Conifer seed inventories are modest, depleted by recent fire restoration planting, and cone-collection efforts targeting tree populations that display high adaptive capacity could help replenish those seed inventories and increase seedling survivorship. Nurseries are primarily operating at their desired capacity with the projected need for expansion hinging on greater certainty, long-term contracts, and consistent demand. Key recommendations include strategic planning with long-term contracts, enhanced collaboration and knowledge sharing, continued research into the demand-need disconnect,



and establishing a formal reforestation network to optimize seed supply, workforce development, and trusted partnerships.

Reforestation Service Provider Capacity, Limitations, and Recommendations:

Reforestation service providers located in Washington and Oregon report steady or increasing demand, particularly due to wildfires, yet face many operational constraints. These include unfair pricing from competitive bidding, workforce instability exacerbated by reliance on the H-2B temporary worker program, burdensome regulatory and federal bureaucratic hurdles, and critical funding gaps for small woodland owners. Despite these challenges, providers are willing and able to expand their capacity if these issues are addressed. Recommendations include implementing long-term contracts, promoting fair pricing, increasing accessible and strategically allocated funding, strengthening workforce development, providing targeted support for small woodland owners, developing a comprehensive regional reforestation strategy, and establishing a digital platform for shared and centralized information exchange among the community.

Current Afforestation Opportunity and Climate-Socioeconomic Vulnerability Assessment

Washington State possesses substantial potential for afforestation. Over 736,350 acres of non-forested land, primarily on privately owned land, is identified as theoretically suitable for forest. The potential forest types vary by region, with Eastern Washington favoring species like Ponderosa Pine and Douglas-fir, and Western Washington suited for Douglas-fir and Western Red Cedar. Additional analysis is needed to determine if specific potential afforestation opportunities are feasible in respect to survivability, ecological benefit, and landowner commitment. Socioeconomic indicators of climate vulnerability can help prioritize outreach and investment for these efforts, with Yakima County showing the highest overall vulnerability to regional shifts in climate and other forms of anthropogenic change. This analysis underscores the importance of climate-informed afforestation, consideration of future fire risk, and the potential benefits of integrated low-density planting in pastureland, as long as infrastructure is established to protect against seedling mortality due to herbivory.

Carbon Project Feasibility on Washington DNR Managed Lands

Our analysis of lands managed by the Washington State Department of Natural Resources found that over 37,000 acres are potentially suitable for Afforestation and Reforestation (ARR) carbon project development based on leading carbon crediting methodologies. Of this, approximately 16,600 acres are suitable for reforestation projects, representing high-priority areas due to their role in addressing ecological conversion risk and minimal agricultural displacement. Preliminary feasibility testing of two large burn scars found that only higher-productivity sites would be readily financially feasible as carbon projects, meaning that carbon revenues would fully offset site preparation, planting, and other reforestation costs. Carbon project development in these areas can complement long-term forest management objectives by providing additional finance for restoring forests. Eligible areas for carbon project



development may increase with expiring current leasing agreements and larger, more severe wildfires expected into the future.

In conclusion, addressing the Pacific Northwest's growing reforestation and afforestation needs and achieving the previous Commissioner's ambitious goal requires a comprehensive and coordinated approach. This involves strategic planning, fostering collaboration across the entire supply chain from seed to planting, and addressing critical workforce and financial barriers. It also means leveraging opportunities for carbon sequestration to enhance forest recovery and regional resilience.



Contents

Executive Summary	2
Acknowledgements	6
Introduction	7
Chapter 1. Current and Projected Reforestation Need for Washington State, USA	1
Chapter 2. Nursery Capacity, Limitations, and Recommendations for Washington.....	1
Chapter 3. Reforestation Service Provider Capacity, Challenges, and Recommendations for Washington	1
Chapter 4. Afforestation Potential and Climate-Socioeconomic Vulnerability Assessment for Washington State, USA.....	1
Chapter 5. Primer on Carbon Project Feasibility & Development for Washington DNR	1
Chapter 5 – Appendix A:	1
Overarching Conclusion.....	8



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Introduction

The Pacific Northwest faces increasing reforestation needs driven by the intensifying effects of wildfires, drought, pests and diseases, ongoing timber harvest activities, and carbon sequestration considerations. In response to this need, the Washington State Commissioner of Public Lands in 2023 set an ambitious goal: to reforest one million acres across the state by 2040.

To help achieve this goal, the Washington State Department of Natural Resources (DNR) secured legislative funding in the 2023 Operating Budget. This funding was for developing internal expertise and conducting comprehensive assessments of reforestation needs and the entire reforestation supply chain. As a result, American Forests was contracted by Washington DNR to develop these assessments, culminating in the "Washington State Reforestation Needs, Capacity, and Carbon Markets Assessment." This comprehensive report offers insights by analyzing current and future projected reforestation needs, identifying barriers and opportunities to scale reforestation projects, and exploring afforestation and carbon market incentives. Ultimately, it provides strategic opportunities and recommendations to increase and improve reforestation efforts across the state.

This report is organized into five distinct chapters to facilitate ease of sharing and allow readers to focus on pertinent components. Each section is designed to stand alone, featuring its own literature cited, table of contents, figures, tables, and abstracts. The supplemental information listed as appendices has been provided to Washington DNR.



Chapter 1

Current and Projected Reforestation Need for Washington State, USA



Current and Projected Reforestation Need for Washington State, USA

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Abstract

Background: Washington State faces a growing reforestation need driven by both stand-replacing wildfires and ongoing timber harvest, particularly as climate change amplifies the scale and frequency of high-severity fire events. To quantify the scale of this need and anticipate future demand, the Washington Department of Natural Resources and American Forests conducted a spatial and temporal assessment of reforestation potential across forested lands from 2014 through 2069. This analysis examined current and projected reforestation need by integrating data on timber harvest and wildfire with downscaled climate projections.

Results: Between 2014 and 2023, reforestation need in Western Washington was primarily associated with timber harvest, while in Eastern Washington it was driven by wildfires. Under projected climate scenarios through 2069, reforestation need in Eastern Washington is expected to increase by more than 500%, with the greatest impact on Douglas-fir and ponderosa pine forest types. Western Washington reforestation need may remain stable but could increase depending on harvest rates and cycle lengths. Additionally, wind-driven fire events—like the 2020 Labor Day Fires—introduce uncertainty not captured in current climate models. This assessment also estimated seed demand by forest type, indicating a substantial increase in seed and seedling needs to meet future reforestation goals.

Conclusion: Reforestation demand in Washington is expected to rise sharply, particularly in fire-prone Eastern Washington. Strategic planning will be needed to meet this demand, including efforts to ensure adequate seed supply, workforce capacity, and reforestation infrastructure. Climate-informed planning and investment in reforestation services are critical to supporting ecological resilience, forest recovery, and carbon sequestration across the region.

Keywords: reforestation, wildfire, timber harvest, seed need, climate change, Washington, forest regeneration, seedling demand



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Contents

Abstract.....	2
Acknowledgments.....	3
Introduction.....	6
Methods.....	7
Seed Zone, Region, Forest Type, and Ownership.....	7
Current Reforestation Need.....	9
Current Reforestation Need – Harvested Areas.....	9
Current Reforestation Need – Wildfire.....	11
Projected Reforestation Need.....	12
Potential Seed Need for Collection.....	13
Results.....	13
Current Reforestation Need – Harvested Areas.....	13
Current Reforestation Need – Wildfire.....	17
Projected Reforestation Need.....	19
Potential Seed Need for Collection.....	23
Assumptions and Limitations.....	23
Discussion and Conclusion: Management Implications and Next Steps.....	25
Divergent Drivers of Reforestation Need.....	25
Climate Change Considerations.....	26
Seed and Nursery Capacity.....	26
Prioritization and Resource Allocation.....	27
Data and Monitoring.....	27
Collaboration and Partnerships.....	27
Recommended Next Steps.....	27
Literature Cited.....	28



List of Figures and Tables

Figure 1. Seed Transfer Zone and Forest Types.....	8
Figure 2. Total Acres of Harvest for Forest Types.....	15
Figure 3. Total Acres of Harvest for Ownership.....	16
Figure 4. Total Annual Harvest Area.....	17
Figure 5 Current Reforestation Need from Wildfire by Forest Type.....	18
Figure 6. Current Reforestation Need from Wildfire by Ownership.....	19
Figure 7 Projected Reforestation Need from Wildfire by Forest Type.....	20
Table 1. Current Reforestation Need.....	14
Table 2. Current and Projected Reforestation Need for High-Priority Forest Types.....	21
Table 3 Current and Projected Reforestation Need for Low-Priority Forest Types.....	22
Table 4. Total Seed, Total Current Reforestation Need, and Potential Seed Need.....	23

Appendices

Appendix A: Flow Chart Projected Reforestation Need Modeling Approach	
Appendix B: Additional Tables for Planting Prescriptions	
Appendix C: Additional Results by Seed Zone(.html)	
Appendix D: Tabular Harvest Reforestation Need (.csv)	
Appendix E: Tabular Wildfire Reforestation Data (.csv)	
Appendix F: Tabular Projected Wildfire Reforestation Need	
Appendix G: Additional Figures Projected Reforestation Need (.docx)	



Introduction

Active reforestation via seedling planting is a key management action that supports sustainable timber harvest practices, recovery from wildfire and other natural disturbances, increased forest cover under a changing climate, carbon sequestration, biodiversity, and provisioning of clean water (North et al., 2019; Keller and Fox, 2019; Cook-Patton et al., 2020). Historically, national reforestation efforts via seedling planting focused on restoring lands affected by large-scale regeneration harvests and wildfire. However, as federal timber harvests declined in the 1970s through the 1990s and the reforestation need for harvest followed suite, an unexpected exponential increase has been measured in wildfire extent, frequency, and area burned at high severity (Parks and Abatzoglou, 2020; Dumroese et al., 2005). Wildfire has emerged as a major driver of reforestation need in the Western United States (e.g., 81% on [National Forest System lands](#) in 2022; accessed March 2025).

Despite national declines over the past decades, timber harvest in Washington remains a key economic driver for the state, providing over 100,000 jobs and \$5.6 billion in wages in 2023 ([Washington Forest Protection Association](#); accessed March 2025). Under Washington State Forest Practices Rules ([Title 222 WAC](#)), reforestation is required following any harvest that removes 50% or more of the timber volume from a stand within a 5-year period. As such, much of the reforestation need across Washington, and particularly in Western Washington, is driven by the legal requirement to replant after timber harvest. Estimating the acreage of timber harvest in recent years provides a baseline for reforestation planning, and if this demand for timber remains stable in the future, the baseline estimates provide guidance on planning for future reforestation needs generated by timber harvest.

In addition to timber harvest, an accelerated increase in post-fire reforestation need across the Pacific Northwest (PNW) is attributed to more frequent wildfires that burn a greater proportion of lands at high severity relative to recent and modeled historical fire regimes (Parks and Abatzoglou, 2020; Haugo et al., 2019; Halofsky et al., 2018). Collectively, these changes impact forest recovery mechanisms and can lead to delayed regeneration or regeneration failure (Davis et al., 2023). Increased wildfire frequency can result in a fire return interval outside the range of natural variability, while an increased proportion of area burned at high severity can lead to reduced seed availability and beneficial bioclimatic buffers that facilitate the natural regeneration of trees (Wolf et al., 2021; Enright et al., 2015). Climate change can directly impact forest recovery by applying more stressful hydroclimatic conditions on seedling regeneration—mainly through an increase in water stress via rising temperatures during more frequent and severe droughts—resulting in an increase in tree mortality, particularly in hotter and drier sites (Tepley et al., 2017). Collectively, these climatic changes increase the risk of community shifts and forest type conversion to non-forested ecosystems (e.g., Coop et al., 2020). These impacts are projected to increase as the effects of climate change become more severe and fire regimes continue to change (Davis et al., 2023; Coop et al., 2020; Halofsky et al., 2018).



Regardless of the disturbances and drivers that result in reforestation need, successful reforestation planning requires a confident estimation of current and future reforestation need to facilitate seed collection planning, coordinate nursery infrastructure, and secure the necessary workforce capacity prior to planting seasons. Quantifying these needs requires both an estimate of current reforestation needs and drivers, as well as an understanding of how future climate change may impact wildfire regimes and hence future reforestation needs. To provide an estimate of Washington’s reforestation needs and facilitate advance planning, we assessed the current (2014-2023; Deliverable 2B) and projected (2024-2069; Deliverable 2D) acreage of reforestation need generated by wildfire and timber harvest. We also estimated potential seed need by region and forest type to facilitate seed planning and collection over time.

In this study, “current reforestation need” is the potential area that could require reforestation due to stand-replacing wildfire or timber harvest occurring between 2014-2023, based on an assessment of geospatial and remote sensing data. It is likely that some areas of potential current reforestation need have already been reforested, and as such ground-truthing or other forms of validation will be needed to verify the true operational reforestation need prior to planting. Likewise, “projected reforestation need” is modeled from total acreage of potential current reforestation need scaled in relation to future wildfire probability. To estimate future wildfire probability, we use data from state-of-the-art general circulation models (GCMs) and a fire risk model developed by Anderegg et al., (2022). As with current reforestation need, projected reforestation need is an estimate of future needs based on historic trends and available climate projections useful for planning efforts and will require verification as future disturbances occur. In this report, we use the terms “current reforestation need” and “projected reforestation need” to refer to the potential current (2013-2024) and projected future (2025-2069) reforestation need, respectively, estimated by our spatial and temporal models.

Methods

Seed Zone, Region, Forest Type, and Ownership

We evaluated current and projected reforestation need at multiple scales, including seed transfer zones, regions, forest type, and ownership. Seed transfer zones (c.1972) were acquired from Washington Department of Natural Resources (WADNR). We then aggregated the seed zones into two general regions, Western Washington and Eastern Washington, based on position relative to the Cascade Divide (Fig. 1).

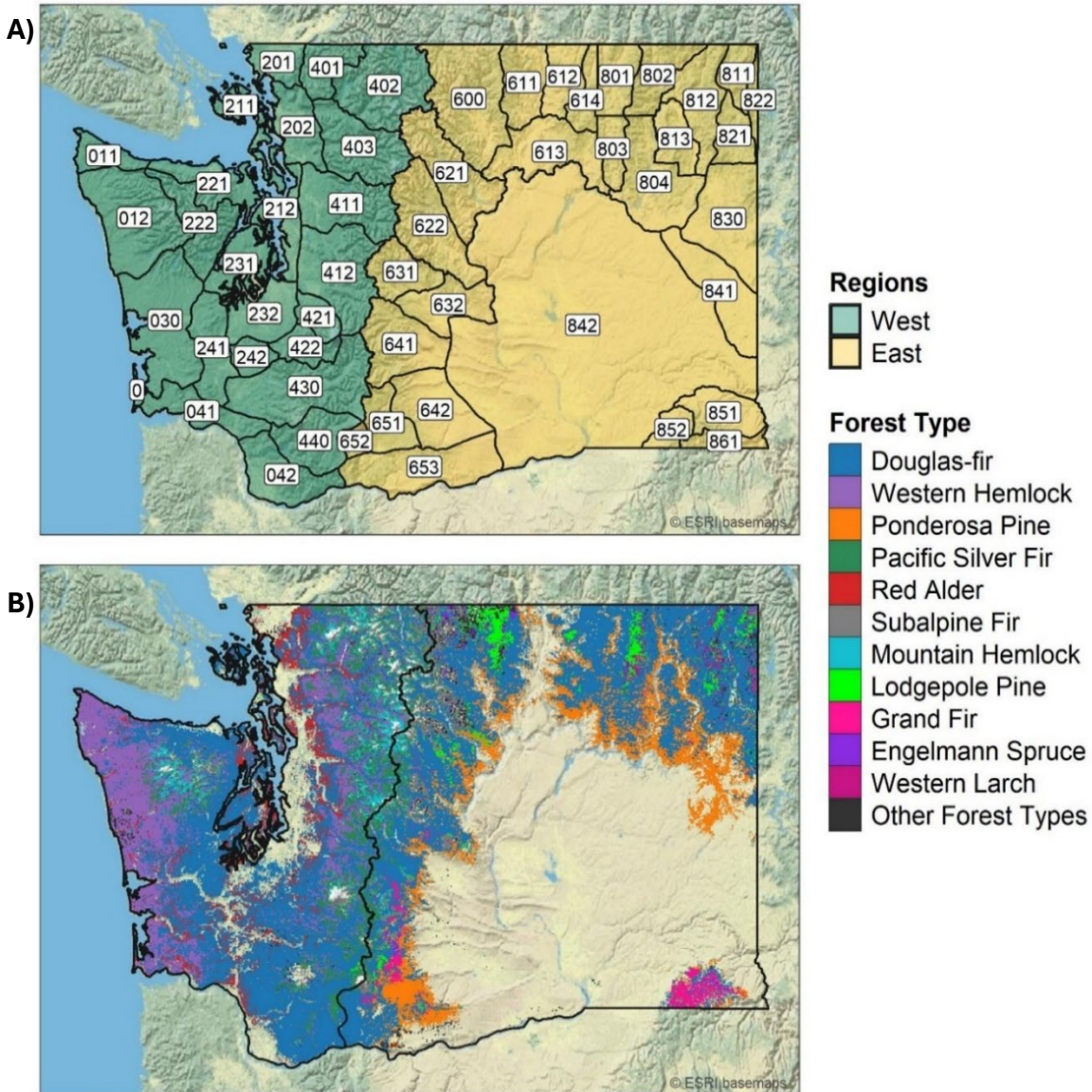


Figure 1. (A) Seed transfer zones and regional divisions (Western vs. Eastern Washington). **(B) Forest types** listed in descending order of total acreage. Forest types with less than 130,000 acres were grouped into “Other Forest Types”.

To distinguish forest type, we used the [National Forest Type](#) (NFT; accessed October 2024) data from the United States Forest Service Forest Inventory and Analysis (FIA) program and Geospatial Technology and Applications Center (GTAC).

Major Timberland Ownership data were acquired from WADNR and Atterbury Consultants Inc. We used our best judgement to distinguish private industrial and nonindustrial lands. Ownership classes REIT (Real Estate Investment Trusts) and TIMO (Timber Investment Management Organizations) were combined into “Private Industrial”. The IFPC (Independent Forest Product



Company) and Lender classes were combined into "[Private Nonindustrial](#)", unless the specific owner was thought to meet industrial criteria of being vertically integrated or known to own more than 45,000 ac of land across the US. The IFPC owners that were classified as "Private Industrial" were Hampton Lumber, Inland Empire Paper Company, Manke Lumber Company, Merrill & Ring, Mid-Valley Wood Products, Pacific Denkmann Company, Port Blakely Companies, Sierra Pacific Industries, Stimson Lumber, Vaagen Timbers, and West Fork Timber HCP. Ownership classes denoted as private were kept as "Private", as it was uncertain if these parcels were industrial or nonindustrial lands.

State lands owned by Washington DNR were kept separate as "State_WADNR", while all other state lands were combined into "State_Other". USDA Forest Service (USFS) land was kept separate as "Federal_USFS", while all other federal lands were combined into "Federal_Other". The ownership class Indian was kept as "Tribal". All other ownership types (ports, conservation land, county, city, and utility) were combined into "Other". The Atterbury ownership data did not fully account for all WADNR managed lands, so we used the WADNR Large Data Overlay (LDO) to identify additional land to classify as "State_WADNR".

Current Reforestation Need

We estimated current reforestation need from 2014 to 2023 caused by two different disturbance types: 1) commercial timber harvest, and 2) wildfire. The estimated current reforestation need for the two disturbance types originated from different datasets and methodologies, which are defined in the two following sections. The current need estimates presented in this report assume that no reforestation has occurred post-harvest or wildfire. We used this approach to identify a total footprint of disturbances causing current potential reforestation need upon which potential future need could be built. As our future projections are scaled from current estimates, excluding areas that have been reforested in our current estimates would result in an underestimate of potential future needs. Additional validation and verification will be required to account for reforestation efforts which have already occurred on lands with current need. However, data corroborating reforestation events (especially on private lands) is limited. The current reforestation need should not be considered as a reforestation backlog but rather as a means to establish a baseline. Some of the current reforestation needs have been addressed through restoration efforts across the decade.

Current Reforestation Need – Harvested Areas

We estimated timber harvest acres from 2014 to 2023 to establish the baseline reforestation need generated by harvest. Inclusion of a harvest event within this report does not imply that the landowner has not completed the statutory requirements to replant required under Washington State Forest Practices Rules ([Title 222 WAC](#)). Rather, because of these requirements, we assume that all listed harvest will need to be replanted, thus influencing the baseline demand for seed and seedlings.

The harvest reforestation needs estimate is based on two publicly available GIS layers which depict proposed harvest activities in Washington. For state and private ownerships, we used the



[WA DNR Forest Practices Application/Notification \(FPA/N\) database](#) accessed via the [Washington DNR GIS portal](#) in October 2024. Data contained within this layer include proposed harvest, road activity, and aerial chemical spray activity boundaries with their associated attribute data as reported in the FPA/N and associated documents. For data pertaining to harvest on USFS owned or managed lands we used the USFS [Forest Activity Tracking System \(FACTS\) Timber Harvests layer](#) downloaded from the [FSGeodatabase Clearinghouse](#) (accessed October 2024). The Timber Harvests layer contains information related to planned and accomplished treatments as part of the USFS Timber Harvest program of work. Defined commercial timber harvest polygons for other non-USFS federal lands (e.g., BLM, NPS) are not publicly available, and as such were excluded from this analysis.

Prior to use, the data required a QA/QC and subsetting process. For the FPA/N data, we first filtered data by ending date ≥ 2014 and starting date ≤ 2023 to ensure we would capture all harvests which could be completed during this period. We further subset the data to only include records pertaining to even-aged harvest types (“EVEN R/W”, “EVEN/SALVAGE”, or “EVEN-AGE”) based on the assumption that even-aged harvest activities would require interventions such as site preparation or planting in order for the forest to regenerate post-harvest. As a result of this subsetting process, we removed almost half of the original 150,380 records, leaving us with 85,901 records. We next corrected for overlapping activity boundaries within the FPA/N dataset to prevent double counting and to correctly attribute a proposed harvest activity to the time range in which it was completed. For this process, we defaulted to the latest ending date for a record.

For FACTS Timber Harvest data, we subset the data to include only completed activities which occurred in Washington with an ending date between 2014 and 2023. We selected only those timber harvest practices that would not result in natural regeneration due to removal of seed sources and thus would require replanting ('Stand Clearcut (EA/RH/FH)' and 'Stand Clearcut (w/ leave trees) (EA/RH/FH)'). We intentionally excluded harvest types which occur as the result of a disturbance (e.g., sanitation or salvage harvests) as well as those harvest types which are meant to release established regeneration from competition (e.g., 'Shelterwood Removal Cut (EA/ NRH/FH)'). We recognize that, depending on the exact silvicultural practice implemented, some low-density planting may be required to supplement regeneration following nominally uneven-aged or regeneration harvests. However, determining the exact reforestation need under these circumstances was beyond the scope of this analysis. Finally, we checked each FACTS record to ensure that it was not otherwise reported in the FPA/N data.

To validate harvests, we compared the FACTS and FPA/N activity boundaries to the forest loss dataset from [Hanson et al. \(2013\)](#). This dataset, which is updated annually, depicts forest gain and loss globally at 30m resolution as derived from multispectral Landsat imagery. For a harvest area to be considered “validated” it must match spatially and temporally to a record of forest loss. Although FACTS Timber Harvest data are internally validated, we chose to apply this same validation process to both datasets. Of the 1,495,767 acres of harvest from FACTS (541 acres)



and the FPA/N (1,495,226 acres) datasets between 2014 and 2023, we validated 775,781 acres (46.8% validation rate for FACTS and a 51.8% validation rate for FPA/N).

Finally, we estimated the overlap between validated harvest footprints and wildfire footprints. This analysis identified 6,263 acres of overlap, meaning less than 1% of the total area of harvest was likely from salvage harvest rather than a true even-aged harvest type. These areas of overlap are included in our total estimate of current reforestation need from harvest because regardless of causal agent, there is a legal requirement to reforest after any even-aged or salvage forest practice occurs, and thus a consequent need for seed and seedlings. For comparison with the reforestation need from wildfire, we summed validated harvest areas for each seed zone over the period between 2014 and 2023. To estimate variability within the sample, we resampled the annual data (with replacement) 10,000 times, and from this distribution of resampled sums calculated the 25th and 75th percentiles.

Current Reforestation Need – Wildfire

Estimates of current reforestation need on burned lands were identified based on fire severity and distance to potential seed source, assuming stand-replacing fire footprints without nearby seed sources would be unlikely to regenerate naturally and would therefore require artificial regeneration (i.e., planting). We first acquired all fire perimeters in Washington for the baseline period (2014-2023) from the [National Interagency Fire Center](#) (NIFC; accessed August 2024), filtering out any patches smaller than 25 acres, a small enough area to be in the natural range of forest openings and mostly within possible seed dispersal distance. We used a Google Earth Engine (GEE) approach based on Parks et al. (2018) to calculate the Relativized Burn Ratio (RBR) and apply a phenological offset for each perimeter using mean composite pre-fire year and post-fire year Landsat imagery. An RBR threshold of 283 was used to identify areas of stand-replacing fire based on empirical relationships described in Parks et al. (2018). We used Global Ecosystem Dynamics Investigation (GEDI)-derived vegetation height data ([Potapov et al., 2021](#)) to assign the distance from each pixel that burned at stand-replacing severity to the nearest potential seed source, defined as unburned or having an RBR value less than 283 and having a vegetation height of at least 5 m. We used [National Land Cover Database](#) (NLCD; accessed September 2024) cover type data to remove pixels containing developed land, agriculture/pasture, snow/ice, and water. We also removed pixels that had less than 10% canopy cover for all years between 1985 and 2023 using [Rangeland Condition Monitoring Assessment and Projection](#) (RCMAP; accessed September 2024) data to limit the analysis to areas that are, or were, forest at any point since 1985. The results for each fire were aggregated using the maximum estimated distance to seed source by year to account for duplicate fires in the NIFC dataset and to track annual trends more easily in reforestation need. All processing was done in GEE.

To account for uncertainty in natural regeneration attributable to variable dispersal distances, we generated three different scenarios of reforestation need based on seed dispersal distances in the literature (Laughlin et al. 2023; Buonanduci et al., 2024; Stevens-Rumann and Morgan; 2019, Liotta et al., n.d.): 1) greater than 0 m from seed sources (i.e., all stand-replacing areas),



2) greater than 60 m—the median distance beyond which regeneration is unlikely in western US forests (e.g., Stevens-Rumann and Morgan, 2019), and 3) greater than 150 m. Although successful regeneration can occur at farther distances, for example in temperate maritime forests (e.g., Laughlin et al., 2023), this approach provides information that can accommodate modifications to seed need estimates, while still providing a range of reforestation acreages to support decisions where reforestation will be more necessary (i.e., drier, low elevation forests).

We summarized current reforestation needs by Potential Vegetation Group (PVG) obtained from WADNR and heat load using the continuous heat-insolation load index (CHILI; Theobald et al. 2015). PVG, which classifies forest land as either Dry, Moist, or Cold, has been previously used to help understand natural regeneration in Washington (Povak et al., 2020; Liotta et al., n.d.). CHILI is a continuous index representing the effect of solar heating on slope positioning and latitude, which we divided into warm, neutral, and cool based on thresholds from Theobald et al. (2015). PVG and CHILI were used together to provide prioritization for areas at higher risk of regeneration failure: high-priority areas had Dry PVG or Moist PVG on a Warm CHILI site, while low priority areas had Cold PVG or Moist PVG on Neutral CHILI or Cool CHILI sites.

We then assigned priority classes based on the likelihood of natural regeneration. For each priority class (high vs. low), seed zone, region, forest type, and ownership class, we extracted the acreage of reforestation need from the three seed distance scenarios and calculated an estimate based on the median, 25th, and 75th percentiles. We chose median instead of mean because we wanted to exclude leverage from outliers that might influence the amount of both current and projected reforestation needs, thus exaggerating or underestimating the pounds of seed that would need to be collected (potential seed need), as well as growing capacity required in tree nurseries.

Projected Reforestation Need

Projected reforestation need was estimated based on current reforestation need from wildfires (see methods above) and scaled based on projected wildfire probability modeled for six downscaled (16 km) GCMs on decadal periods to mid-century (Anderegg et al., 2022). We used forest type as a predictor variable and assumed it to be stationary with future climate change. Other predictor variables used to estimate wildfire probability included monthly temperature, precipitation, and climatic water deficit (CWD). The specific GCMs downscaled by Anderegg et al. (2022) include: ACCESS-ESM1-5, MRI-ESM2-0, MPI-ESM1-2-LR, CanESM5-CanOE, ACCESS-CM2, and MIROC-ES2L.

We calculated projected reforestation need by multiplying the total acreage of current reforestation need for 2014-2023 by the ratio of mean burn probability from 2014-2023 to mean burn probability for future decadal periods (e.g. 2060-2069) for each GCM for each combination of seed zone, PVG, CHILI, and forest type:

$$\text{Projected Reforestation Need}_{GCM,t} = \left(\frac{\text{Future Burn Probability}_{GCM,t}}{\text{Baseline Burn Probability}_{GCM}} \right) \times \text{Current Reforestation Need}$$



where GCM refers to a specific GCM (e.g., ACCESS-CM2), t refers to a temporal period (i.e., 2030-2039, 2040-2049), Future Burn Probability $_{GCM,t}$ is the mean fire risk for the given GCM and temporal period, Baseline Burn Probability $_{GCM}$ is the mean fire risk for the baseline period (2014-2023) for the same GCM, and Current Reforestation Need is the total acreage of current reforestation need from 2014-2023. We then calculated the median projected reforestation need among the GCMs for each temporal period. We estimated variance by calculating 10,000 bootstrap samples with replacement for the median for each temporal period. All data was resampled to 30 m to match the spatial extent and resolution of the current reforestation needs estimates. A flow chart for the modeling approach that combines current and projected reforestation need from wildfire can be found in Appendix A (Fig. 1).

Potential Seed Need for Collection

We used expert opinion from WADNR scientists and land managers (*personal communication*) to estimate seedling planting density for each seed zone and forest type for Washington (Appendix B, Table 1). The average pounds of seed per bushel of cones from the dominant tree species in each forest type and average seeds per pound were estimated from records by the same WADNR scientists and managers (Appendix B, Table 2). In addition, we utilized a 20+ year dataset from WADNR that recorded the number of trees produced per pound of seed from WADNR nurseries (*personal communication*, Table 4). We used *The Woody Plant Seed Manual* (Bonner et al., 2008) to estimate seedlings per pound of seed for those species that did not have data from WADNR. With this information, we were able to estimate the number of bushels of cones necessary for each species for current and projected reforestation needs for each forest type and seed zone in Washington.

Results

Current Reforestation Need – Harvested Areas

Analysis of harvest activities reported in the FPA/N and FACTS Timber Harvest database indicate that, between 2014 and 2023, a total of 775,781 acres of forest land in Washington were harvested using a practice that would necessitate replanting (Table 1). When broken out by forest type (Fig. 2), Douglas-fir is the most highly harvested type (515,454 acres), of which 81.2% (418,725 acres) occurred in Western Washington (seed zones 611-861). Western Hemlock (174,813 acres) and Red Alder (52,865 acres) were the next most harvested forest types with 99.9% and 100% (respectively) of their harvest in Western Washington. Ponderosa Pine (13,566 acres) was the fourth most harvested forest type with all its harvest in Eastern Washington. Finally, Pacific Silver Fir was the fifth most harvested forest type (8,042 acres) with 97.4% of its harvest in Western Washington. Across the remaining 17 forest types for which there was harvest, none had more than 3,000 acres of harvest removals over the same period, with a sum total of 3,207 acres of harvest occurring in Western Washington and 7,835 acres of harvest occurring in Eastern Washington. In total, 84.7% of the harvest area (657,247 acres)



was in Western Washington. Harvest activities broken out by seed zone and forest type can be found in Appendix C. The tabular data used for harvest activity results and figures in this document can be found in Appendix D.

Forest Type	Harvested Acres (2014-2023)	
	West	East
<i>Bigleaf Maple</i>	1,713 ± 199	-
<i>Cottonwood</i>	161 ± 70	15 ± 7
<i>Douglas fir</i>	418,725 ± 46,255	96,728 ± 9,074
<i>Engelmann Spruce</i>	-	80 ± 23
<i>Engelmann Spruce/Subalpine Fir</i>	-	33 ± 9
<i>Grand Fir</i>	-	1,680 ± 279
<i>Lodgepole Pine</i>	84 ± 42	2,624 ± 346
<i>Misc. Western Hardwood Woodlands</i>	16 ± 0	-
<i>Mountain Hemlock</i>	84 ± 20	4 ± 0
<i>Noble Fir</i>	244 ± 41	-
<i>Oregon Ash</i>	74 ± 31	-
<i>Pacific Madrone</i>	<1 ± 0	-
<i>Pacific Silver Fir</i>	7,831 ± 955	211 ± 56
<i>Paper Birch</i>	7 ± 4	-
<i>Ponderosa Pine</i>	-	13,566 ± 1,655
<i>Red Alder</i>	52,865 ± 5,257	-
<i>Sitka Spruce</i>	79 ± 28	-
<i>Subalpine Fir</i>	4 ± 0	205 ± 28
<i>Western Hemlock</i>	174,618 ± 27,717	195 ± 43
<i>Western Larch</i>	-	1,936 ± 433
<i>Western Redcedar</i>	743 ± 136	1,245 ± 222
<i>Western White Pine</i>	-	12 ± 6

Table 1. Current reforestation need 2014-2023 (ac) post-harvest across Washington State. Data are summed by National Forest Type classification and broken out by region (east = seed zones 0-600, west = seed zones 611-861). Uncertainty (25th and 75th quantiles) is represented by resampling the annual harvest data 10,000 times with replacement and taking half of the interquartile range of the resampled population.

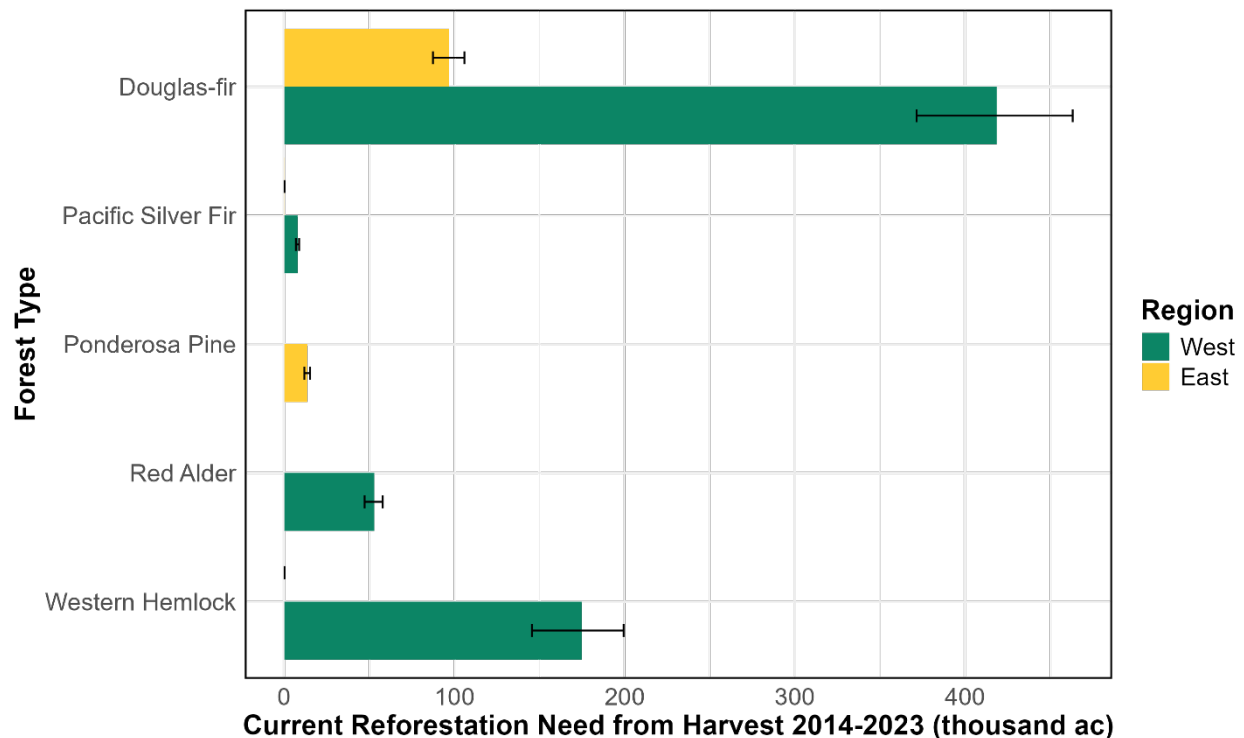


Figure 2. Total acres of harvest (2014-2023) across Washington by forest type classification, broken out by region (east = seed zones 0-600, west = seed zones 611-861). Bars represent the sum of all harvest area for a given grouping and error bars represent the 25th and 75th percentiles of a sample constructed by resampling the data 10,000 times with replacement. Groups with a total harvest less than 3,000 acres are not shown.

Looking at harvest area by ownership (Fig. 3), the majority (63.5%) of harvest occurs on private industrial lands, with 63,383 acres in Eastern Washington and 429,332 acres in Western Washington. Harvest is higher in Western Washington for all ownerships other than the USFS (1,631 acres in Eastern Washington vs. 374 acres in Western Washington). WADNR (134,858 acres) and other state agencies (3,255 acres) account for 17.8% of the total harvest area across the state. The comparatively low (0.28% of total) harvest on USFS owned and managed lands may be due to differences in data between FACTS (USFS) and FPA/N (state, local, tribal, and private) datasets (see Assumptions and Limitations section). However, this result reflects the fact that clearcut style harvests have become increasingly uncommon on USFS managed lands across the Pacific Northwest following the passage of the Northwest Forest Plan (Spies et al. 2019).

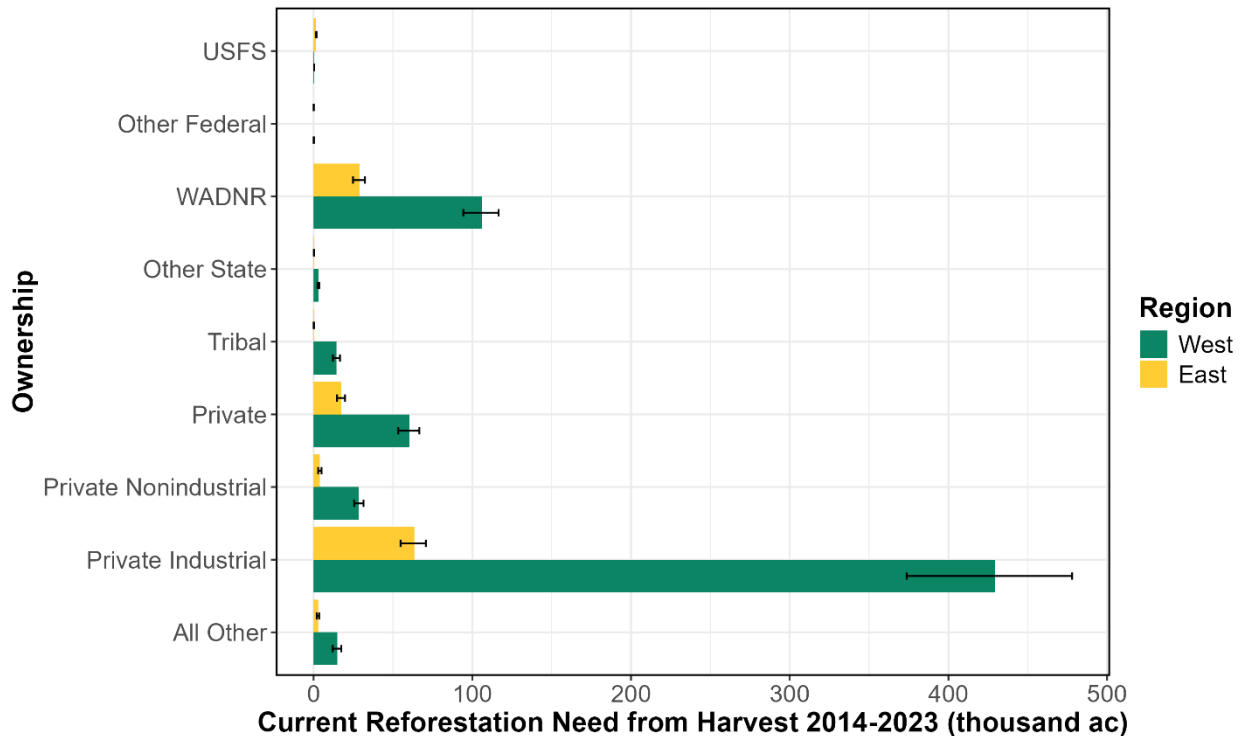


Figure 3. Total acres of harvest (2014-2023) across Washington by ownership classification, broken out by region (east = seed zones 0-600, west = seed zones 611-861). Bars represent the sum of all harvest area for a given grouping and error bars represent the 25th and 75th percentiles of a sample constructed by resampling the data 10,000 times with replacement.

Across our assessment period from 2014-2023 (Fig. 4), annual harvest levels are relatively stable with an average of 77,578 acres harvested per year. The ratio of Eastern Washington to Western Washington harvest is consistent, with the harvest in Western Washington accounting for 81.8% (2015) to 85.9% (2018 & 2022) of total harvest. In 2023, total harvest area declines slightly, to about 85% of the prior year's total. To determine whether this may indicate a pattern of declining harvest, we analyzed expiration dates for proposed activity areas in the FACTS and FPA/Ns data and found 3,340 records with an expiration date of 2022 and 3,349 records with an expiration date of 2023, compared to an annual average of 3,159 records from 2000-2021. This suggests that the decline in harvested acres in 2023 is likely the result of currently incomplete harvest FPA/Ns activity records issued in 2022 and 2023. FPA/Ns are issued with a three-year active period (with the option for a three-year renewal) and harvests may be completed at any time in this period, often when market conditions are most favorable. FPA/Ns with starting years from 2014 to 2020 have an average validation rate of 70%, which drops to 58% for FPA/Ns issued in 2021, 42% for those issued in 2022, and 9% for those issued in 2023. In contrast, the validation percentage for FPA/Ns by ending years from 2014 to 2023 remained stable at an average of 68%. This suggests that the decline in harvest area observed in 2023 is likely due to a short-term lag in harvest, rather than being indicative of the onset of a long-term trend.

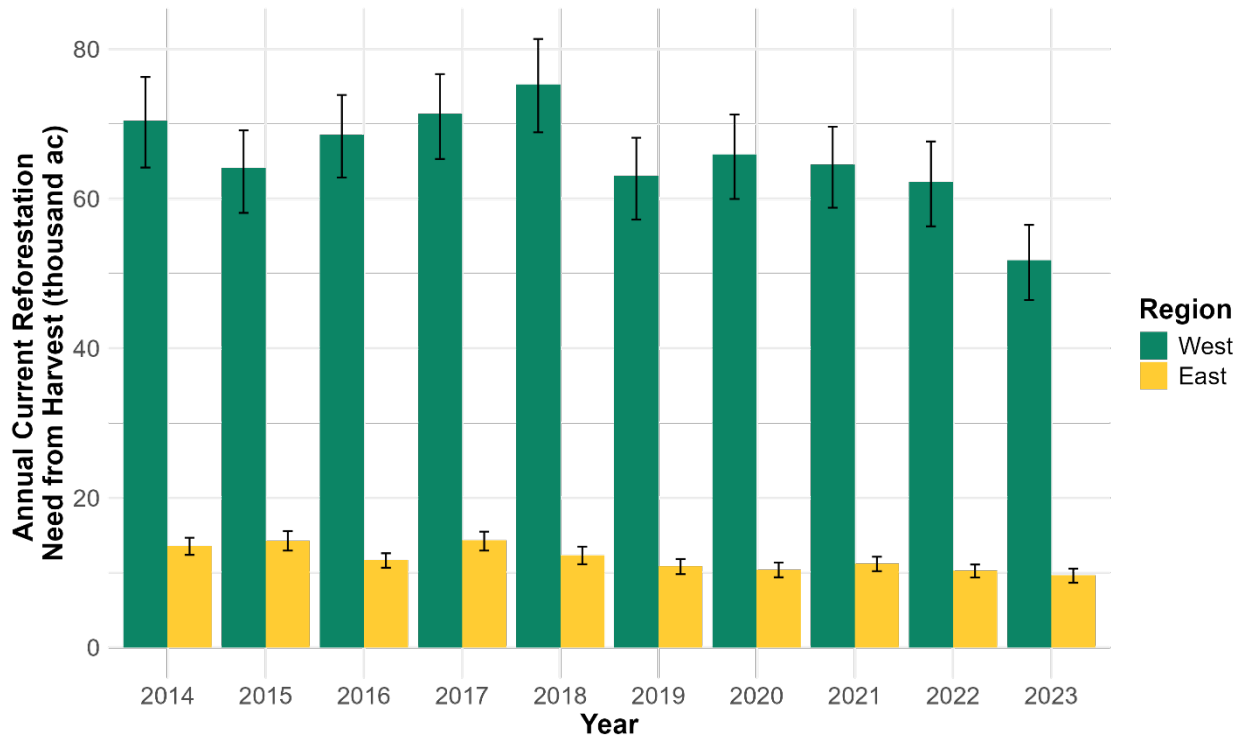


Figure 4. Total annual harvest area (2014-2023) across Washington by location (East = seed zones 0-600, West = seed zones 611-861). Bars represent the sum of all harvest area for a given year, and error bars represent the 25th and 75th percentiles of a sample constructed by resampling the data 10,000 times with replacement.

Current Reforestation Need – Wildfire

Across Washington, we identified a median of 207,494 acres of cumulative current reforestation need from wildfire between 2014 and 2023. Around 55% of the current need is in high-priority areas (113,509 ac), with the remaining 45% in low-priority areas (93,985 ac). Around 95% (197,120 ac) of the current reforestation need from wildfire is in Eastern Washington (Fig. 5). Eastern Washington also has a greater proportion of high-priority current reforestation need (56% vs. 26% in Western Washington). The Douglas-fir forest type is the largest by area and has the highest current reforestation need in each region. Current reforestation need from wildfire by forest type within each seed zone can be found in Appendix C. The tabular data used for results and figures in this document can be found in Appendix E.

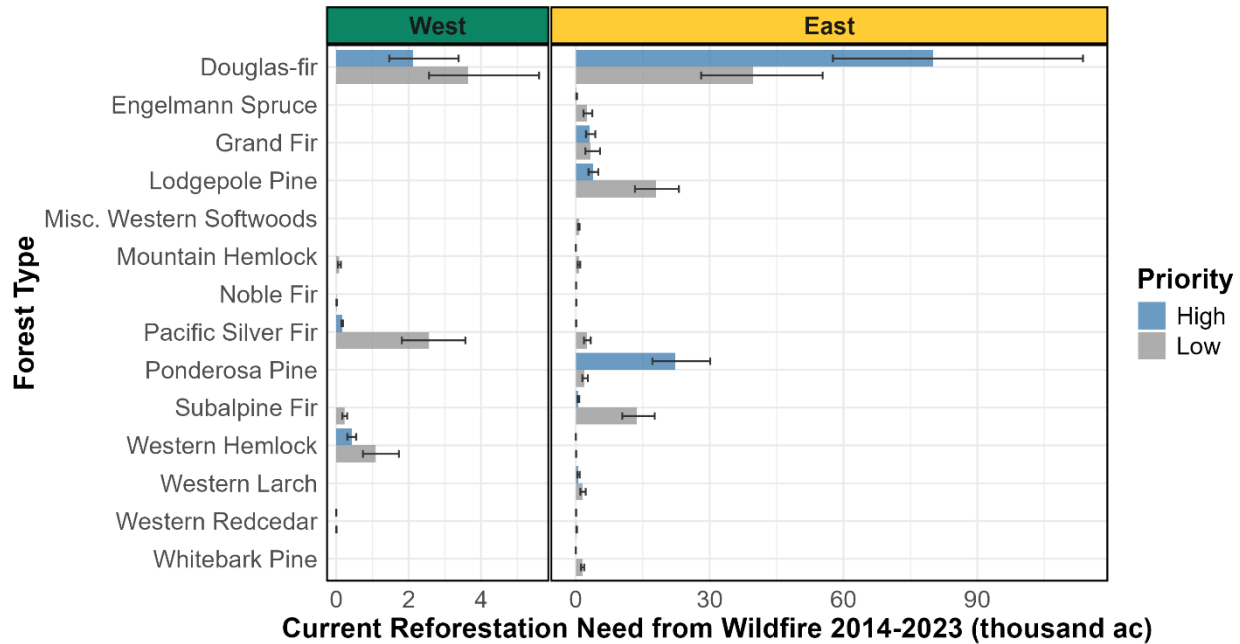


Figure 5: Cumulative current reforestation needed from wildfire (2014-2023) across Washington by forest type, region, and priority. High priority areas had Dry PVG or Moist PVG on a Warm CHILI site. Low priority areas had Cold PVG or Moist PVG on Neutral CHILI or Cool CHILI sites. Bars represent the median need calculated using three seed distances, while error lines represent the 25th and 75th percentiles. Forest types having less than 75 acres of need at the 75th percentile are not shown.

In terms of land ownership (Fig. 6), the USFS has the greatest current reforestation need, with 61% (121,923 ac) of the current reforestation need in Eastern Washington and 76% (7,941 ac) in Western Washington. Tribes (36,339 ac) and WADNR (18,221 ac) each have notable current reforestation need in Eastern Washington. However, current reforestation needs on Tribal land are relatively evenly split between priority classes, while 84% (15,261 ac) of the need on WADNR managed lands is in high-priority areas. For private lands in Western Washington, 89% (1,148 ac) of the current reforestation need is on Industrial Forests. Comparatively, 37% (6,383 ac) of current reforestation need on private lands in Eastern Washington is on Industrial Forest. Most of the current reforestation need on Private, Private Nonindustrial, and Private Industrial lands in Eastern Washington are in high-priority areas (5,342, 4,211, and 4,528 acres respectively).

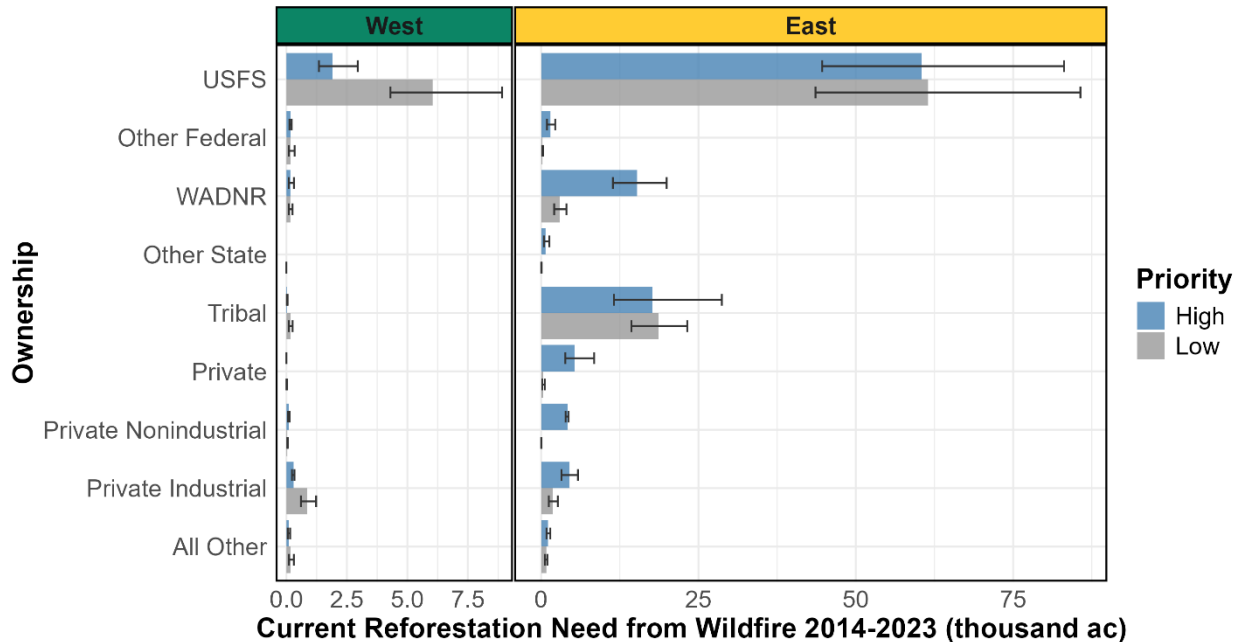


Figure 6. Cumulative current reforestation needed from wildfire (2014-2023) across Washington by ownership and region. Bars represent the median need calculated using three seed distances, while error lines represent the 25th and 75th percentiles.

Projected Reforestation Need

Generally, forest types in Eastern Washington had a magnitude higher increase of total acreage of projected reforestation need when compared to the same forest type in Western Washington (Fig. 7). For example, the projected reforestation need for high-priority Douglas-fir sites in Western Washington increased from 2,129 acres of current reforestation need to 16,497 acres of projected reforestation need in 2060-2069 (an increase of 14,368 acres), while that same forest type in Eastern Washington increased from 80,108 to 541,605 acres (461,497 acres). However, some forest types that correspond to sites with higher moisture and occur in greater concentrations in Western Washington, like Pacific Silver Fir and Western Hemlock, had a greater increase in Western rather than Eastern Washington (Table 2). Tabular data used for projected reforestation results and figures in this document can be found in Appendix F.

Overall, the five forest types with the highest projected reforestation need (2060-2069) in Western Washington included: 1) low-priority Douglas-fir (659% increase since 2014-2023), 2) high-priority Douglas-fir (675% increase), 3) low-priority Pacific Silver Fir (536% increase), 4) low-priority Western Hemlock (676% increase), and 5) high-priority Western Hemlock (446% increase). For Eastern Washington, the five forest types with greatest projected need (2060-2069) included: 1) high-priority Douglas-fir (576% increase since 2014-2023), 2) low-priority



Douglas-fir (570% increase), 3) high-priority Ponderosa Pine (503% increase), 4) low-priority Lodgepole Pine (429% increase), and 5) low-priority Subalpine Fir (524% increase). Annually scaled projected reforestation need is provided for all forest types and region for high-priority (Table 2) and low-priority (Table 3) acreage.

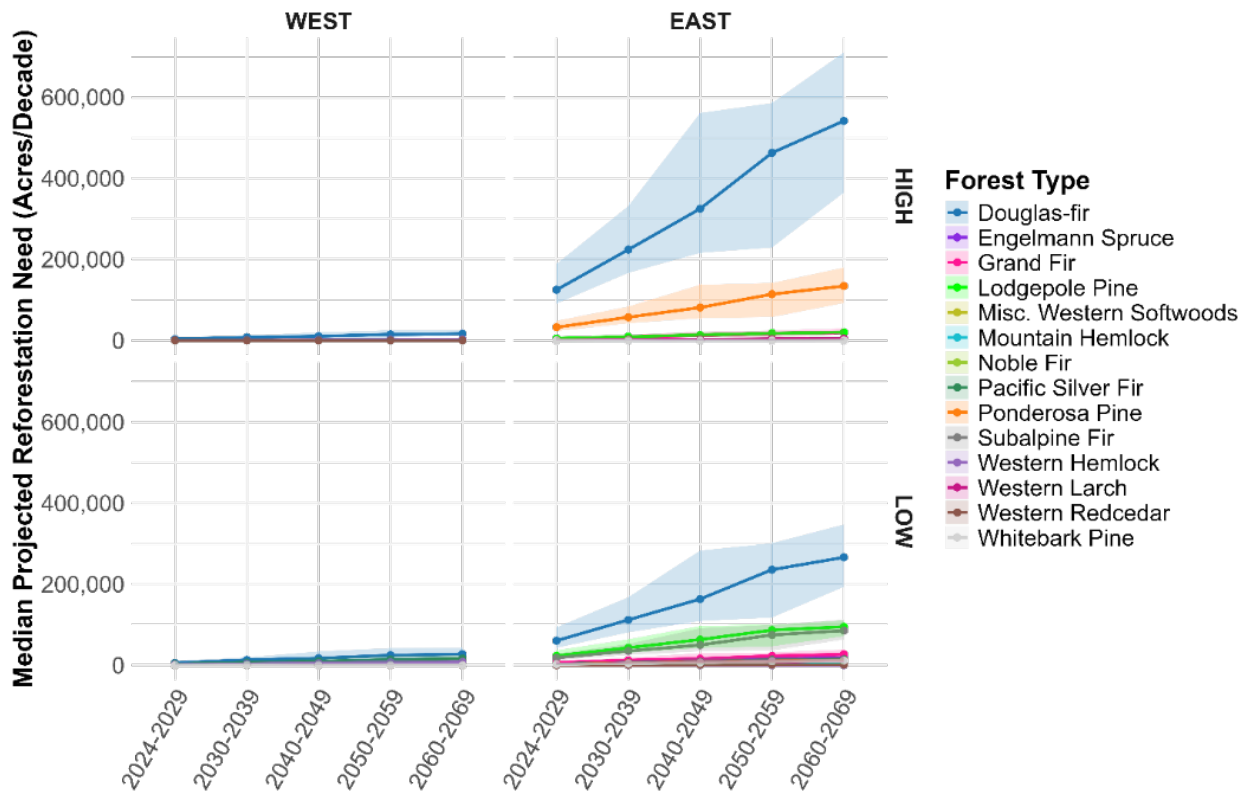


Figure 7. The median projected reforestation need (acres/decade) among the GCM projections 2024 (Shared Socioeconomic Pathway 3) for Western and Eastern Washington and high vs. low-priority areas. Forest 75 acres of current reforestation need. The confidence intervals (95%) represent the standard deviation of a sample constructed by resampling the data 1,000 times with replacement.



Table 2. Current (2014-2023) and projected (2024-2069) reforestation need (acres/year) for high-priority forest types by region (Western and Eastern Washington).

Forest Type-Region	2014-2023	2024-2029	2030-2039	2040-2049	2050-2059	2060-2069
<i>Douglas-fir-East</i>	8010.8 ± 2802.4	20800.8 ± 5074.3	22399.5 ± 1907.7	32487.5 ± 10033.1	46282.5 ± 9820.7	54160.5 ± 13753
<i>Engelmann Spruce-East</i>	15.5 ± 8.1	57.8 ± 16.4	59.6 ± 5.7	80.3 ± 19.4	109.4 ± 19	122.2 ± 18.3
<i>Grand Fir-East</i>	310.8 ± 105.2	833.6 ± 225.4	893.8 ± 83	1170 ± 416.1	1735.9 ± 420.1	1965.4 ± 512.1
<i>Lodgepole Pine-East</i>	389.3 ± 109.6	847.8 ± 191.8	918.2 ± 84.9	1340.2 ± 339.1	1800.9 ± 328.9	2016.4 ± 367.2
<i>Mountain Hemlock-East</i>	1.3 ± 0.7	4.5 ± 1.4	5.1 ± 0.4	7.3 ± 2.3	10.3 ± 2.3	11.1 ± 2.2
<i>Noble Fir-East</i>	5.3 ± 0.6	8.3 ± 2.7	10 ± 0.4	11.1 ± 0.8	11.8 ± 0.9	11.9 ± 0.3
<i>Pacific Silver Fir-East</i>	5.3 ± 3.4	16.4 ± 5.5	19.7 ± 2	28.8 ± 13	43.5 ± 11.1	51.6 ± 15.6
<i>Ponderosa Pine-East</i>	2224.7 ± 648.8	5403 ± 1319.2	5729.9 ± 490.7	8117.8 ± 2410.1	11414.8 ± 2383.3	13407.4 ± 3292.6
<i>Subalpine Fir-East</i>	54.4 ± 20.7	150.2 ± 43.1	164 ± 15	237.8 ± 74.7	347.8 ± 78.1	402.4 ± 97.7
<i>Western Hemlock-East</i>	0.9 ± 0.4	2.8 ± 0.7	3.1 ± 0.4	4.6 ± 1.3	5.8 ± 1.4	7.3 ± 1.3
<i>Western Larch-East</i>	50.9 ± 26.1	160.3 ± 37.2	175.7 ± 19.4	264.3 ± 82.4	363 ± 80.8	446.3 ± 104.3
<i>Western Redcedar-East</i>	4.8 ± 2.4	13 ± 3	13.8 ± 1.6	20.9 ± 6.3	24.9 ± 6.7	33 ± 6.1
<i>Whitebark Pine-East</i>	0.2 ± 0	0.3 ± 0.1	0.4 ± 0	0.5 ± 0.1	0.8 ± 0.1	0.7 ± 0.1
<i>Douglas-fir-West</i>	212.9 ± 95.9	566.2 ± 258	785.2 ± 94.5	1031.8 ± 443.9	1472.2 ± 419.5	1649.7 ± 455.7
<i>Pacific Silver Fir-West</i>	16.7 ± 1.9	26.5 ± 9.9	33.4 ± 4.1	46.6 ± 18.3	68 ± 17.2	71.1 ± 12.7
<i>Western Hemlock-West</i>	42.6 ± 12.2	83 ± 31.8	100.3 ± 13.8	141.4 ± 59.1	201.4 ± 62.5	232.8 ± 70.5
<i>Western Redcedar-West</i>	0 ± 0	0 ± 0	0 ± 0	0.1 ± 0	0.1 ± 0	0.1 ± 0

* Combinations missing from this table (e.g., *Engelmann Spruce-West*) are not included because they were below the cutoff of >75 acres of current reforestation need or occur in low-priority areas (Table 3). However, this does not mean that these forest types should not be included in management planting strategies.



Table 3. Current (2014-2023) and projected (2024-2069) reforestation need (acres/year) for low-priority forest types by region (Western and Eastern Washington).

Forest Type-Region	2014-2023	2024-2029	2030-2039	2040-2049	2050-2059	2060-2069
<i>Douglas-fir-East</i>	3968.9 ± 1361.9	10081 ± 2712.1	11186.9 ± 1014.8	16324.3 ± 5049.7	23565.7 ± 4920.7	26607.3 ± 5928.6
<i>Engelmann Spruce-East</i>	249.5 ± 98.5	689.8 ± 209.4	730.6 ± 67.7	1069.4 ± 313.5	1571.6 ± 342.7	1861.8 ± 458.8
<i>Grand Fir-East</i>	335.3 ± 164.5	1123.7 ± 356.7	1230.9 ± 118.7	1598.6 ± 535.1	2292.1 ± 505.3	2694.8 ± 539.3
<i>Lodgepole Pine-East</i>	1795.4 ± 493.7	3909.6 ± 883.9	4302.9 ± 427.7	6330 ± 1618.9	8658 ± 1532.9	9500.9 ± 1479.8
<i>Misc. Western Softwoods-East</i>	67.2 ± 16.8	156.9 ± 48.3	176.1 ± 16.7	266.8 ± 77.9	395.1 ± 95.1	468 ± 128.6
<i>Mountain Hemlock-East</i>	68.1 ± 28.4	161 ± 50.1	190.4 ± 19.1	269 ± 114.5	410 ± 104.7	466.6 ± 144.6
<i>Noble Fir-East</i>	8.4 ± 1	13.7 ± 4.5	17.1 ± 1.1	21.2 ± 3.5	24.7 ± 3.5	25.1 ± 1
<i>Pacific Silver Fir-East</i>	251.4 ± 76.1	517.2 ± 184.4	666.7 ± 53.8	888.2 ± 396.7	1350.9 ± 355.5	1498 ± 317.4
<i>Ponderosa Pine-East</i>	192.3 ± 62	488.4 ± 130.5	535.1 ± 42.3	712.7 ± 219.4	1047.6 ± 233.4	1184.4 ± 271.7
<i>Subalpine Fir-East</i>	1370.4 ± 363.1	3055.5 ± 953	3496 ± 300	4978.2 ± 1699	7459.5 ± 1785.2	8547.6 ± 2079
<i>Western Hemlock-East</i>	5.3 ± 2	12.4 ± 2.9	13.6 ± 1	20.9 ± 5.8	24.3 ± 5.5	31.4 ± 5.6
<i>Western Larch-East</i>	149.5 ± 59.8	404.2 ± 94.1	443.2 ± 49.1	662.9 ± 185.2	864 ± 180.2	1053.6 ± 206.1
<i>Western Redcedar-East</i>	15.5 ± 7.8	48.8 ± 12	54.2 ± 6.6	83.4 ± 25.7	100.8 ± 26.1	134.1 ± 25.2
<i>Whitebark Pine-East</i>	153.8 ± 33.9	379.4 ± 120.3	429.4 ± 42.7	648.9 ± 189.8	964.3 ± 224.7	1141.4 ± 308.7
<i>Douglas-fir-West</i>	364 ± 152	955.2 ± 413.9	1310.7 ± 151.3	1720.4 ± 767.5	2452.7 ± 710.3	2764 ± 752.4
<i>Mountain Hemlock-West</i>	8.4 ± 3.9	22.6 ± 7.8	25.8 ± 3.3	37.7 ± 16.2	53 ± 15.1	65.3 ± 18.8
<i>Noble Fir-West</i>	1.1 ± 0.8	4.2 ± 1.6	5.1 ± 0.7	7 ± 3.5	9.6 ± 2.9	11.4 ± 3.2
<i>Pacific Silver Fir-West</i>	255.9 ± 87.5	551.8 ± 198.3	660 ± 88.6	948.6 ± 437.7	1363.9 ± 395.7	1629.1 ± 493.8
<i>Subalpine Fir-West</i>	22.9 ± 6.6	49.6 ± 17.8	58.8 ± 6.9	83.8 ± 40.4	113.7 ± 34	135.5 ± 34
<i>Western Hemlock-West</i>	109.6 ± 49.8	300.5 ± 116.9	372.5 ± 48.9	516.6 ± 240.3	729.8 ± 215	850.3 ± 248.9
<i>Western Redcedar-West</i>	0.3 ± 0.4	0.8 ± 0.3	0.9 ± 0.1	1.4 ± 0.4	2 ± 0.6	2.3 ± 0.7



Potential Seed Need for Collection

The potential seed needed for the density of trees (seedlings/acre) commonly planted in reforestation projects varied substantially (Table 4). Oregon White Oak in Eastern Washington was the lone combination to have a potential seed need reach greater than one pound (10.0 lbs/ac). Pacific Silver Fir in Western and Eastern Washington had the next greatest potential seed need (0.44 lb/ac and 0.3 lb/ac). Aside from Grand-fir in Eastern Washington (0.101 lb/ac), all other species and region combinations require less than 0.1 lb/ac of potential seed need.

Table 4. Total seed (lbs), total current reforestation need (acres), and potential seed need (lbs/acre) for commonly grown species based on current reforestation need (2014-2023).

Species-Region	Total Seed (lbs)	Total Current Reforestation Need (acres)	Potential Seed Need (lb/ac)
<i>Douglas-fir-East</i>	2,153	119,794	0.018
<i>Douglas-fir-West</i>	123	5,728	0.021
<i>Engelmann Spruce-East</i>	23	2,636	0.009
<i>Grand Fir-East</i>	647	6,424	0.101
<i>Lodgepole Pine-East</i>	138	21,743	0.006
<i>Mountain Hemlock-East</i>	7	694	0.01
<i>Mountain Hemlock-West</i>	1	81	0.015
<i>Noble Fir-East</i>	12	137	0.086
<i>Oregon White Oak-East</i>	40	4	10
<i>Pacific Silver Fir-East</i>	770	2,567	0.3
<i>Pacific Silver Fir-West</i>	1,200	2,726	0.44
<i>Ponderosa Pine-East</i>	1,724	24,096	0.072
<i>Subalpine Fir-East</i>	714	14,228	0.05
<i>Subalpine Fir-West</i>	17	228	0.073
<i>Western Hemlock-East</i>	0	32	0.009
<i>Western Hemlock-West</i>	13	1,495	0.009
<i>Western Larch-East</i>	12	1,812	0.006
<i>Whitebark Pine-East</i>	47	1,527	0.031

**Not all species-regions were included because there was either no current reforestation need or species were not commonly grown in tree nurseries. These estimates are a benchmark for the potential seed need for future reforestation projects, and not backlog projects, assuming that market trends hold constant.*

Assumptions and Limitations

Current reforestation needs from wildfire were developed based on a set of conditions for stand-replacing fires from 2014-2023. In this analysis, we assumed that no current reforestation was needed for fires before 2014 due to uncertainty regarding long-term (>10 years) natural regeneration. We also assumed that no active reforestation had been completed after 2014-2023 fires or harvest due to insufficient planting data across ownerships. Although, according to FACTS, 15,738 acres were planted in the 60+ seed distance since 2014 (12% of the USFS current reforestation need), while WADNR reported 5,966 acres were planted in the 60+ seed distance since 2014 (32% of the WA DNR current reforestation need). We further assumed that



no reforestation would occur in Wilderness Areas, due to policy constraints, although ecological restoration may be beneficial in some cases. In the case of the Lodgepole Pine forest type, the actual reforestation need could be substantially lower than our estimate because of lodgepole pine's ability to naturally regenerate in stands with complete mortality, but we chose not to omit these results because actual species mix within forest types can vary and much of the current need in the Lodgepole Pine forest type is classified as low-priority. This analysis represents the best estimate of current need, but ground-truthing will be critical in any reforestation planning effort.

For harvest area estimation, the primary limitation stems from the use of public harvest planning data, and the necessity of validating all harvest areas against a forest loss dataset. Submitting an FPA/N is required prior to conducting forest practices on private and state forest land in Washington. However, in practice this requirement is not always met, and proposed forest activities do not always go to plan, cover the area proposed, or occur during the proposed period. In addition, FPA/N activity categories are broad, and can include more than one type of activity (e.g., salvage logging AND even-aged harvest) meaning that it is not always possible to identify where within the proposed area a harvest is occurring. For all of these reasons, we chose to validate the proposed harvest data against an external forest loss dataset, which brings with it a separate set of limitations and model assumptions. We likely excluded some areas in which harvest has occurred; however, the forest loss dataset did not register a sufficient change in tree cover, and thus did not indicate that a forest loss had occurred. Similarly, any harvest not reported occurring outside of a proposed area or occurring before or after the effective and expiration dates for the FPA/N was not included in our estimates.

A secondary limitation, inherent to any examination of reforestation need, is the requirement to establish a cutoff for which practices will necessitate human intervention post-harvest. Our methodology included practices such as clearcuts, while excluding other harvest activities such as shelterwood harvest, where seed trees are left on the landscape to allow for natural regeneration. Within the FPA/N process, legal definitions for harvest categories are quite broad, which limited our ability to make nuanced distinctions about the specific silvicultural practices taking place. As such, we chose to filter the FPA/N data and only consider categories which contained even-aged harvests. The FACTS Timber Harvest dataset contains more information about the exact silvicultural practices which have occurred, which allowed us to only consider clearcut style harvests, more accurately representing true post-harvest reforestation need on these jurisdictions.

The projected reforestation need analysis relied on multiple assumptions that can influence the final results. For instance, we assumed the forest type from the USFS National Forest Type dataset would stay consistent until the end of our projection period in 2069. We acknowledge that the assemblage of different tree species is likely to change over the next century, with potentially novel forest types emerging as disturbance regimes and climate are altered. We assume that projected reforestation need is strongly linked to projected wildfire probability and does not account for other drivers of widespread mortality events like drought and pathogenic



outbreaks. Furthermore, fire footprints from 2014-2023 may not represent different climate zones that might be more susceptible to fire in the future. Our methodology assumes that the proportion and spatial distribution of stand-replacing fire remains consistent over time, although severity and size of wildfires continue to increase on a decadal scale. Stand-replacing patch sizes, wildfire management strategies, and other general forest management strategies might change over the next five decades in a way not reflected in this analysis. Furthermore, since our projections were based on a scaling up of current reforestation needs, any forest type not currently included in those estimates will inherently be excluded from our projections. This does not indicate, however, that those forest types will not experience regeneration challenges and need reforestation in the future.

Finally, there remains a high amount of disagreement among the GCMs (Appendix G, Fig. 1 and 2), especially for overestimations of projected reforestation need based on ACCESS-CM2 and CanESM5-CanOEC, which is categorized as a “Too-Hot Model” for the CMIP6 generation of GCMs (Hausfather et al., 2022). In addition, stochastic fire weather events, including intense wind events, can increase fire intensity in Western Washington which can be detrimental to forests (e.g., 2020 Labor Day Fires in Oregon and Washington). These events are extremely difficult to predict and are not accounted for in GCM projections (Dye et al., 2024). If stand-replacing wildfire becomes more common in Western Washington, then our projected reforestation need for Western Washington would require a reassessment.

Discussion and Conclusion: Management Implications and Next Steps

This study provides a spatial and temporal analysis of reforestation needs for forested lands in Washington, highlighting the increasing challenges facing Washington DNR and other land managers as future reforestation need continues to grow. Our findings emphasize the necessity for strategic and proactive planning and investment in reforestation efforts to maintain forest health, ecosystem services, and timber productivity. Management implications of key findings are further discussed below.

Divergent Drivers of Reforestation Need

Western Washington's reforestation needs are primarily driven by timber harvest, whereas Eastern Washington's reforestation needs are increasingly driven by wildfires, with a projected 800% statewide increase in reforestation need for 2060-2069 when compared to the current reforestation need (2014-2023). Management considerations should include more fire-resilient forest management and post-fire restoration strategies for Eastern Washington. While reforestation in Western Washington will largely be mandated as the need is mostly due to harvest, reforestation need in Eastern Washington from wildfires are less likely to be mandated and therefore may prove to be more challenging to implement due to capacity and financial constraints.



Additionally, while we expect approximately 5,000 acres of post-fire reforestation need in high-priority Douglas-fir in Western Washington, it is acknowledged that large fire events in this system are rare but can be extreme (Dye et al., 2024). A single fire season dominated by wind-driven fires in Western Washington, similar to the Yacolt Burn or the 2020 Labor Day Fires, could result in a dramatic increase in post-fire reforestation need in the region.

Climate Change Considerations

The projected drastic increase in wildfire-driven reforestation need in Eastern Washington, particularly in Douglas-fir and ponderosa pine forests, indicates profound climate change impacts on reforestation needs. WADNR planning should emphasize climate adaptation strategies, including investing in wildfire mitigation and adaptation strategies; promoting forest restoration with genetically appropriate, climate-adapted seed; and developing long-term, strategic forest health and restoration plans that account for changing climate conditions. Strategic plans that encompass all lands and build upon partnerships can increase capacity, impact, and efficiency to better meet reforestation needs.

The potential effects of climate change also raise questions about shifts in species distribution (Peterson et al., 2014). While the projected reforestation need and associated seed need were based on current forest types, the use of assisted migration may result in seed zone or species shifts across Washington. In Western Washington, this could mean increased use of seed zones for current primary planting species sourced from farther south, or even a shift toward greater inclusion of ponderosa pine. Similar shifts are likely in Eastern Washington, with seed being sourced from farther south or lower elevations, potentially leading to gradual changes in species composition. A key question for future planning is whether we should expect a transition from Douglas-fir-dominated forests to more ponderosa pine forests.

Seed and Nursery Capacity

The current reforestation supply chain in Washington is heavily focused on producing Douglas-fir as the dominant species in Western Washington and a mixture of ponderosa pine and Douglas-fir for Eastern Washington. These species are the dominant timber species of the regions, and the availability of both seeds and seedlings is likely correlated with historic demand for each species and seed zone. Ensuring adequate seed is sourced and stored for the appropriate deployment areas, along with maintaining nursery capacity that aligns with future planned and unplanned disturbance reforestation needs, will be crucial in meeting future reforestation demand (Dobrowski et al, 2024).

This analysis is part of a larger study conducted by American Forests in partnership with WADNR that also includes surveys and follow-up conversations with nurseries and reforestation service providers to assess reforestation capacity statewide. The results of that work will be included in a broader discussion to be provided to WADNR in June 2025. Based on this analysis alone, recommendations include developing a comprehensive seed strategy that prioritizes collection in high-risk areas and diversifies seed sources, as well as collaborating with private



nurseries and seed banks to ensure adequate supply and increase overall capacity to meet increasing reforestation need.

Prioritization and Resource Allocation

The study provides valuable information for prioritizing reforestation efforts based on seed zones, forest types, and ownership. Based on the results, American Forests recommends focusing on high-priority areas with dry potential vegetation groups and warm CHILI sites, where natural regeneration is less likely to occur. The information from this study can support management decisions to allocate resources strategically, considering the varying needs of different ownerships (e.g., USFS, state, Tribal, private). Decisions can be further supported and aided by data visualizations and a centralized reforestation information resource that is readily and easily available to all stakeholders.

Data and Monitoring

The limitations of harvest data highlight the need for improved project tracking and monitoring. A comprehensive system for tracking harvest data across land ownerships could help refine and improve the accuracy of estimated reforestation need from harvest. Similarly, more regeneration surveys and post-planting monitoring can better inform and provide more accurate estimates of post-fire reforestation need and outcomes. Monitoring efforts that collect information on planting outcomes can provide timely updates to reforestation needs that consider both the successful planting efforts and areas that fail and require re-entry. Monitoring can further provide insight into the utility of specific planting plans and approaches, facilitating adaptive management approaches, and increasing the probability of successful reforestation given expected changes to climate change and wildfire regimes.

Additionally, comparing these results with other published studies on reforestation need in the Pacific Northwest could help validate or refine findings. Future research should also consider how Washington's reforestation projections compare to similar efforts in Oregon.

Collaboration and Partnerships

Addressing increasing reforestation needs requires collaboration with various stakeholders, including federal agencies, Tribes, private landowners, nonprofits, and research institutions. WADNR may benefit from continuing to foster strong partnerships to leverage resources and expertise and increase capacity to meet this ongoing issue. Continued and increased public outreach and education to promote reforestation awareness is important to keep the public engaged, informed, and supportive of reforestation efforts and policies.

Recommended Next Steps

1. **Develop a long-term reforestation strategic plan:** This plan should incorporate climate change projections, prioritize high-risk areas, and outline strategies for seed collection, nursery capacity, and resource allocation. It should include building partnerships and collaborative efforts.



2. **Invest in wildfire adaptation strategies:** This includes fuel reduction, prescribed burning, and community wildfire preparedness.
3. **Improve data collection and monitoring:** This includes enhancing data and resource sharing with private landowners and developing a comprehensive reforestation resource that is accessible to all.
4. **Foster collaboration and partnerships:** This involves engaging with federal agencies, Tribal governments, private landowners, nonprofits, and research institutions.
5. **Prioritize funding:** Seek and allocate funding to support reforestation efforts, wildfire risk reduction, climate adaptation, partnership building and collaboration, and public engagement and awareness.

By implementing these recommendations, WADNR can more effectively address increasing reforestation challenges and improve the resilience of Washington's forests. American Forests will include a more comprehensive discussion with management implications and recommended next steps that encompasses all five activities of this larger project in June 2025.

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Chapter 2

Nursery Capacity, Limitations, and Recommendations for Washington



Nursery Capacity, Limitations, and Recommendations for Washington

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Abstract

Background: The Pacific Northwest faces escalating reforestation needs, currently estimated at 2.073 million acres in Oregon and Washington, driven by intensifying wildfires and timber harvest. This report synthesizes findings from surveys conducted from fall 2024 to winter 2025 with nurseries serving this region, aiming to deepen understanding of their capacity, challenges, and recommendations to support the industry in meeting current and projected reforestation demands.

Results: Surveyed nurseries report a total annual seedling capacity ranging from 162.75 million to 284.75 million seedlings, with many operating at or near maximum utilization, particularly for container stock. While latent capacity for expansion exists (62% can expand beyond limits), this is largely hindered by uncertainty of future demand, infrastructure constraints, labor availability, and inconsistent ordering patterns. Container seedling capacity is highly utilized, while bareroot capacity is increasingly underutilized, suggesting a market shift. Furthermore, seed inventory, especially for conifers, is modest (most have two years or less), with fire restoration planting having depleted supplies.

Conclusion: Nurseries are largely operating at their desired capacity and expansion is contingent upon greater certainty, long-term contracts, and demonstrable increases in consistent demand. Key recommendations to support the industry include developing strategic planning with long-term contracts, fostering greater collaboration and knowledge sharing across the reforestation supply chain, conducting continued research to understand the disconnect between need and demand, and establishing a formal reforestation network to optimize seed supply, develop the workforce, and build critical partnerships. Addressing these areas will enable the nursery industry to enhance its capacity and contribute more effectively to successful forest restoration efforts.

Keywords: nursery capacity, seedlings, reforestation, Pacific Northwest, wildfires, seed supply, long-term contracts, forest restoration



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Contents

Abstract.....	2
Acknowledgments.....	3
Introduction.....	6
Methods.....	6
Results.....	7
General Information and Operations.....	7
Total Capacity.....	7
Bareroot Capacity.....	8
Container Capacity.....	10
Expansion Potential and Limitations.....	12
Bareroot Expansion Potential.....	16
Container Expansion Potential.....	17
Seed Supply and Inventory.....	19
Conclusion.....	24
Recommendations.....	24
Strategic Planning and Long-term Contracts.....	24
Collaboration and Knowledge Sharing.....	25
Continued Research.....	25
Establishment of a Reforestation Network.....	25
Literature Cited.....	26



List of Figures

Figure 1. Maximum Total Capacity Utilized.....	8
Figure 2. Maximum Bareroot Seedling Capacity	9
Figure 3. Bareroot Seedling Capacity Utilization	10
Figure 4. Maximum Container Seedling Capacity.....	11
Figure 5. Container Seedling Capacity Utilization.....	12
Figure 6. Ability to Expand Beyond Maximum Capacity.....	13
Figure 7. Ability to Increase Production to Meet Increasing Orders within Current Capacity	13
Figure 8. Limitations to Expanding	14
Figure 9. Would grants prompt you to increase capacity?	15
Figure 10. Bareroot Expansion Potential (Percentage).....	16
Figure 11. Annual Bareroot Potential Expansion (Seedlings).....	17
Figure 12. Container Expansion Potential (Percentage).....	18
Figure 13. Annual Container Potential Expansion (Seedlings).....	19
Figure 14. Annual Sources of Seed.....	20
Figure 15. Percentage of seed needs met through annual collections (and not current inventory)	21
Figure 16. Current Conifer Seed Inventory.....	22
Figure 17. Current Hardwood Seed Inventory	23
Figure 18. Minimum Seedling Orders Accepted	24

Appendices

Appendix A: Nursery Capacity Survey

Appendix B: Nursery Capacity Survey Results



Introduction

The intensifying wildfire regime in the Pacific Northwest coupled with timber harvest as a key economic driver in the region necessitates a thorough evaluation of existing and potential reforestation capacity to address the escalating reforestation needs. This report contributes to a broader data assessment quantifying current and projected reforestation needs in Oregon and Washington, which estimates a substantial 817,000 acres within wildfire scars with limited potential for natural regeneration (i.e., >60m from viable seed sources), and 1.279 million acres post-harvest reforestation need, which equates to a total of 2.073 million acres across Washington and Oregon for estimated current reforestation need. While this report is for Washington State, it is important to consider this need across state lines as many nurseries work across state lines and this impacts the overall capacity for reforestation in the Pacific Northwest.

Historically, reforestation efforts focused on regenerating harvested areas, but a decline in timber harvests in the 1970s through 1990s coupled with recent increases in wildfire extent, frequency, and area burned at high-severity, has led to post-fire restoration emerging as a dominant factor influencing reforestation needs in the Western United States (Parks and Abatzoglou, 2020; Haugo et al., 2019; Halofsky et al., 2018; Dumroese et al., 2005) and accounts for a substantial proportion of the demand (e.g., 81% on National Forest System lands ; USDA Forest Service 2022).

Concurrently, reforestation in Washington State remains significantly influenced by regulatory requirements following timber harvest, a key economic sector contributing to employment and wages (Washington Forest Protection Association; accessed March 2025). State Forest Practices Rules (Title 222 WAC) mandate reforestation after significant timber removal, establishing a consistent demand, particularly in Western Washington.

Addressing the multifaceted drivers of reforestation demand necessitates not only accurate estimations of current and future reforestation needs, but also a comprehensive understanding of the logistical and operational constraints of nurseries who grow the seedlings for reforestation efforts. This report presents findings from research employing surveys to nurseries conducted from fall 2024 to winter 2025. The objective was to deepen the understanding around capacity, challenges, and obstacles encountered by nurseries that serve Oregon and Washington, and glean their recommendations on how to better support their industry. The overarching objective of this research is to provide insights that can inform the development of evidence-based strategies and policies aimed at supporting the reforestation industry's capacity to effectively address current and projected reforestation demands in the Pacific Northwest.

Methods

In the fall and winter of 2024, a survey was sent to nurseries serving Oregon and Washington to better understand their current capacity to provide seedlings for reforestation efforts across the Pacific Northwest region, the challenges they might face in meeting current and future demand, and their potential for expansion. Nurseries were identified in consultation with the Washington



Department of Natural Resources (DNR) and the US Forest Service Reforestation, Nurseries, and Genetic Resources (RNCR) program. American Forests developed the survey with feedback from Washington DNR, Oregon Department of Forestry, and Sustainable Northwest on the content. The survey was developed using GoogleForms and was emailed with a link for responses to the list of providers (n=138). Surveys were also distributed via QR code at conferences and through partners to relevant contacts. We received 26 responses, including one representing four nurseries. Of the respondents, 12 were based in Oregon, 8 in Washington, and the rest in neighboring regions, including California, Idaho, and Canada. The results of this survey do not represent the entirety of nursery capacity across Washington, as not every nursery responded that supplies seedlings to the state. However, they provide valuable insights into the current capacity of nurseries, their potential for expansion, the limitations they may face, and recommendations to better support the nursery industry. Please refer to Appendix A to see a copy of the survey.

Results

General Information and Operations

The majority of respondents (73%) represented private nurseries (19), with the remainder representing nonprofit organizations (3), federal (2), tribal (2), and state (1). The nurseries serve a diverse range of markets, including public agencies, private industry, small woodland owners, and tribal entities.

When asked which species they grow, most nurseries grow conifers, with Douglas Fir (92%), Ponderosa Pine (89%), Western Red Cedar (81%), and Western Hemlock (77%) being the most common species grown by respondents.

Total Capacity

The total annual seedling capacity, calculated by summing the minimum and maximum values of all response ranges, is 162,750,000 to 284,750,000 seedlings. It is important to note that not all nurseries responded to the survey, therefore this is not reflective of total capacity across Washington and Oregon, it is rather a reflection of overall capacity of all of those that responded. Many of the respondents (44%) are currently operating at over 75% of their total maximum capacity, with an additional 20% reporting they are at full capacity. A smaller percentage of respondents indicated lower utilization rates, with only 8% operating at less than 25% capacity and 16% between 25-50% capacity (see Figure 1). Several respondents provided additional context. One noted that "capacity is dependent upon labor availability not growing space," while another remarked on dual constraints; that their "capacity is limited by space and staffing." One respondent indicated a potential for growth, stating, "With orders we will build more nurseries." However, the need for reduced risk when increasing capacity was also highlighted: "Any increases in production will require a contract or other method to limit risk."



At What Percentage of Your Maximum Total Capacity Are You Currently Running?

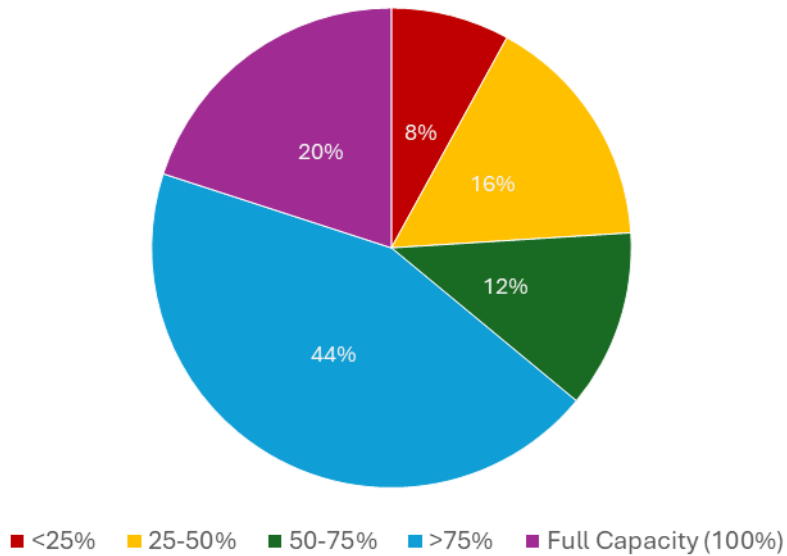


Figure 1. Maximum Total Capacity Utilized

Bareroot Capacity

Of the respondents, 5 do not grow bareroot seedlings. Of those that do grow bareroot seedlings, 5 reported an annual bareroot seedling capacity of up to 250,000, 2 had a capacity between 250,000 and 1,000,000, 5 reported a capacity of 1,000,000 – 5,000,000, 4 had a capacity of 5,000,000 to 10,000,000, and 2 had a maximum annual capacity between 10,000,000 and 20,000,000 seedlings (see Figure 2).



What is your maximum capacity for Bareroot tree seedling production per year?

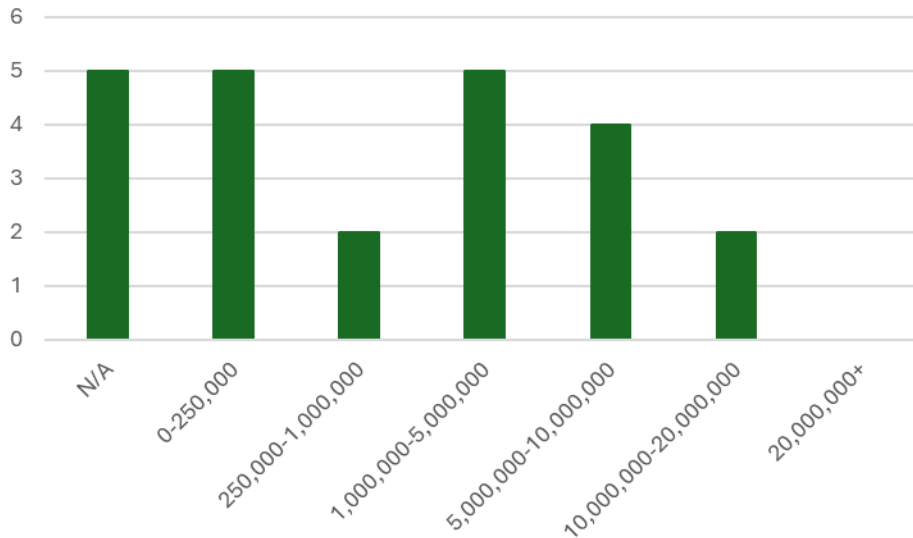


Figure 2. Maximum Bareroot Seedling Capacity

Regarding the utilization of this capacity, 30% of respondents indicated they are operating at over 75% capacity, and 20% are at full capacity. Notably, 45% of respondents reported utilizing less than 50% of their available bareroot capacity (see Figure 3). This underutilization aligns with the comment: "Our container capacity is near max most years, but bareroot capacity is very underutilized." This suggests a potential decrease in bareroot orders. One respondent elaborated on the potential, stating, "We could easily grow 5 million bareroot seedlings per year. Most of our clients have switched to container which is not the best stock type for our harsher sites." The general sentiment suggests that "bareroot seedling capacity is underutilized and could increase," likely due to a shift in demand toward container stock types.



What Percentage of your Available Capacity for Bareroot Tree Seedlings Are you Currently Producing on Average per Year?

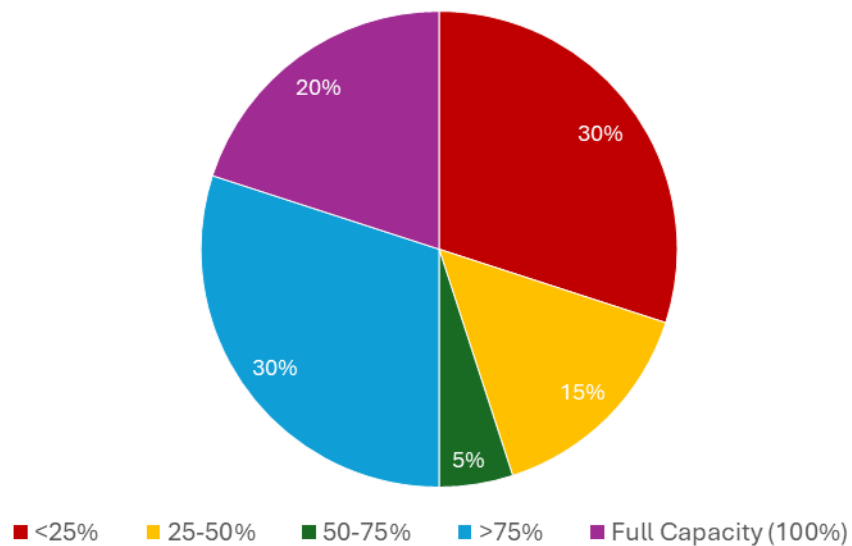


Figure 3. Bareroot Seedling Capacity Utilization

Container Capacity

Out of 26 responses, 2 nurseries do not grow container seedlings, 5 respondents reported a container seedling capacity of up to 250,000 annually, 5 had a capacity between 250,000 and 1,000,000, 6 reported a capacity of 1,000,000 – 5,000,000, 2 had a capacity of 5,000,000 to 10,000,000, 2 were between 10,000,000 and 20,000,000, and 4 respondents indicated a capacity of over 20,000,000 container seedlings annually (See Figure 4).



What is your maximum capacity for CONTAINER tree seedling production per year?

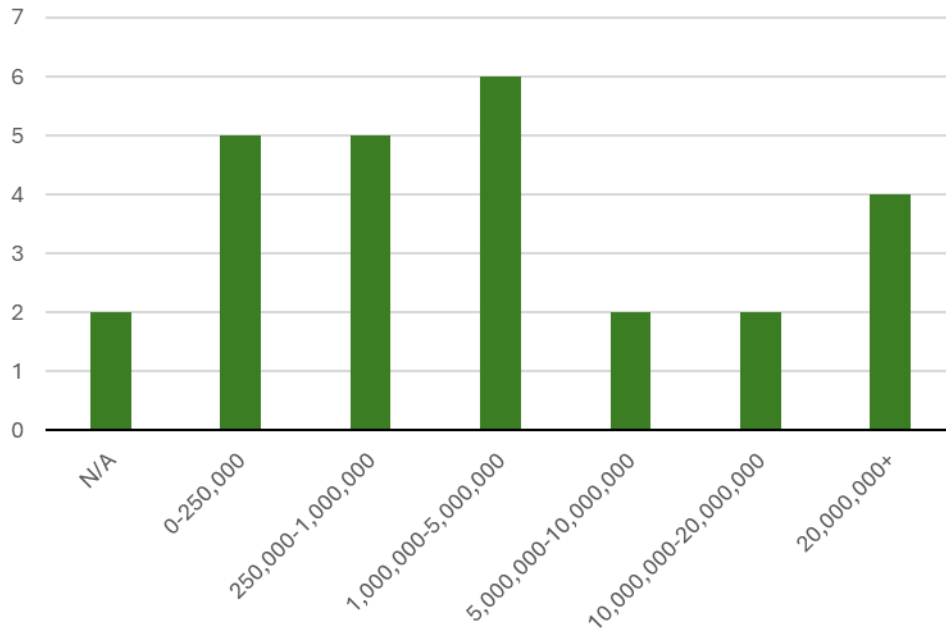


Figure 4. Maximum Container Seedling Capacity

In terms of capacity utilization, 33% of respondents indicated they are using over 75% of their container capacity, and 25% reported operating at full capacity. In contrast, only 21% of respondents indicated they are using 50% or less of their available container capacity, on average (Figure 5). This higher utilization is reflected in the comment: “Our container capacity is near max most years...” Furthermore, one respondent indicated an increasing trend: “Growing more plants in the Greenhouses. We have a lot of capacity for new customers” and another mentioned, “...there are increases in container orders.” The remarks that container orders are increasing while bareroot capacity is underutilized suggests a potential mismatch between current production capacity and market demand. This trend may indicate a need for nurseries to potentially shift resources towards increasing container seedling capacity to meet the growing demand for that stock type.



What Percentage of Your Available Capacity for Container Tree Seedlings Are You Currently Producing On Average Per Year?

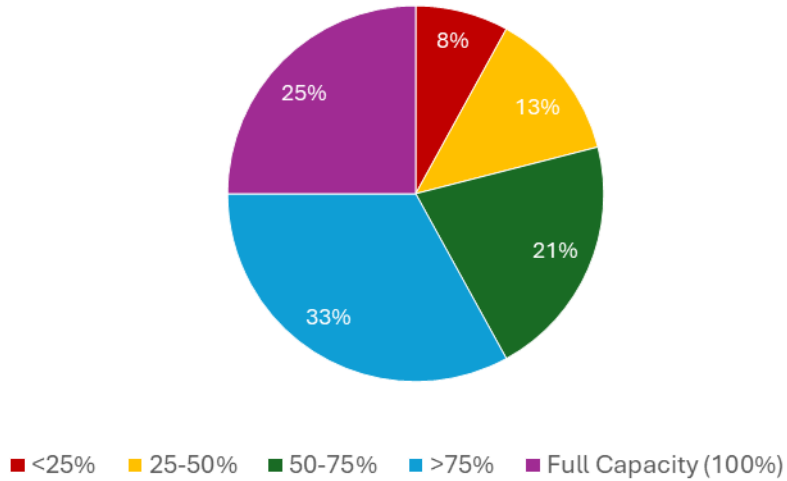


Figure 5. Container Seedling Capacity Utilization

Expansion Potential and Limitations

While many respondents indicated they were operating at over 75% of their total maximum capacity, 62% reported having the ability to expand beyond their current operational limits (Figure 6), and an even larger 69% indicated they could increase production to meet growing orders within their existing facility capacity (Figure 7). This suggests a latent capacity within the sector.



Do You Currently Have the Ability to Expand Beyond Your Operation's Maximum Capacity?

26 responses

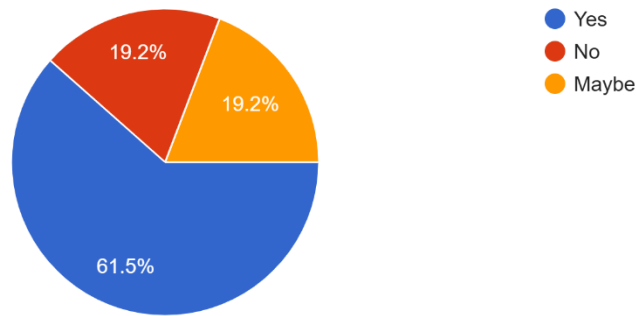


Figure 6. Ability to Expand Beyond Maximum Capacity

Are You Able to Increase Production to Meet Increasing Orders Within Your Current Facility Capacity?

26 responses

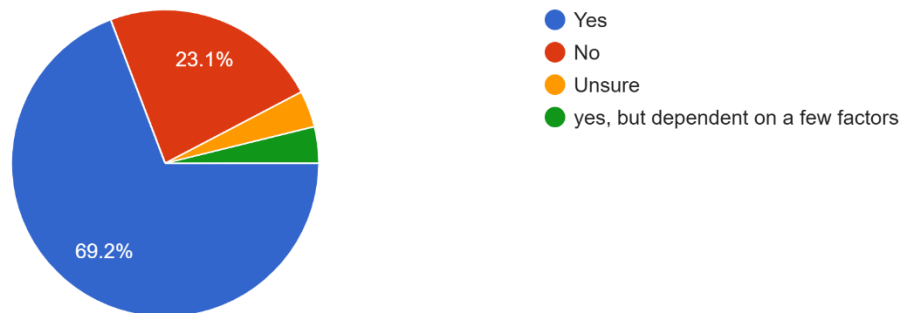


Figure 7. Ability to Increase Production to Meet Increasing Orders within Current Capacity

When elaborating on their ability to expand, respondents cited various factors. Some highlighted their existing capabilities and resources: “We have the ability to quickly increase infrastructure,” “We are looking to build a new site,” “We’re good at building nurseries,” “We have an extra can yard that we could put containers outside,” “We have open ground. Plenty of open space,” and “5 acres already purchased but not cropped.” Others discussed historical capacity and potential: “Historically we produced 20 million Bareroot seedlings in the 1980s. If federal demand were to



increase, we could comfortably increase to 5 million per year and have the capacity to do 10 million,” and “Historically the nursery has added capacity to meet market demand, we have land and resources to do so again if the seedling demand required it.”

However, limitations also exist. When asked what the limitations were for expansion, the largest response was the uncertainty of future demand, followed by infrastructure, full time labor, and inconsistent ordering patterns (Figure 8).

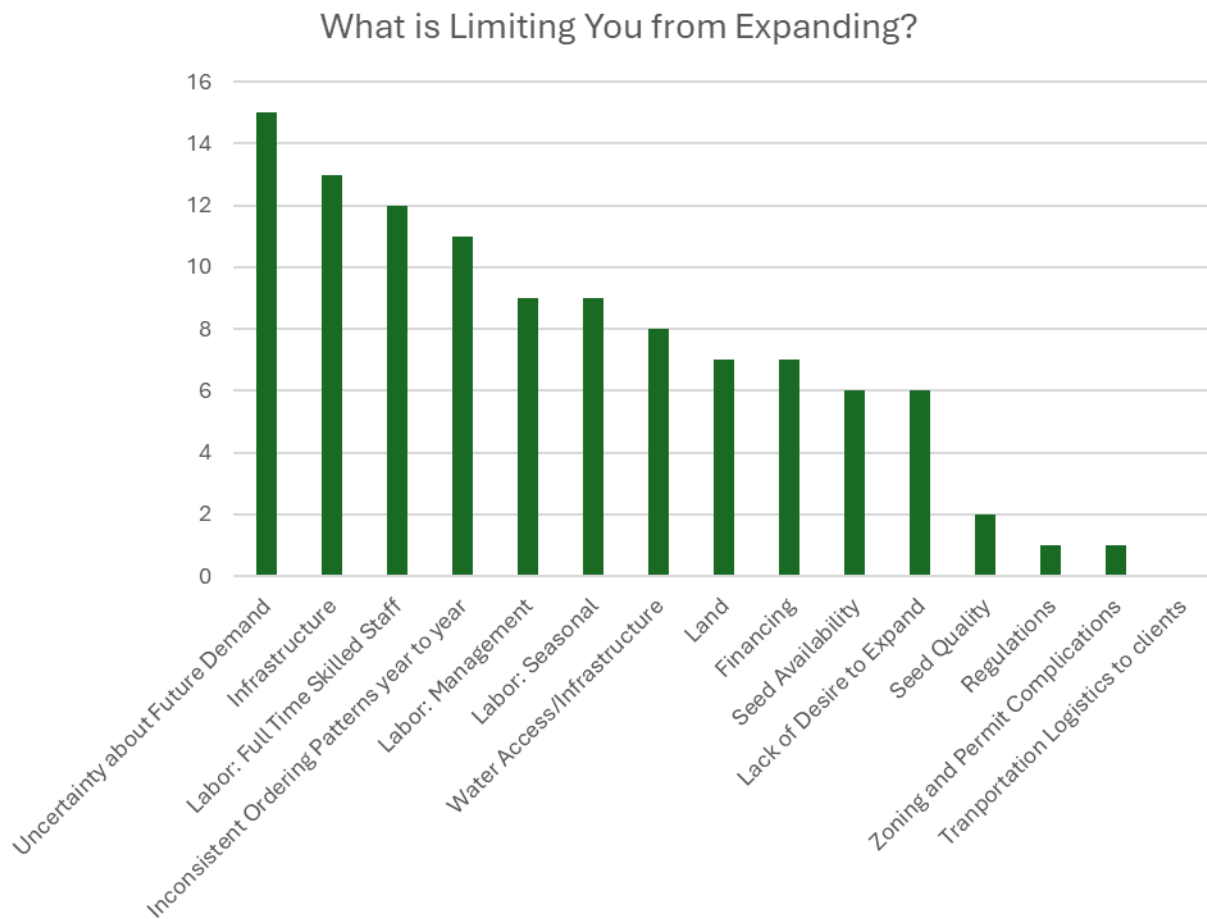


Figure 8. Limitations to Expanding

Several respondents elaborated on expansion constraints. Regarding infrastructure and staffing the following comments were included: “Our nursery is in an active flood plain which limits our ability to expand. We have looked at a few possibilities to expand a bit, but we are still limited by staff and funding,” “Out of space,” “Labor and hiring issues,” “if we had more personnel we could expand,” and “It basically comes down to labor. It’s not as easy for us to hire additional labor



especially given the fact that {our location} does not have affordable housing.” Another highlighted the cost to adjust to container stock type: “There is a plan to increase containerized capacity but will depend on funding.”

The uncertainty of future demand was a recurring theme when asked about limitations and concerns with expansion: “Uncertainty about future demand,” “Give us long term contracts and we’ll spend money to expand,” “We expanded rapidly. We are waiting for market demand to increase before expanding more,” and “What direction is the market going? What is the economy going to do? We have the capacity to take on new customers when they are ready.” The need for assurances, longer term commitments, and consistent market trends was also emphasized: “Funds are available for expansion if market needs are shown and have tied expansion to multi-year commitments in the past at other nursery sites,” “Expansion may be possible but only with adequate assurances and support,” “We hear a lot about future increasing demand but we are not seeing any increase in orders yet,” and “Seed supply and our ability to find appropriate seed sources to purchase, getting contracts for orders a year in advance rather than a month or two before folks need them and we are sold out by that point.”

Finally, some respondents indicated they are currently meeting demand and do not see a need for expansion: “We can grow and contract easily based on orders”, “We currently have extra ground for production so until that is fully utilized we are not considering expanding,” and “I think we have positioned ourselves to meet Federal expansion of reforestation efforts.” As one respondent succinctly put it: “Why would we want to expand?”

When asked if grants would prompt nurseries to increase capacity for reforestation, 50% responded yes, and 39% responded maybe, with only 12% saying no (Figure 9).

Would Access to Grants Prompt You to Increase Capacity for Reforestation?

26 responses

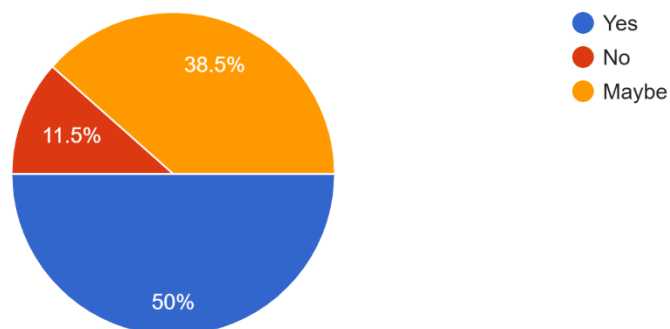


Figure 9. Would grants prompt you to increase capacity?



Bareroot Expansion Potential

Expansion potential for bareroot seedlings beyond current capacity varied considerably, with many respondents either not growing or expressing no interest in expanding bareroot production (46%). However, for those wanting to expand, most indicated a potential increase in the range of 10-25% (Figure 10)

How Much Could You Expand for Bareroot Seedlings Produced Per Year (Beyond Your Current Capacity)?

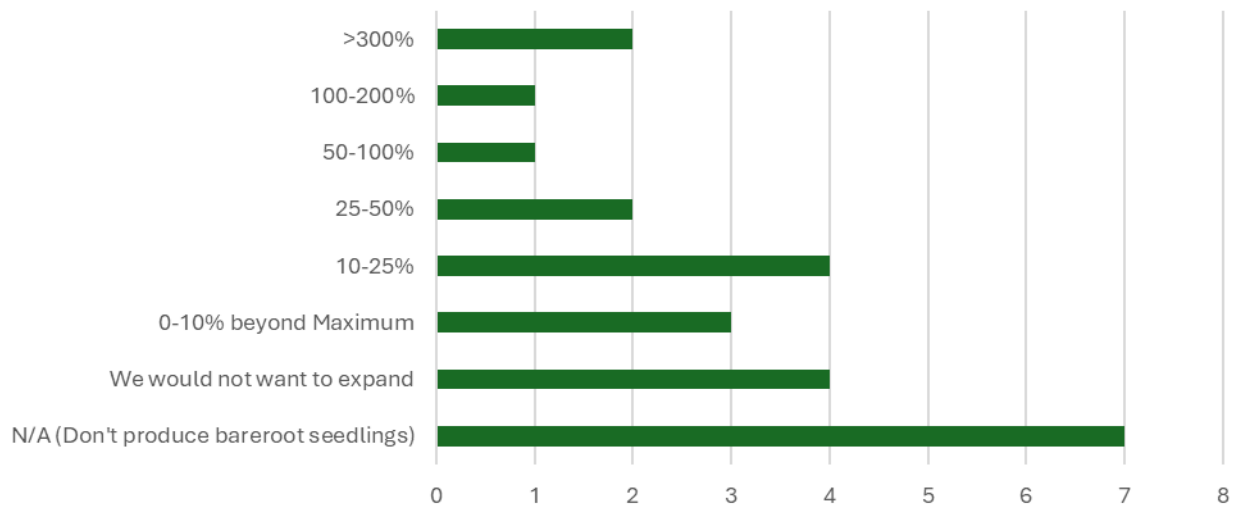


Figure 10. Bareroot Expansion Potential (Percentage)

Numerically, the total potential annual expansion for bareroot seedlings across all responses ranges from 20,200,000 to 55,200,000 seedlings (See Figure 11). One respondent noted, “To get back to historic levels of 20 million some of the fields would have to be cleared of native seed production plots.” This highlights that while potential exists, it may require specific actions or market conditions, and most are not wanting to expand for bareroot seedlings under current conditions and ordering trends.



Annual Expansion Potential: Bareroot Seedlings

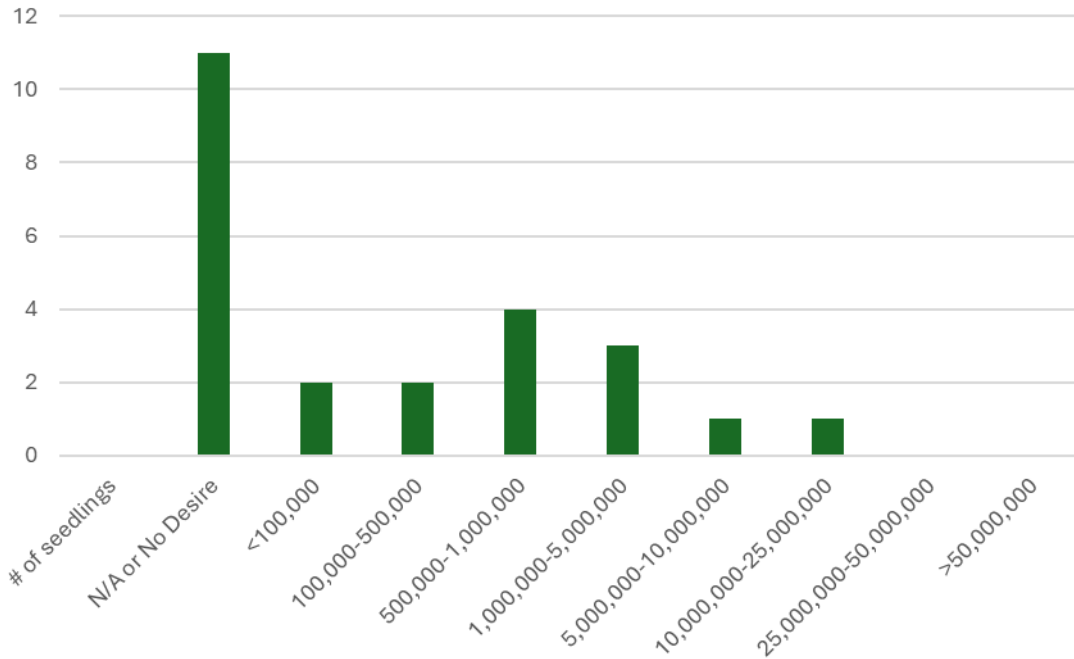


Figure 11. Annual Bareroot Potential Expansion (Seedlings)

Container Expansion Potential

There was a wide range in the reported potential for expanding container seedling production beyond current maximum capacity, with most respondents (27%) falling within the 10-25% expansion range (Figure 12).



How Much Could You Expand for Container Seedlings (Beyond Your Current Capacity?)

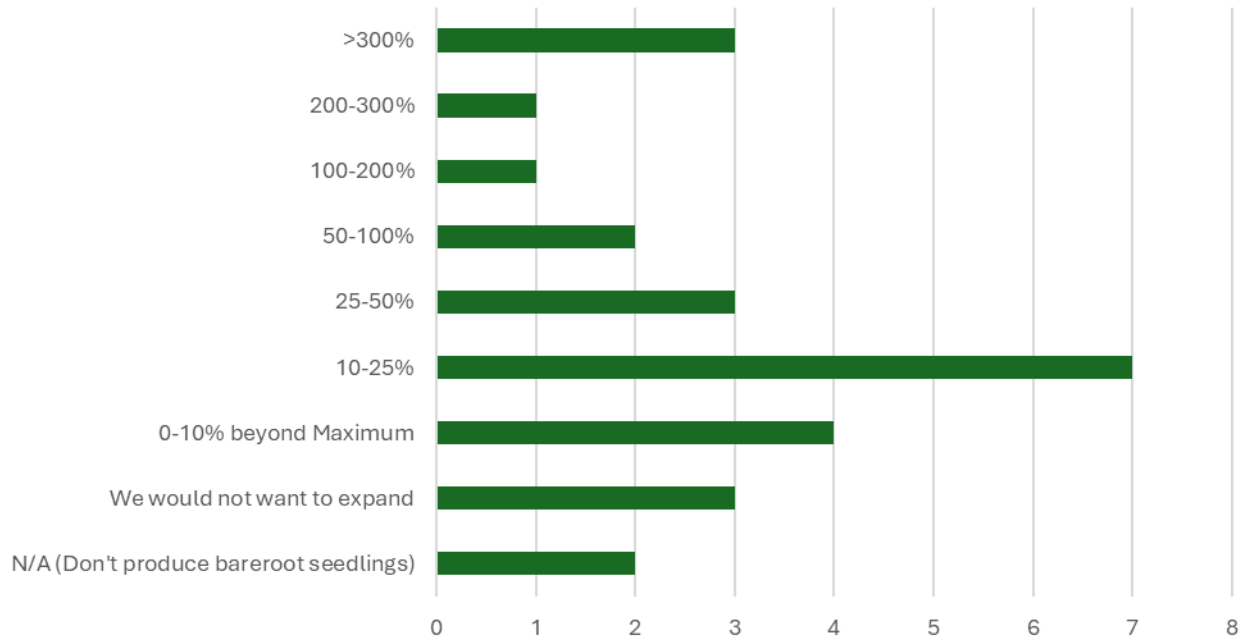


Figure 12. Container Expansion Potential (Percentage)

Based on these responses, the total potential annual expansion for container seedlings across all responses is estimated to be between 140,700,000 and 195,800,000 seedlings per year (Figure 13).

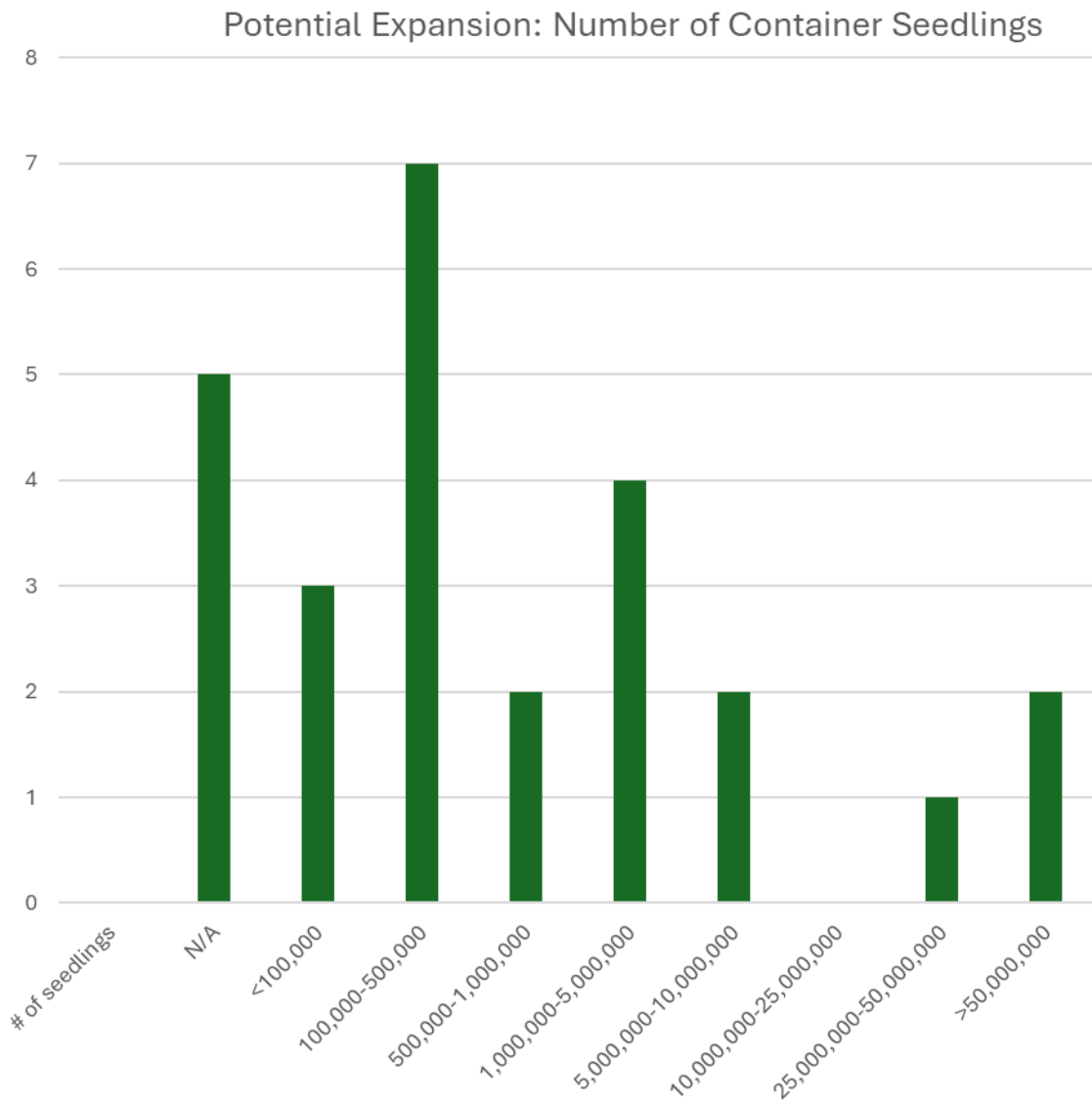


Figure 13. Annual Container Potential Expansion (Seedlings)

Seed Supply and Inventory

Nurseries in the survey utilize a combination of orchard-produced and wild-collected seed to meet their needs (Figure 14).



On Average, What Are the Annual Sources of Your Seed?

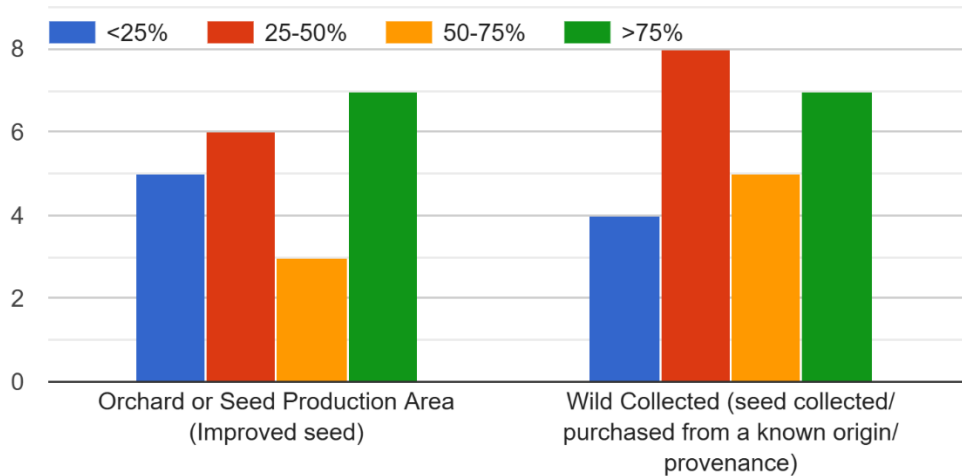


Figure 14. Annual Sources of Seed

There was large variance in seed needs met through annual collections, with 38% of respondents having over 75% reliance on annual collections, and another 33% of respondents with less than 25% reliance on annual collections (Figure 15).



What Percentage of Your Seed Needs Are Met Through Annual Collections (As Opposed to Through Your Current Seed Inventory in Storage?)

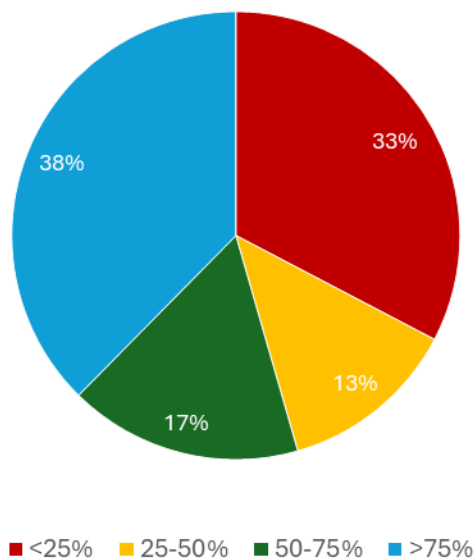


Figure 15. Percentage of seed needs met through annual collections (and not current inventory)

Regarding current conifer seed inventory, 36% of respondents indicated having a two-year supply of conifer seed, and 16% had a year's supply. Most responses fell under a 2 year supply or less, with 20% indicating they do not have any conifer seed inventory (N/A).



How many years of seed do you have in your inventory to support your current production for CONIFERS (i.e. average season's worth of stored seed)?

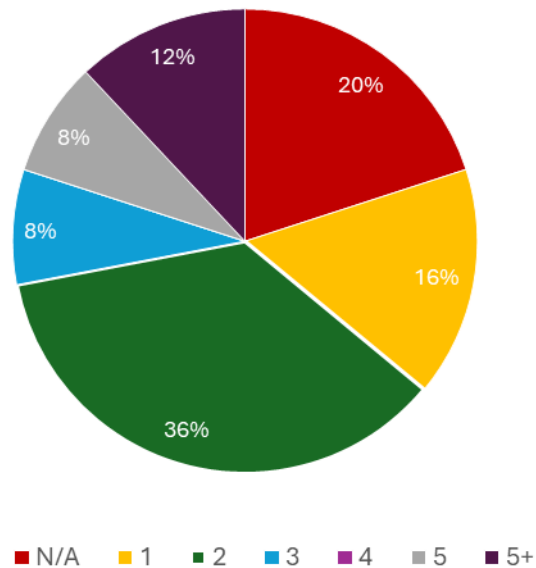


Figure 16. Current Conifer Seed Inventory

In terms of current hardwood seed inventory 44% maintained a one-year inventory of hardwood seed, and 30% indicated hardwood seed inventory was not applicable (Figure 17). This suggests a generally modest seed inventory, particularly for hardwoods, although most respondents indicated they grow conifers.



How many years of seed do you have in your inventory to support your current production for HARDWOODS (i.e. average season's worth of stored seed, including tropical species)?

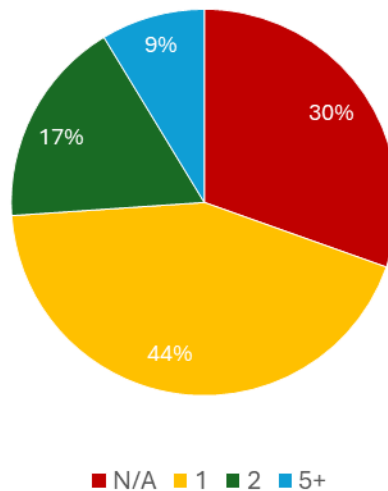


Figure 17. Current Hardwood Seed Inventory

Several additional comments shed light on seed inventory. One respondent noted that "fire restoration planting over the last 10 years has depleted seed inventory," highlighting the impact of wildfires on seed availability and inventory. Another indicated a willingness to "buy and store more conifer seed if more suitable seed was available," pointing to potential limitations in finding appropriate seed sources. Some nurseries "mainly store / supply seed as needed on an ad-hoc basis and do collections based on availability and needs," indicating a more reactive approach, which ties to previous responses on a lack of long-term planning and inconsistent orders year to year.

It was also noted that seed collection and storage are sometimes handled by other departments within organizations, or not at all by respondents. Additionally, 44% do not collect cones, 56% do not perform cone or seed processing, and 50% do not conduct seed testing. This highlights a potential gap in the current capacity assessment, as the capacity, demand, and expansion potential of entities that *do* undertake these activities remain unquantified. It is recommended that future surveys incorporate this component to gain a more comprehensive understanding of overall seed management capacity.

In terms of seedling supply for small woodland owners, order size appears to be a potential constraint. While 54% of respondents indicated they would accept orders of less than 500 seedlings, many have higher minimum order requirements: 23% require a minimum of 500-



1,000 seedlings, 15% have a minimum of 1,000-5,000, and 8% have a minimum order size exceeding 10,000 seedlings (Figure 18).

What is the Minimum Number of Seedlings You Will Consider for an Individual Order?

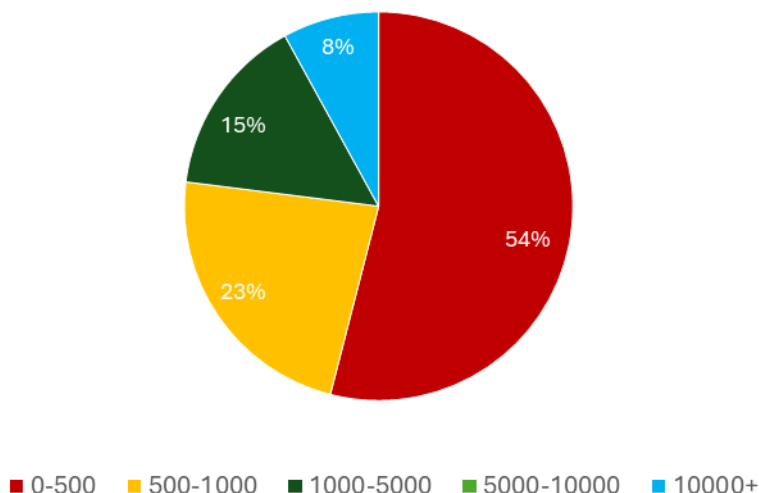


Figure 18. Minimum Seedling Orders Accepted

Conclusion

The nurseries surveyed are largely operating at or near their current desired capacity, particularly in container seedling production. While many possess the *capability* to expand, a lack of consistent increased demand is preventing them from doing so. This cautious approach is a pragmatic business decision, reflecting a preference for operating efficiently relative to existing demand rather than risking underutilized space. Expansion is contingent upon greater certainty in long-term contracts, reduced financial risk, and a demonstrable, consistent increase in demand. The higher utilization of container seedling capacity alongside underutilized bareroot capacity suggests a growing preference for container seedlings and a potential need for nurseries to adjust to accommodate more container seedlings.

Recommendations

Strategic Planning and Long-term Contracts

Strategic planning across reforestation activities can mitigate risks associated with capacity expansion for nurseries, particularly through the establishment of long-term contracts. These multi-year agreements can provide the consistent demand necessary for nurseries to confidently increase their production capacity under a more stable and advanced ordering



framework. Developing and actively promoting the adoption of such long-term contracts will provide nurseries with the financial security required to invest in growth. Furthermore, a comprehensive and collaborative strategy that integrates seed collection as a component, advocating for an all-lands approach, is essential to ensure both the quality and quantity of available seed. As climate continues to impact seed viability, having collections across all-lands can better ensure appropriate seed sources for different regions. Exploring the establishment of seed orchards to supplement wild collections should be considered to increase seed availability and viability.

Collaboration and Knowledge Sharing

Building stronger relationships and communication among nurseries, industry partners, non-profit organizations, community stakeholders, and state and federal agencies will facilitate the exchange of best practices, enable collective problem-solving, inform effective reforestation strategies, increase overall reforestation capacity, and support the development of supportive policies. Additionally, by maintaining open and transparent communication across the sectors of the reforestation supply chain, businesses such as nurseries can make more informed decisions regarding stock type and capacity expansion.

Continued Research

We must conduct further research to understand the apparent disconnect between growing reforestation needs and the actual demand for nursery seedlings. Investigating the underlying causes of this gap can lead to the identification of solutions for achieving an increase in reforestation pace and scale. Additionally, to gain a more complete understanding of regional capacity, future surveys need to encompass all entities involved in the various aspects of seed management, such as seed extractories and seed orchards.

Establishment of a Reforestation Network

Create a formal partnership, such as [California's initiative](#), to streamline coordination and address critical bottlenecks in the reforestation pipeline. This partnership should focus on:

- **Optimizing Seed Supply:** Increasing cone surveys, developing strategic collection plans, and investing in workforce development for seed collection.
- **Developing the Workforce:** Establishing programs like the California Cone Corps to train and retain skilled nursery workers.
- **Building Partnerships and Collaboration:** American Forests is actively working with Washington DNR, Sustainable Northwest, the University of Oregon, Oregon Department of Forestry, and other organizations to establish a reforestation network in the Pacific Northwest. Data from this project and other relevant sources will be used to inform the priorities and goals of this partnership.
- **Strategic Planning and Long term Contracts**



These recommendations are interconnected and require a coordinated effort across the reforestation sector to achieve long-term success in meeting the region's escalating reforestation need. By addressing these recommendations and leveraging existing partnerships, the nursery industry can be better supported to improve its capacity to meet future demand and contribute to successful forest restoration efforts.

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Chapter 3

Reforestation Service Provider Capacity, Challenges, and Recommendations for Washington



Reforestation Service Provider Capacity, Challenges, and Recommendations for Washington

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Abstract

Background: The Pacific Northwest faces an escalating reforestation need, driven by intensifying wildfires and ongoing timber harvest. To better address and understand the capacity to meet this growing need, an assessment of reforestation service provider capacity, challenges, and recommendations was conducted through surveys and learning conversations in Oregon and Washington from fall 2024 to spring 2025.

Results: Demand for reforestation services has remained steady or increased, particularly due to wildfires, yet providers face significant constraints. Key challenges identified include unfair pricing and competitive bidding practices that lead to unsustainable margins; workforce instability due to difficulties in retaining seasonal employees and complex reliance on the H-2B temporary worker program; burdensome regulatory and federal bureaucratic hurdles; and critical funding gaps, especially for small woodland owners, compounded by restrictive grant eligibility. Despite these obstacles, providers generally express interest and possess capacity to undertake more reforestation work if these issues are addressed and demand continues to increase.

Conclusion: Recommendations were gathered and synthesized on how to best support the growth and efficiency of the reforestation industry. These include implementing long-term contracts, promoting fair pricing models, increasing and strategically allocating accessible funding, strengthening workforce development, providing targeted support for small woodland owners, developing a comprehensive regional reforestation strategy, and establishing a centralized information hub. Addressing these challenges will foster a more stable, equitable, and effective reforestation sector that is better suited to support the region's ecological health, economic resilience, and long-term sustainability.

Keywords: reforestation, Pacific Northwest, wildfire, forest management, workforce, funding, contracts, Oregon, Washington



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Contents

Abstract..... 2

Introduction 6

Methods 7

Results 7

 General Information and Operations..... 7

 Reforestation Demand and Need 11

 Reforestation Capacity 13

 Challenges to Reforestation Efforts 14

Recommendations for Reforestation Efforts 19

 Long term Contracts..... 19

 Fair Pricing and Streamlined Processes..... 20

 Increased and Strategic Funding..... 20

 Comprehensive Reforestation Strategy 21

 Workforce Development and Capacity Building..... 21

 Collaborations and Partnerships..... 22

 Support for Small Woodland Owners..... 22

 Adaptive Reforestation 22

 Centralized Information Hub..... 23

Conclusion 23

Literature Cited 24

List of Tables and Figures

Table 1. Key Terms..... 7

Figure 1. What type of work does your organization do?..... 8

Figure 2. Annual Reforestation or Planting in Acres 9

Figure 3. Annual Acres of Thinning..... 9

Figure 4. Annual Acres of Prescribed Burning 10

Figure 5. Reforestation Demand 11

Figure 6. Interest in Increasing Reforestation Work..... 13

Figure 7. Challenges to Reforestation Work..... 14



Appendices

Appendix A. Reforestation Provider Survey

Appendix B. Reforestation Provider Survey Results



Introduction

The intensifying wildfire regime in the Pacific Northwest coupled with timber harvest as a key economic driver in the region necessitates a thorough evaluation of existing and potential reforestation capacity to address the escalating reforestation needs. This report contributes to a broader data assessment quantifying current and projected reforestation needs in Oregon and Washington, which estimates a substantial 817,000 acres within wildfire scars with limited potential for natural regeneration (i.e., >60m from viable seed sources), and 1.279 million acres post-harvest reforestation need, which equates to a total of 2.073 million acres across Washington and Oregon for estimated current reforestation need. While this report is for Washington State, it is important to consider this need across state lines as many reforestation providers and nurseries work across state lines and this impacts the overall capacity for reforestation in the Pacific Northwest.

Historically, reforestation efforts focused on regenerating harvested areas, but a decline in timber harvests in the 1970s through 1990s coupled with recent increases in wildfire extent, frequency, and area burned at high-severity, has led to post-fire restoration emerging as a dominant factor influencing reforestation needs in the Western United States (Parks and Abatzoglou, 2020; Haugo et al., 2019; Halofsky et al., 2018; Dumroese et al., 2005) and accounts for a substantial proportion of the demand (e.g., 81% on National Forest System lands ; USDA Forest Service 2022).

Concurrently, reforestation in Washington State is significantly influenced by regulatory requirements following timber harvest, a key economic sector contributing to employment and wages (Washington Forest Protection Association; accessed March 2025). State Forest Practices Rules (Title 222 WAC) mandate reforestation after significant timber removal, establishing a consistent demand, particularly in Western Washington.

Addressing the multifaceted drivers of reforestation demand necessitates not only accurate estimations of current and future reforestation needs, but also a comprehensive understanding of the logistical and operational constraints facing the reforestation sector. This report presents findings from research employing surveys and semi-structured learning conversations conducted from fall 2024 to spring 2025. The objective was to deepen the understanding around capacity, challenges, and obstacles encountered by reforestation service providers in Oregon and Washington, and what they see as solutions to better support their reforestation efforts. The study also incorporates insights gleaned from engagement with the Western Oregon Cascades Recovery Effort (WOCRE) group. The overarching objective of this research is to provide insights that can inform the development of evidence-based strategies and policies aimed at supporting the reforestation industry's capacity to effectively address current and projected reforestation demands in the Pacific Northwest.



Key Terms	
H-2B Workers (or H-2B)	A temporary non-immigrant visa program that permits U.S. employers to hire foreign workers to come to the United States to perform temporary non-agricultural services or labor on a seasonal basis.
Indefinite Delivery, Indefinite Quantity (IDIQ)	A type of contract allowing for an indefinite quantity of services over a fixed period, with specific work ordered as needed.
Occupational Safety and Health Administration (OSHA)	The U.S. Department of Labor agency responsible for ensuring safe and healthful working conditions by setting and enforcing standards.
Contracting Officer Representative (COR) (for federal contracts)	A federal government employee who is designated and authorized in writing by a Contracting Officer (CO) to perform specific technical or administrative functions in the administration of a federal contract. The COR must be a federal employee for federal contracts.
FPA Mandatory Reforestation	Refers to the legal requirement mandated by the Forest Practices Act (FPA) for landowners to replant areas where trees have been harvested.

Table 1. Key Terms

Methods

Reforestation service providers were identified through multiple sources, including the Reforestation, Nurseries, and Genetic Resources (RNGR) Directory, the Washington State Department of Labor and Industries, WOCRE, and input from Washington Department of Natural Resources (DNR), Oregon Department of Forestry (ODF), and reforestation providers.

A survey was distributed via email to a list of providers (n=108), and distributed after meetings and through partners, yielding 26 responses. One-on-one conversations were held with 11 providers in Washington and Oregon to yield deeper insights into the survey responses. An interactive meeting was held with the Western Oregon Cascades Recovery Effort group, with 17 attendees. Data from the surveys, learning conversations, and WOCRE meeting were analyzed to identify key findings and themes.

Results

General Information and Operations

The reforestation survey, drawing responses from 26 individuals primarily working in either or both Washington (15) and Oregon (19), provides insights into the current state of the industry. The majority of respondents (60%) are affiliated with for-profit organizations, and their primary activities encompass reforestation (92%), thinning (84%), and site preparation (76%) (Figure 1).



What Type of Work Does Your Organization Do?

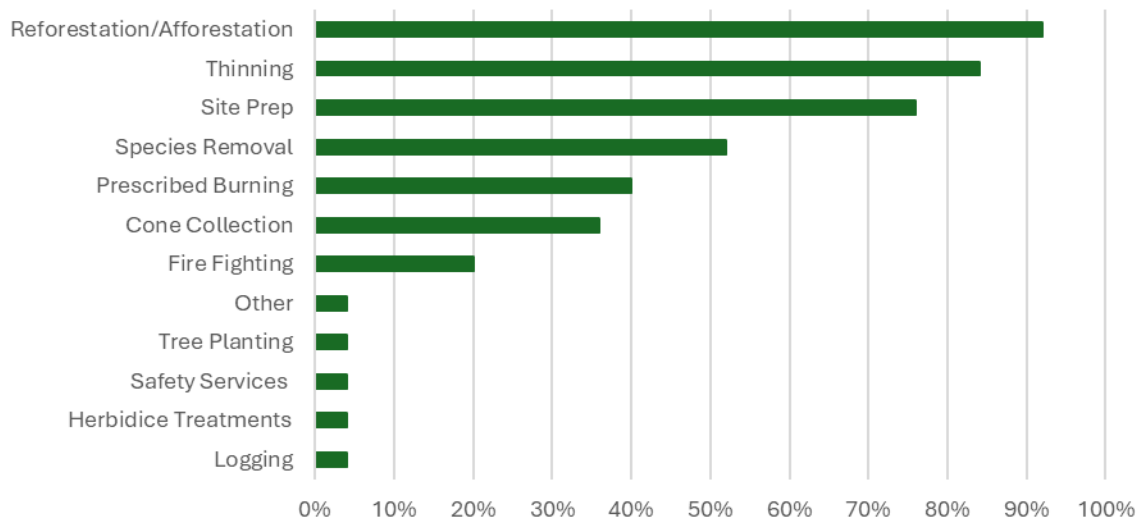


Figure 1. What type of work does your organization do?

When asked what their top three activities that make up their organization's work each year were, "Reforestation/Planting" was cited as the top activity (68%), followed by Hazardous Fuels Reduction and Harvest/Logging (both at 32%). In terms of business scale, most organizations operate with budgets between \$1,000,000 and \$5,000,000 (58%) and a majority (60%) employ fewer than 25 people annually. The work undertaken spans various land ownership types, including small woodland owners (64%), private industrial lands (60%), state lands (44%), federal lands (36%) and tribal lands (32%). The acquisition of work predominantly occurs through direct contracts (64%), with a quarter of respondents engaging in both direct contracts and subcontracts. Word-of-mouth referrals (36%) and online government platforms (20%) serve as the primary avenues for securing work. The busiest months for reforestation activities are September and October, followed by April, March and August. The least busy month is December, followed by January and June.

Reforestation or active planting efforts are largely between 500-10,000 acres annually among respondents (Figure 2).



How Many Acres Do You Reforest or Actively Plant on an Annual Basis?

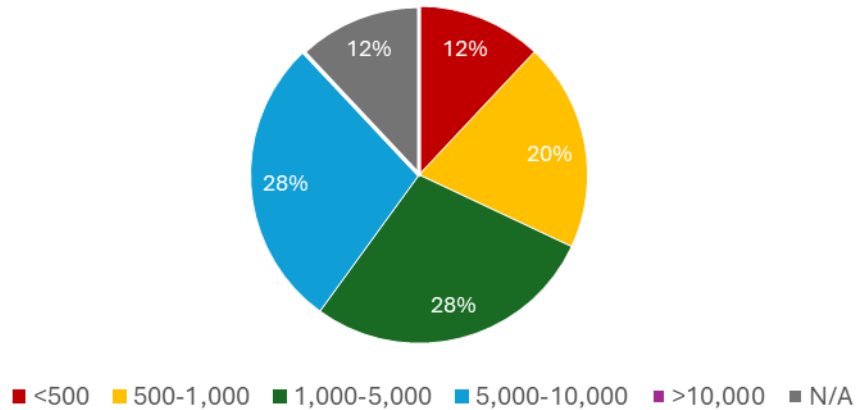


Figure 2. Annual Reforestation or Planting in Acres

The majority of respondents thin less than 500 acres per year (Figure 3), and half of the respondents do not do any prescribed burning (Figure 4).

How Many Acres of Thinning Do You Do on an Annual Basis?

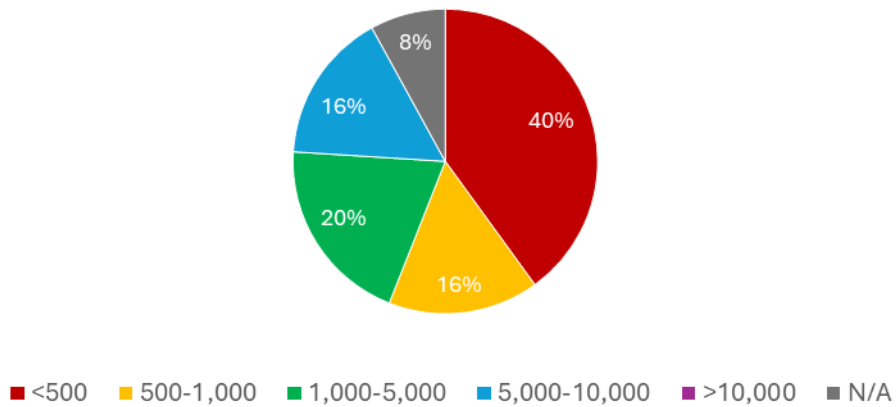


Figure 3. Annual Acres of Thinning



How Many Acres of Prescribed Burning Do You Do on an Annual Basis?

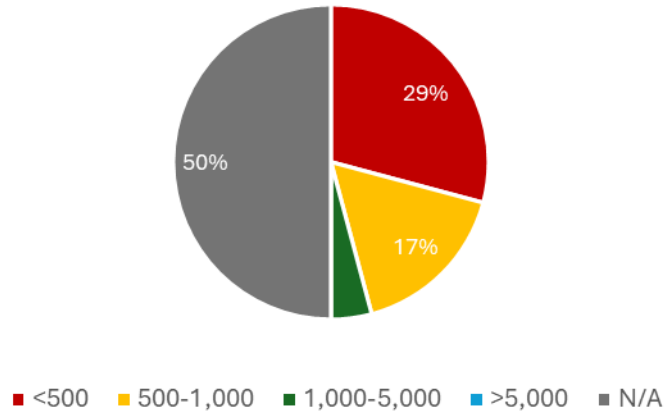


Figure 4. Annual Acres of Prescribed Burning



Reforestation Demand and Need

Based on discussions with reforestation service providers in Oregon and Washington, the demand for their services appears stable or on the rise, with wildfires as an underlying factor. Survey data asking about demand for the last five years corroborates this, indicating that demand has either remained consistent or increased (Figure 5).

Has the demand for reforestation work for your company increased or decreased in the last 5 years?

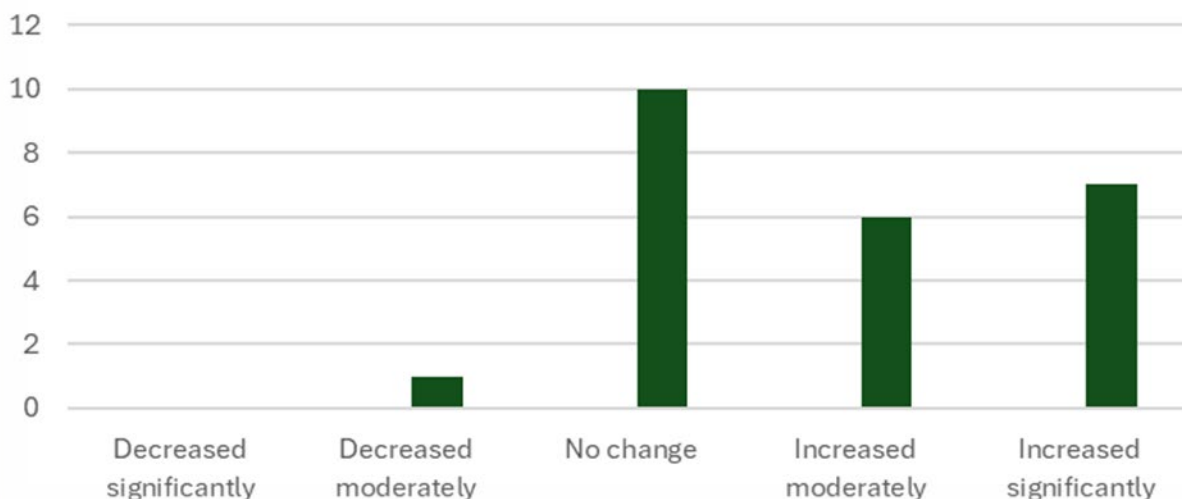


Figure 5. Reforestation Demand

Fluctuations in demand were sometimes linked to the dynamics of the log market and timber harvest schedules. However, a notable driver for increased demand, according to many respondents, is the increasing prevalence of wildfires. One participant clearly stated that "large scale wildfire has significantly increased our need for reforestation." The extensive Labor Day fires of 2020 were frequently mentioned as a key contributor to this heightened demand. Consequently, landowners have also shown a greater interest in active reforestation on their lands, seemingly becoming "more responsible with what needs to be done on their properties" as one individual explained, also noting that they "get better help assistance, that's why they choose to manage their lands more."

A reforestation service provider with extensive experience since 1987, and currently leading a reforestation company, pointed out that this shift in what is driving demand necessitates a reevaluation of traditional practices like "even aged management, grid planting, et cetera." This individual observed that "this is a different era because it is post-fire," emphasizing the need to



embrace "natural regeneration that's happening" and advocating for "a more holistic approach for reforestation," essentially a "need to redefine what reforestation is."

Conversations exploring the relationship between reforestation demand and actual need revealed a strong consensus regarding their misalignment. One participant articulated this by stating that "silviculture is on the expenditure side of forestry, and logging is on the side of the business, if a fire hits an area that hasn't been logged before, the incentive to reforest is relatively low." The influence of cost or available funding on this discrepancy emerged as a recurring theme, exemplified by the comment, "There's way more need than anything. I talk to CORs, foresters all over the United States and they're all saying, if I had the budget, we could do all of this work. There's a lot of need to do it, but funding is a limitation."

One participant offered a perspective on the interplay between demand and need, remarking that "the demand has to catch up with the need," while also emphasizing that "the need needs to also be strategic," suggesting "we need to let nature do a lot of the work, and we need to be there to help."

The challenges associated with scaling reforestation efforts across numerous small woodland owners were also highlighted. As one respondent pointed out, "if someone just had their house burn down it can be harder for them to go through the process of post planting...operations are the easy part. The problem is funding and getting landowners on board. There's a lot of client meetings for people with 20-40 acres for them to understand what's going on."



Reforestation Capacity

Reforestation capacity in Washington and Oregon appears to be largely sufficient for the current demand, as indicated by the strong interest among the majority of respondents in undertaking more reforestation work (Figure 6). Many participants expressed a desire for an increased workload to optimize their schedules and facilitate business growth within the region, however funding for reforestation projects is a limitation. Several also highlighted the importance of reforestation for maintaining healthy forests and bolstering local economies in Washington and Oregon. One respondent stated, "We feel like we need to manage better the lands that need to be planted to keep the forests healthy and to keep the jobs for many families, so we would like for reforestation to increase more."

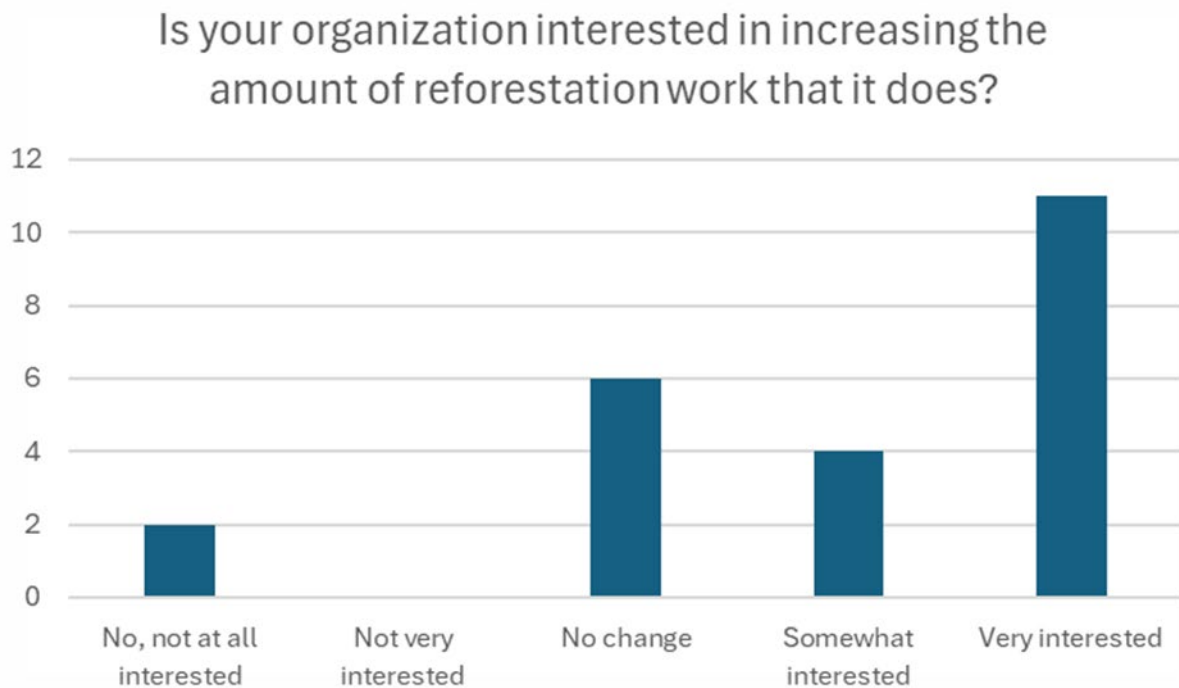


Figure 6. Interest in Increasing Reforestation Work

When specifically questioned about their ability to increase capacity, most indicated it was not a limiting factor. One individual asserted, "Capacity is not an issue. Right now, at this time, [we] could get 5,000 workers in Oregon or Washington immediately," while also noting that these workers "are all dispersed in different states because there is not enough work in Washington and Oregon to keep them here." He added many would prefer to stay local. Another respondent noted, "We have the capacity and the infrastructure to expand. We can handle expansion," while also pointing out, "It's a matter of if it's possible to obtain that many workers and that number can fluctuate all the time" (referring to H-2B workers). Furthermore, the ease of scaling



operations if demand were to increase was mentioned, with one participant explaining, "We could definitely scale. If the demand was there...Operations are easy. It's the funding and paperwork that are the challenges."

Challenges to Reforestation Efforts

Despite an increase in demand and a desire to increase reforestation work, the survey and learning conversations identified several challenges, including low bids and insufficient pay, complex contracts with federal agencies, and regulatory hurdles that impact profitability (Figure 7). Workforce issues, such as the difficulty in finding and retaining experienced seasonal employees and navigating the H-2B worker process, were also prominent concerns. Limited funding for small private landowners post-burn and complicated funding applications pose additional obstacles.

What are challenges for your organization in conducting reforestation work?

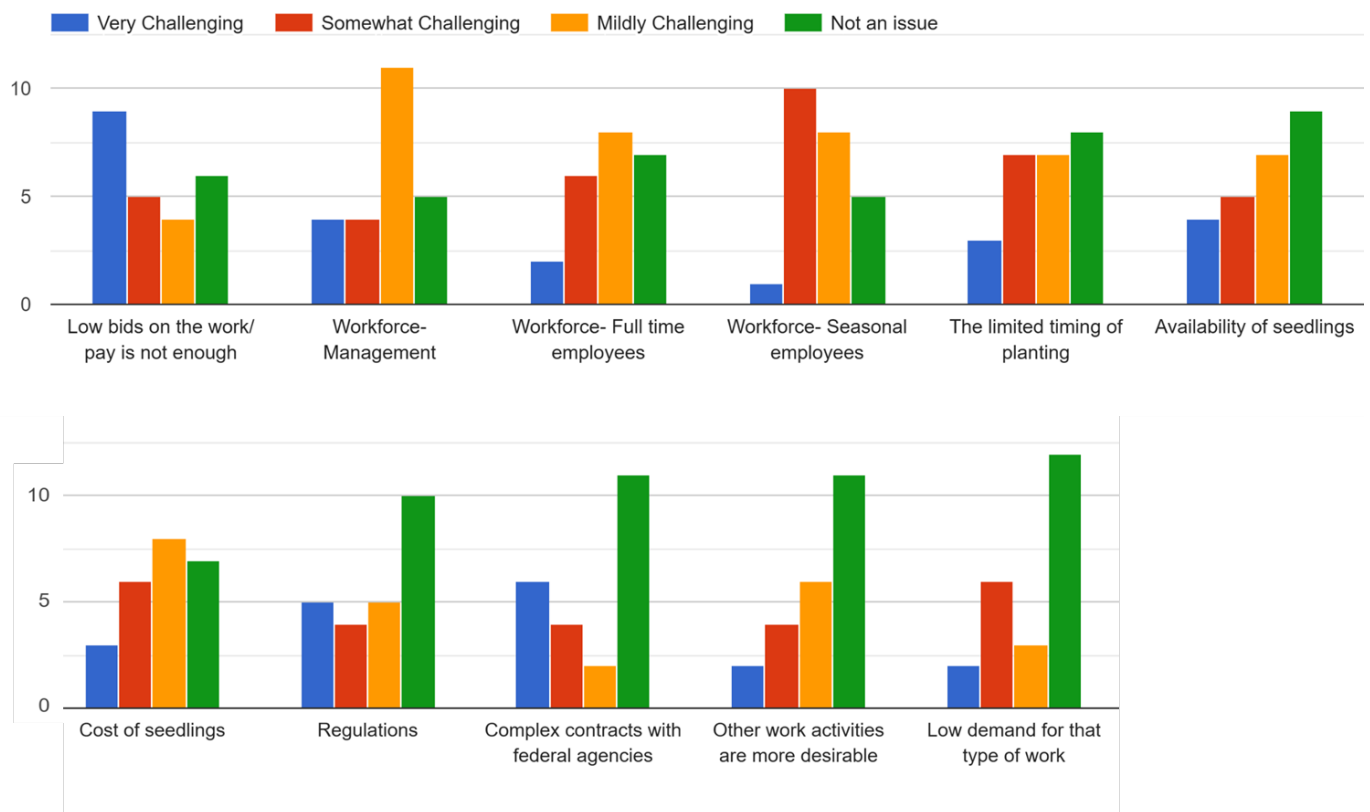


Figure 7. Challenges to Reforestation Work



Low Bids/Unfair Pricing

Low bids and the challenges of unfair pricing emerged as a predominant concern in both the survey responses and subsequent discussions regarding reforestation. One respondent identified "lowball competing bids" as the "biggest challenge," also noting the difficulty in "finding employees who are experienced and able to be seasonal." The bidding process itself was frequently cited as problematic. As one participant explained:

There is a lot of competition with bidding. {We} are trying to work with new companies, but it makes it harder to bid when {the new} companies place their bids way too low. It makes it hard to actually place a fair bid."

The issue of fair pricing and equitable pay was a recurring theme among reforestation service providers. One provider pointed out, "They are paying so little for the jobs. The lowest bid gets the job." This can create an uneven playing field, as some organizations, the respondent explained, "do firefighting, too. So, they will make all their money firefighting, and then just pick up very low bids to keep their employees busy year-round," making it difficult for companies without this additional revenue stream to compete with those "that do and then come in with the low bids, which larger businesses often can do versus smaller businesses."

Frustration with the bidding process was also evident, with one participant noting the extensive requirements: "Bids require a safety plan, there's like 5 factors: Past Performance Evaluations, Questionnaires...It's a lengthy process." However, the outcome often seems disconnected from these considerations, as the respondent concluded, "but then it doesn't matter, the PPE, all of it, it doesn't matter, they just go with the lowest bid." This approach, as another participant pointed out, occurs because "they have a budget, and if someone goes half price, they will get the work because it's a low bid," even though "you have to look at the quality of the work, the past experience, too, and they don't." This dynamic puts pressure on reforestation organizations to balance offering fair wages with the necessity of submitting competitive bids, a situation highlighted by one participant who stated, "Most contractors know each other. We will talk to each other. Ask how things are going. Many contractors are losing money {on projects}."

One participant also shed light on how regulations can unintentionally contribute to pricing disparities and potential non-compliance. Regarding federal contracts, they explained the requirement to "pay benefits on top of that {minimum} wage," recounting an instance where informing subcontractors that "with the minimum wage and benefits, they would have to pay \$30.08 an hour" revealed that "several had no idea they had to pay that much to their {H-2B} workers legally." This suggests a potential lack of awareness or enforcement, leading the participant to conclude, "I guarantee you there are other contractors paying them less because they don't know or don't care about meeting those legal requirements" he went on to say he felt most were unwittingly paying too little "...no one will know they're not paying well enough unless they are audited."



Workforce

Feedback regarding workforce challenges in reforestation pointed to issues of consistency and planning rather than a fundamental lack of available workers. The fluctuating nature of both reforestation and general forestry work, combined with insufficient long-term planning, makes it difficult for contractors to maintain a stable workforce, invest in their operations, and secure dependable projects. The extended and uncertain timeline of the H-2B process, often requiring 12 to 18 months, combined with the unpredictable demands of reforestation, hinders effective workforce planning. As one contractor stated, "If I know I will have the work, I can line out workers no problem. But I need to know in advance because it is a lengthy process, and I have to be able to demonstrate they will have the work."

Furthermore, the annual cycle of the H-2B visa program necessitates recurring expenses for visas, travel, and relocation, and contributes to the loss of trained workers, requiring continuous retraining efforts. "The more they work, the more they learn," one participant noted, "But they work ten months at a time and if they leave and don't come back, then I have to train all over again," highlighting the difficulty in retaining skilled labor. The federally mandated cap on H-2B visas appears inadequate to meet the labor needs of seasonal businesses, often requiring a lottery system if demand exceeds the quota, typically in January for an April 1st start date. This introduces significant unpredictability and uncertainty for businesses trying to reliably forecast their workforce capacity and plan for contracted work. "A huge percentage of the work being done in the West is done with foreign workers," one individual emphasized, stating plainly, "If you don't have foreign workers, you don't have a business. That's it in a nutshell." This reliance is underscored by the difficulty in attracting domestic workers, as evidenced by the statement, "There's not an understanding of how much US businesses and industries rely on the foreign worker programs. The idea we are displacing the US workforce is a fallacy. We advertise in 11 Western states and we get no one applying for our jobs with a pay range of \$25-35 per hour." This represents a shift from the past, as one participant recalled, "In the 80s, 80% of the workforce were Americans. Now it's mostly H-2B workers," further suggesting a connection to pay, noting, "It was better pay then, for everyone. They could negotiate for enough money to pay everyone. Now, it's mostly H-2B workers because they have to hire people from poorer areas that want the work for less pay."

This dependence on the H-2B program raises questions about the long-term sustainability of the reforestation workforce. Given this reliance, any disruptions or changes to the visa program could substantially impact the availability of labor for reforestation efforts. This begs the question of sustainability: what would happen to the reforestation workforce if this program were significantly altered or eliminated? Furthermore, the ethical implications of such a dependence on a temporary foreign workforce also warrant consideration, alongside the need to understand why domestic workers are not interested in this type of work or how to better incentivize it for them. The inadequacy of the federal cap on H-2B workers and the resulting lottery system further exacerbate the unpredictability and uncertainty for businesses attempting to expand their workforce to meet reforestation needs.



Regulatory and Administrative

The reforestation sector in Washington and Oregon faces considerable regulatory and administrative burdens that affect both how efficiently they can operate and their financial stability. A primary challenge stems from complying with labor regulations, especially those enforced by the Department of Labor (DOL). This is highlighted by the concern that "many contractors do not have a concept of what it takes to stay in compliance and be prepared for audits." For some, interactions with the DOL feel more punitive than supportive; as one individual described, "The Department of Labor just comes in and runs them over," rather than trying to "educate, help them, get them compliant," they simply "come in and {heavily} fine the {business}." This is particularly challenging for many independent contractors and newer businesses who reportedly lack the expertise to navigate complex requirements around insurance, payroll, and foreign worker programs, increasing their risk. This lack of knowledge around basic requirements, like adhering to minimum wage, leaves them vulnerable to costly DOL scrutiny, where "audits will never be painless," and it's expensive "just to get ready for audits," with the likelihood that "every time they will still find something, and it will be a few thousand dollars." This vulnerability contributes to the sentiment that "most will not be in business in 5 years due to undercapitalization or DOL or USCIS (U.S. Citizenship and Immigration Services) audits."

Beyond DOL regulations, the increasing cost of OSHA fines for even minor infractions poses another challenge. Furthermore, the relevance of some OSHA regulations to the specific work of reforestation is questioned, with concerns that "OSHA regulations don't make sense" because "they require training, but the training is geared toward loggers, not replanting or site prep," focusing on "safety that's unrelated to the work." This disconnect underscores a broader need to revisit and redefine reforestation practices, as some existing regulatory requirements may no longer be applicable or appropriate for the realities of current reforestation efforts, particularly in the context of post-fire restoration.

Federal

Many federal obstacles and challenges are included in the above paragraphs, such as regulatory hurdles, complex contracts, the H-2B process, and low bids being prioritized over the quality of work. Reforestation efforts on federal lands face a unique set of challenges. The complexities of federal contracting are an impediment, with convoluted processes leading to missed opportunities, as evidenced by instances where contractors "sometimes have not gotten an IDIQ contract because of a small oversight." Furthermore, the availability of Contracting Officer Representatives (CORs) can severely impact projects, with instances reported where projects were "ready to go on federal contracts and then a COR can't be found and the whole project is off." The prioritization of low bids often overshadows the quality of work, and agencies are perceived as "so cheap. {They} just go with the lowest bids." There are also concerns that work on federal lands is more dangerous work because "{Federal lands are} not as safe to work on as private industrial. Snags can be left for years, which creates a safety hazard for crews. Private will clear after fire, so it's safe, and they plant bigger trees {2 years old}, so they have



better survival rates." These paradigms lead some to feel the "work isn't worth it" and that they "don't make much more than you would at McDonalds." There is a reluctance to engage with federal agencies on federal projects, as evidenced by the comment "There is a desire to work with others than federal agencies on federal lands...If there are more opportunities, a private agency would be better to work with." Another noted that, "it would be preferable to work with private or nonprofit organizations representing federal agencies." The inherent bureaucracy within federal agencies can also cause significant delays, with reports of how "Federal bureaucracy can slow down or stall projects." The unreliability of government funding, exemplified by instances where federal hiring freezes have halted work that is dependent on proper timing, further complicates reforestation efforts on these lands.

Small Woodland Owners

Reforestation efforts on non-industrial private forest lands face other challenges. One of which is the fundamental issue of seedling availability. As one respondent noted, even when attempting to source seedlings from a state nursery, they are "short on the seedlings, they are unable to fulfill the entirety of the order." This necessitates time-consuming searches for alternative suppliers. Many noted the difficulty getting smaller orders filled at nurseries. The escalating "cost of planting" further exacerbates the situation, particularly for landowners undertaking reforestation projects. While "robust funding through USDA and WA DNR" exists, respondents remarked that the demand far exceeds the supply, resulting in many applicants denied or facing significant out-of-pocket expenses, often a 50% cost share that many small woodland owners "don't have the capacity to pay." There is also a general "lack of understanding of how to go about doing {reforestation}." Participants noted that many landowners lack forestry experience and may not even realize the need to replant degraded lands or be aware of available resources. One participant highlighted that "labor is not an issue so much as people don't know how to find them, how to contract with them, how to design a planting project that meets their objectives," underscoring the need for better support in project implementation.

Funding remains a fundamental obstacle hindering widespread reforestation efforts for small woodland owners. The current system can counterintuitively penalize proactive forest management, as landowners who undertake salvage logging after events like wildfires may become ineligible for reforestation funding. As one source pointed out, it would be "a huge help" if "the DNR grants could get away from the salvage logging restriction." This is particularly perplexing considering that landowners are often advised to conduct salvage logging because "it's good forestry, it gets it cleaned up, it's safety." However, current legislative guidance dictates that "if it's under FPA mandatory reforestation then they can't get funding," because salvage logging is considered harvest. These requirements "need to be relooked at and more nuanced." Participants consistently highlighted the necessity for more streamlined funding mechanisms and targeted outreach to effectively engage and support small woodland owners in undertaking reforestation.



Navigating the complexities of various funding sources further complicates the process, including federal programs like the NRCS with their associated "hurdles and paperwork," and state-level initiatives with their specific eligibility criteria. The financial burden on individual landowners is significant, as one respondent noted, "Small private landowners can't spend \$50,000 to replant a forest if they didn't make any money salvage logging." Furthermore, the sheer scale of landowner engagement required for extensive reforestation across numerous smaller properties adds to the financial strain and administrative burden. As one individual explained, while managing "a million acres on one landowner's land...is no big deal," dealing with "a million acres on multiple landowners, that's a lot of meetings and handholding." The "unreliability of government funding and even temporary freezes" further exacerbate these challenges, hindering the ability of organizations to implement reforestation work for small private landowners. In February of 2025, multiple federal funding sources for reforestation efforts were frozen, causing a delay or even preventing reforestation projects from occurring. While many of these were temporary freezes, there is a small window to conduct reforestation and planting efforts, and typically that window only occurs in the Fall and Spring. Even a two-month freeze of funds can have significant impacts on the ability to reforest. In the end, as one expert succinctly summarized, "The big issue is funding. Where's the money coming from. It's expensive to do this work."

Recommendations for Reforestation Efforts

Based on the information gathered from reforestation service providers in the Pacific Northwest, several recommendations emerged to better support reforestation efforts. These include long term contracts, fair pricing and streamlined processes, increased and strategic funding, the development of a comprehensive reforestation strategy, workforce development and capacity building, fostering collaborations, and providing support for small woodland owners, alongside the need for adaptive reforestation and a centralized information hub.

Long term Contracts

The need for long-term contracts to foster stability and growth within the industry is a common theme mentioned in the survey, meetings, and conversations. The current system of more short-term agreements makes it difficult for businesses to invest in their infrastructure, workforce development, and long-term planning. As one participant stated, "It's tough to run a business in reforestation because it's so unpredictable." The lack of consistent work prevents companies from securing reliable labor, and the time-consuming and expensive H-2B annual visa process further exacerbates uncertainties with a seasonal workforce. Providers emphasized that "if they KNOW they will have the work then they can invest in their companies" and achieve "consistency and continuity" in their workforce. Transitioning from short-term contracts to longer-term agreements (e.g., 3-5 years) would provide contractors with the stability needed to make strategic investments, project planning, retain skilled workers for multiple planting seasons, and ultimately have more effective reforestation outcomes. As another provider noted, "with long term contracts we can plan for and keep workers on year-round."



Simplifying and extending visa durations to accommodate longer term projects would also reduce administrative costs and improve workforce retention. One contractor suggested:

If they could do something like a 3 year visa or longer term H-2B contracts where they could see their family in the winter but know they have work to come back to in the spring, then I wouldn't have to retrain or pay a lawyer to go through the H-2B process all over again.

Long term commitments can also help with issues with seed sourcing and survival, as one forester now working in the nursery field noted, "Several buyers don't have long term contracts; they just order the extra ones produced from a pool of seedlings. Then they don't survive as well because it's not the right climate." Long term contracts also help to support partnerships between landowners, government agencies, tree nurseries, and reforestation contractors. "Long term commitments and agreements are needed to create long term relationships." This can foster trust and ensure a more reliable supply and demand of services, reducing risk to those involved.

Fair Pricing and Streamlined Processes

A significant concern revolves around fair pricing, bidding processes, and the need for more streamlined administrative procedures. Many providers emphasized the necessity of aligning pay with the work involved, noting that "we should look into what's actually fair pricing to pay for something." To address disparities in bids and pay, providers suggest "simple contracts where specifications are clear, easier to negotiate price" and "fair pricing. Pay has to match the work," to better ensure outcomes that are "good for the contractor and the land." The current bidding process is described as creating "tension, super low pay." One provider emphasized the importance of proactive communication and collaboration, stating, "We need to include reforestation guys in the planning process, so they know it's coming up. If they know the work will be here, there will be less tension on contracting and bidding." The lack of adequate quality control is also an issue noted, with one participant stating, "There are no checks and balances for who is doing good work versus who isn't." Many suggest the need for a "best value vs low bid" approach, emphasizing the need to "spend real time vetting contractors prior to award." Some suggested a shift towards "pay per hour instead of IDIQs" and "private contracts instead of federal; work with private or nonprofits representing federal" to improve fairness and efficiency.

Increased and Strategic Funding

Securing dedicated and long-term funding is another common theme mentioned for successful reforestation. Ultimately, as one expert emphasized, "Grant funding is just required. You can't squeeze blood out of a stone and tell people to plant," especially given that "a lot are elderly {or vulnerable}, so they don't have the money to do it." The financial strain on private landowners post-burn is a significant barrier, with one stating:



Helping private landowners obtain funds for the reforestation work after a burn is the single biggest challenge and barrier to reforestation work getting completed. Burns usually have a negative balance sheet impact to private landowners and reforestation expenses become low on the list of priorities after, say, rebuilding a home."

One suggestion is "a simple reforestation fund with fixed cost share \$/acre rates for site prep, spray, and tree planting for burn reforestation" to streamline and simplify the process.

Comprehensive Reforestation Strategy

An overwhelming consensus points to the need for, "an actual state-wide strategy for responding to catastrophic wildfire events and deploying resources for reforestation." According to participants the strategy should encompass various elements, including:

- Local and state changes to forest type designations
- Tax incentives
- Research on forest transition
- Carbon sequestration considerations
- Workforce development efforts
- Nurseries that will serve small woodland owners
- Establishment of seed and seedling networks
- Prioritization of coordination and partnerships

Such a strategy can ensure a cohesive and effective approach to reforestation in the face of increasing wildfire events. As one participant stressed, "there needs to be a strategy. A plan. Start to finish. That includes planting the trees...I need to have consistency and commitment for the work in advance." Another emphasized the need for a strategy to prioritize where to focus efforts, "the need comes back to influence of reforestation planning and objectives of federal and state partners. We have a lot of work in redefining reforestation in the new climate. How do we prioritize where we put our investment? That's key."

Business Development and Capacity Building

Investing in business development and building capacity within the reforestation sector is another key consideration. This includes the need for training in areas such as "management and leadership" and "best practice for prep work," alongside the provision of more supportive tools. However, the realities of "often 70-80 hours a week and for low wages" raise questions about the practicality and accessibility of such development opportunities. Safety training is also a concern, with one comment highlighting that "injuries are blamed on reforestation but there's not as many resources for training and safety for reforestation." Suggestions to improve workforce development include creating programs offered in both English and Spanish to be more inclusive. Recognizing the administrative burdens faced by many independent contractors, the idea of a "Small Business Development Center for Contractors" was proposed to provide support with essential functions like "insurance, payroll, accounting, how to make



spreadsheets." As one participant pointed out, "A lot of these are independent contractors, they don't have administrative skills... And they end up getting fined for mistakes." Another noted the potential for such support to also address the issue of unfair bidding prices, explaining that "if they received help with {legal requirements}, it would bring the price to a more level playing field because they'd be paying what they are supposed to." This could help ensure "everyone is playing on the same rules," as the current situation suggests that "most aren't. In fact, none are. It's not intentional. It's just not knowing any better," especially given that "for most, English is a second language" and "the myriad of regulations is off the chart," a complexity even those with dedicated staff struggle to keep up on.

Collaborations and Partnerships

Strengthening collaborations and partnerships across different stakeholders is integral for overcoming the challenges in reforestation. This includes bridging perceived divides, as one participant noted:

Some people don't want to work {with loggers} because they think they just want to cut down the trees. But that's not true. Loggers love the forest. They are more environmentally aware. There is a disconnect between conservatives and liberals but really everyone needs to come together.

There is a need to recognize and acknowledge that "there are right ways and wrong ways to manage the forests, we need to all work together to learn and streamline the process to have healthier, resilient forests." Participants advocate for bringing people together and innovating local partnerships into broader collaboratives, especially in the context of increasing post-fire recovery needs. As one provider stated, "It has become more and more clear that the only way to be successful is partnerships."

Support for Small Woodland Owners

Providing targeted support and resources for small woodland owners (SWOs) is recommended for expanding reforestation efforts across private lands. This includes developing "more educational materials" and a "guidebook for small woodland owners that would help them know how to plant, what to plant, why to plant so they understand the importance of it and connects them to the resources out there." The guidebook should provide information on where to obtain seedlings, how to find consulting foresters and tree planting companies, and available financial resources. Participants also suggest "approaching property owners with incentives to replant/reforest" through "targeted outreach." The financial constraints faced by SWOs post-burn are a significant challenge, as one provider highlighted: "Small private landowners generally have limited or no funds available for reforestation post-burn; the burn already puts them in a financial hole."

Adaptive Reforestation

The need to adapt reforestation strategies to changing environmental conditions and specific site requirements was also emphasized. This includes considering "replanting strategies for



different conditions and locations" and ensuring the "right tree in the right location." The concept of "assisted migration" was mentioned, along with the need for "education on the strategy" and "resources on how to find the seed stock that meets that criteria." Participants also stressed the importance of not only planting but also ensuring maintenance to prevent project failure due to competing vegetation. Identifying priority areas for reforestation based on factors like natural regeneration, riparian zones and high productivity soils was also suggested.

Centralized Information Hub

Finally, the creation of a centralized information hub or platform was brought up by numerous participants. This idea was also proposed at the 2025 Reforestation Summit to improve communication and access to resources. This platform would combine the multi-decadal knowledge and experience of American Forests with the innovative and community-driven Planscape platform. Initial buy-in and community development by user working groups is necessary to make an information hub or platform like this a success. A suggestion for the hub is to include a way to connect landowners with relevant available surplus seedlings. The idea of a website where contractors could find opportunities with nonprofits and other organizations (and vice versa) was also put forth. "A website where they could find contracts with nonprofits or others might be good, too. There are other reforesters out there working with organizations I didn't even know existed. A centralized platform to find projects could help." As one participant put it "communication among nurseries and reforesters, everyone is key." However, funding and developing a platform to account for these gaps in the reforestation pipeline has been difficult to produce. This would require dedicated funding to maintain the longevity and accuracy of the platform.

In alignment with the USFS Forest Landowner Support grant awarded to American Forests and a suite of state, private, and Tribal partners, American Forests is developing a landowner-centric resource hub that supports landowners in understanding reforestation (primarily post-fire) resources, options, and considerations; educates landowners about emerging market opportunities (carbon, water, biodiversity), and will ultimately help connect landowners with technical service providers to develop and implement reforestation plans. There are opportunities to build additional landowner support services into this nascent platform once it is implemented (estimated launch January 2026).

Conclusion

Overall, the key findings of this research indicate a strong demand for reforestation services, yet providers face numerous challenges. Low bids and unfair pricing stand out as major concerns impacting profitability and fair wages. Workforce sustainability and complex contracts, especially with federal agencies, present substantial obstacles. The lack of long-term planning and inconsistent work availability add to these difficulties. Funding for small woodland owners to be able to reforest on their lands is a large barrier. Despite these challenges, there is a desire to increase work in reforestation. Improved collaboration, streamlined processes, and increased funding are needed to better support the reforestation industry. The research strongly suggests



the need for a statewide, long-term reforestation strategy to effectively address these challenges and ensure successful reforestation efforts. This strategy should:

- Leverage data and insights from this project to inform long-term planning and decision-making that can result in higher levels of consistency and commitment for reforestation projects.
- Prioritize building partnerships and collaborative efforts to gain stakeholder input, increase capacity, improve communications, streamline processes, build needed networks, and ensure the strategy's effectiveness.
- Explore funding mechanisms to streamline processes and incentivize reforestation efforts.
- Consider policy reforms to support the reforestation workforce, such as modifying the H-2B visa program to allow for long-term commitments to specific projects.
- Promote fair contracting practices that reward quality work and sustainable business models.

American Forests is actively working with Washington DNR, Sustainable Northwest, the University of Oregon, Oregon Department of Forestry, and other organizations to establish a reforestation network in the Pacific Northwest. Data from this project and other relevant sources will be used to inform the priorities and goals of this partnership. Addressing the challenges identified in this report will support a more effective and sustainable reforestation industry in Oregon and Washington. These efforts could be adapted to other regions across North America and be a model example of how reforestation partnerships and action can be successfully managed. By implementing the recommendations outlined above, it is possible to support reforestation efforts, promote economic growth, and enhance the environmental and community resilience of the region.

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Chapter 4

Afforestation Potential and Climate-Socioeconomic Vulnerability Assessment for Washington State, USA



Afforestation Potential and Climate-Socioeconomic Vulnerability Assessment for Washington State, USA

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Abstract

Background: Intentional afforestation provides ecosystem services such as carbon sequestration, water quality, erosion control, flood regulation, gene pool protection, cultural appreciation, and timber supply. To estimate the potential for afforestation in Washington State we identified non-forested lands that could theoretically support afforestation efforts, characterized those lands by current land cover type, ownership, and potential forest type, and developed a method to prioritize counties with based on socioeconomic indicators of climate vulnerability.

Results: We identified 736,350 acres theoretically suitable for afforestation across all current land cover types. Most afforestation potential was found to be on privately owned land. Forest type varied by region, with potential areas in Eastern Washington forest types typified by Ponderosa Pine, Grand Fir, Douglas-fir, Lodgepole Pine, and Western Larch, and potential areas in Western Washington typified by Douglas-fir, Western Red Cedar, and Western Hemlock. Yakima County had the highest overall indicators of climate vulnerability across all current land cover types, while Skamania County had the lowest vulnerability scores overall.

Conclusion: This analysis demonstrates that there is a considerable amount of non-forested land across Washington that is theoretically suitable for afforestation, although the feasibility of efforts is likely to vary by ownership and future climate conditions. We also highlight the importance of climate-informed afforestation, consideration of future fire-risk, and the potential benefit of mixing low-density planting with pastureland. The results of the climate vulnerability and exposure analysis provide a prioritization framework for targeting outreach and maximizing investment.

Keywords: afforestation, reforestation, climate vulnerability, climate exposure, climate-informed forestry, Pacific Northwest, Washington



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Contents

Abstract..... 2

Acknowledgments..... 3

Introduction..... 5

Methods..... 5

 Afforestation Opportunity..... 5

 Ownership..... 7

 Forest Type..... 7

 Seed Zones..... 7

 Climate-Socioeconomic Vulnerability..... 7

Results..... 8

 Afforestation Opportunity..... 8

 Climate-Socioeconomic Vulnerability..... 12

 Assumptions and Limitations..... 14

Discussion and Conclusion..... 15

Literature Cited..... 16

List of Tables and Figures

Table 1: USDA plant codes..... 12

Table 2: Yakima County climate vulnerability and exposure..... 13

Table 3: Skamania County climate vulnerability and exposure..... 14

Figure 1: Potential afforestation by current land cover type..... 9

Figure 2: Potential afforestation by ownership..... 9

Figure 3: Potential afforestation by BpS group..... 10

Figure 4: Potential afforestation by region and BpS forest type (Conifer group only)..... 11

Figure 5: Potential afforestation by region and BpS forest type (Riparian group only)..... 12

Appendices

- Appendix A. Afforestation Tabular Results (.csv)
- Appendix B. Vulnerability Scores by County (.xlsx)
- Appendix C. County Vulnerability Matrix (.csv)



Introduction

In the Western U.S., the combined effects of fire exclusion, land management practices, and climate change have altered forest composition and structure, reducing their capacity to recover from natural disturbances (Hagmann et al., 2021). Following disturbance, as much as one-third of forestland may experience further altered composition and structure or transition to non-forest (Wickham et al., 2023). Non-forested land is expanding more rapidly than current reforestation efforts can address, highlighting the need for innovative approaches to the reforestation supply chain and improved understanding of where type conversion is occurring or has already occurred (Dobrowski et al., 2024; Dumrose et al., 2019; Fargione et al., 2018).

In the first chapter of this report, we estimated the reforestation need created by recent (2014-2023) harvest and wildfire. However, recently disturbed areas represent only a portion of the nearly 100 million acres of non-forested land in the U.S. that is theoretically suitable for forestation (Cook-Patton et al., 2020). In this chapter, we use the term afforestation to refer to planting opportunities on persistent non-forested lands that are biophysically suitable for forest cover but have remained without forest for more than 10 years.

There are several notable benefits of afforestation. One of the most studied benefits is carbon sequestration (Fargione et al., 2018; Griscom et al., 2017). Domke et al. (2020) estimates that the total carbon sequestration capacity of forests in the U.S. (71,808 Million Metric Tons of CO₂) could be increased by approximately 20% by fully stocking productive forestland. Afforestation can also provide other ecosystem co-benefits, such as water quality improvement, erosion control, flood regulation, gene pool protection, and cultural appreciation (Pérez-Silos et al., 2021). While there are many reasons to not convert prime agricultural land to forest, marginal or abandoned agricultural and pastoral lands exist that are suitable for forest (Zhang et al., 2023; Cook-Patton et al., 2020; Lark et al., 2020). Alternatively, agroforestry or silvopasture (mixing low-density trees with active cropland or pastureland) can provide ecological and economic co-benefits (Smith et al., 2022; Angima, 2009; Garrett et al., 2004). Through climate-informed forestry practices and innovative wood use, afforestation can be used to help increase local timber production and provide economic stimulus (Zhang et al., 2023; Spies et al., 2019).

The objectives of this assessment are (1) to identify non-forested land across Washington State that could theoretically support afforestation efforts, (2) to characterize lands with afforestation potential by ownership, historical forest type, and current land cover type, and (3) to develop a methodology to prioritize counties based on socioeconomic indicators of climate vulnerability.

Methods

Afforestation Potential

We derived our baseline estimate of lands theoretically suitable for afforestation in Washington State from data developed for the Reforestation Hub (<https://www.reforestationhub.org/>; accessed January 2025). These data, originally assembled by The Nature Conservancy and American Forests, were developed by intersecting non-forested land cover classes (from the



2019 National Land Cover Database (NLCD) and the 2010 North American Forest Dynamics (NAFD) database) with LANDFIRE Biophysical Setting (BpS) forest and woodland classes to classify current non-forested areas that historically supported forest (Cook-Patton et al., 2020). We developed our baseline afforestation potential layer by excluding non-forest lands on urban and developed sites, and only including shrubland, grassland, pastureland and cropland. Pastureland and cropland were further limited to areas with poor-productivity soil types (defined as “challenging soils” in the Reforestation Hub) to avoid prescribing afforestation on productive agricultural land.

In our exploratory analysis, we observed that the baseline afforestation potential overestimated non-forested land in disturbed areas (i.e. harvest and fire) where young forest was often mis-identified. Tabular data from the Reforestation Hub includes post-processing that accounts for these issues, using a semi-spatial deduction process based on verifying random samples and estimating forest growth in disturbed areas (Cook-Patton et al., 2020). However, after discussions with the Reforestation Hub team, we chose to instead make our own spatially explicit adjustments, which is a more conservative approach, but serves the objectives of this study better.

First, we overlaid our baseline layer derived from the Reforestation Hub with Rangeland Condition Monitoring, Assessment, and Projection Tree Cover data (RCMAP; <https://www.mrlc.gov/>; accessed July 2024) and identified areas with >10% canopy cover at any point between 2000 and 2023. Overlapping areas represent relatively recent disturbances that might be in the process of recovery or areas that were mistakenly identified as non-forest. We supplemented the RCMAP data with NLCD Tree Canopy Cover data (2011-2021) (<https://www.mrlc.gov/>; accessed March 2025), which we observed to be more accurate than the RCMAP data in Northeastern Washington, identifying any additional areas with >10% canopy cover. Second, we identified any areas with validated harvest (since 2000, see Chapter 1 for methods), in which there is a legal requirement to reforest. Third, we identified areas that were forested and have experienced wildfires (since 2014, see Chapter 1 for methods). Finally, we repeated the analysis described in Chapter 1 on wildfires between 2000-2013 to identify older burn scars in the baseline area. We divided the burn scars into warmer/drier sites (i.e., high priority in Chapter 1) and cooler/moister sites (i.e., low priority Chapter 1), which others have shown to influence natural regeneration in Washington (Povak et al., 2020; Liotta et al., n.d.).

Using these data, we excluded harvest areas and wildfires 2014-2023 from the baseline afforestation potential as these are accounted for in reforestation need (Chapter 1). Next, we excluded areas which had >10% canopy cover at any point between 2000-2023, except where they were also identified as an older burn scar (2000-2013). Visual inspection showed that areas with >10% canopy cover in the RCMAP or NLCD Tree Canopy Cover data typically were mis-identified as non-forest or had unaccounted harvest activities. Thus, the final afforestation potential includes: (1) persistent non-forest (i.e., areas remaining non-forest for the last 25



years, classified as shrubland, grassland, cropland, or pastureland) and (2) portions of wildfires 2000-2013 that may not have regenerated naturally (classified as Warm/Dry or Cool/Moist).

Ownership

Land ownership was initially determined using the Major Timberland Ownership dataset acquired from Washington Department of Natural Resources (WADNR) and Atterbury Consultants Inc. We distinguished private industrial and non-industrial where information was available and grouped ownership classes (see Chapter 1). We then used the WADNR Large Data Overlay (LDO) to identify additional WADNR managed lands absent in the Atterbury dataset (see Chapter 1 methods). The Atterbury ownership data did not include a large portion of the Columbia Basin, which is primarily non-forested. Therefore, we used PAD-US (<https://www.usgs.gov/programs/gap-analysis-project/science/pad-us-data-overview>; accessed March 2025; version 4.0) to fill in public ownership classes, attributing WADNR managed lands using the LDO, and assuming all lands not identified in PAD-US were privately owned.

Forest Type

To determine potential species suitability, we analyzed forest type in the potential afforestation areas. In Chapter 1, we used the National Forest Type (NFT) data from the US Forest Service Geospatial Technology and Applications Center (https://data.fs.usda.gov/geodata/rastergateway/forest_type/; accessed October 2024) to determine potential reforestation need by forest type and provide a crosswalk to potential seed need for forested seed zones. However, the NFT data does not have good coverage of non-forested areas, and due to its coarse native resolution (250m), contains numerous artifacts at the forest edge and produces erroneous results when attempting focal interpolation. Therefore, we present the results in terms of BpS forest types, which align with the Reforestation Hub methodology (Cook-Patton et al., 2020). These are the best estimates of what forest type occurred historically. Since there are many BpS forest types, we also evaluated afforestation opportunity by BpS group, which more broadly describes dominant vegetation.

Seed Zones

Seed Transfer zones (c. 1972) were acquired from WADNR. We aggregated seed zones into two regions based on relative position to the Cascade divide, Western Washington and Eastern Washington.

Climate-Socioeconomic Vulnerability

We relied on [The U.S. Climate Vulnerability Index](#) (CVI; accessed April 2025), to quantify the climate vulnerability of the potential afforestation areas. CVI incorporates two themes, baseline vulnerabilities which include health, social and economic, infrastructure, and environment indices and climate impact vulnerabilities, which include health, social and economic, and extreme event (storms, floods, drought, and wildfire) indices (Lewis et al., 2023). We used zonal statistics in R to calculate mean CVI scores, based on census tracts, for the afforestation



potential areas within each county for the four NLCD categories (shrubland, grassland, pastureland, and cropland) and fire scars greater than 10 years old. Only areas with afforestation potential were used to calculate the mean scores. We then normalized the CVI scores for all counties in Washington State instead of nationwide. They are scaled from 0 to 1, with 0 being the least vulnerable county and 1 being the most vulnerable county. For further information on methods for calculating CVI scores, please refer to Lewis et al. (2023).

In addition, we used the climate exposure layers from the [NatureServe Climate Change Vulnerability Index](#) (CCVI; accessed April 2025) and zonal statistics in R to calculate the mean climate exposure for each county. Similar to the CVI, we normalized the climate exposure scores to only counties in Washington State, with 0 being the least vulnerable county in Washington to changes in climate exposure and 1 being the most vulnerable county in Washington to changes in climate exposure (Lyons et al., 2024; Young et al., 2015). The climate exposure layers use temperature and climatic water deficit from a multi-mean of 20 statistically downscaled climate data from the MACAv2.0 dataset (Abatzoglou and Brown, 2012) projected to mid-century (2040-2069) for the RCP4.5 and RCP8.5 emissions scenario from the 5th generation of General Circulation Models for the Coupled Modeled Intercomparison Project (CMIP5).

Results

Afforestation Potential

We identified 736,350 acres theoretically suitable for afforestation on persistent non-forested areas across Washington State (Fig. 1). From the initial Reforestation Hub baseline of 3,469,353 acres, we removed 839,721 acres that had been harvested since 2000, which have a legal requirement for reforestation. We removed 550,864 acres in areas burned 2014-2023, which was accounted for in Chapter 1. We removed 847,455 acres identified as currently forested (i.e., RCMAP showed >10% canopy cover in 2023). Finally, 494,302 acres were removed in areas that were forested at some point between 2000-2022 but could not be accounted for as being lost due to harvest or wildfire. The largest afforestation potential was in grassland (261,055 ac), followed by shrubland (228,291 ac), cropland (123,410 ac), pastureland (74,789 ac), cool/moist burn scars 2000-2013 (29,007 ac) and warm/dry burn scars (20,457 ac). A full table of the raw results can be found in Appendix A.

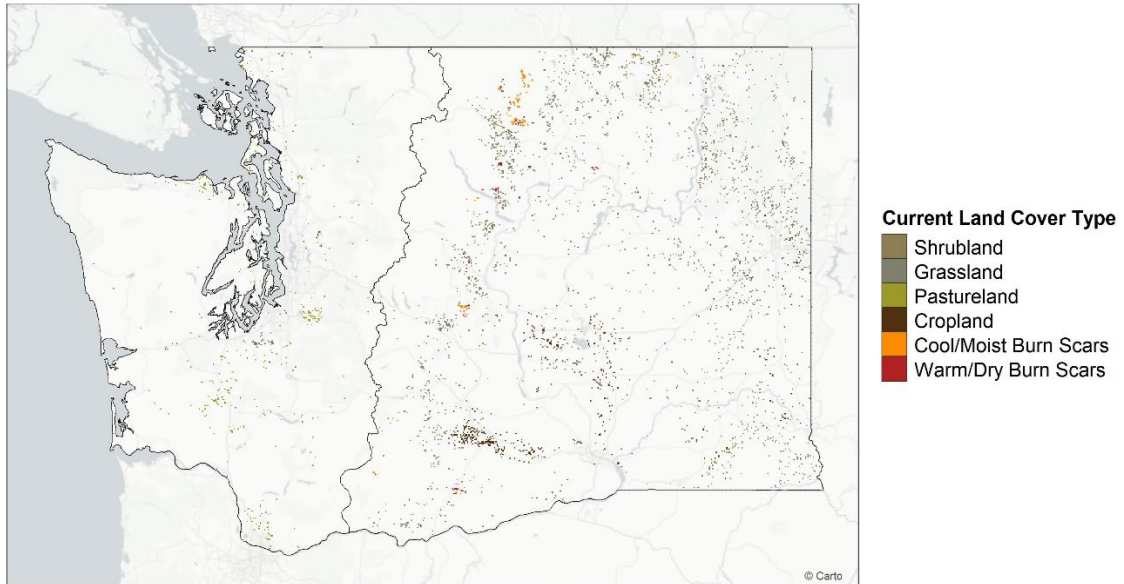


Figure 1: Potential afforestation by current land cover type.

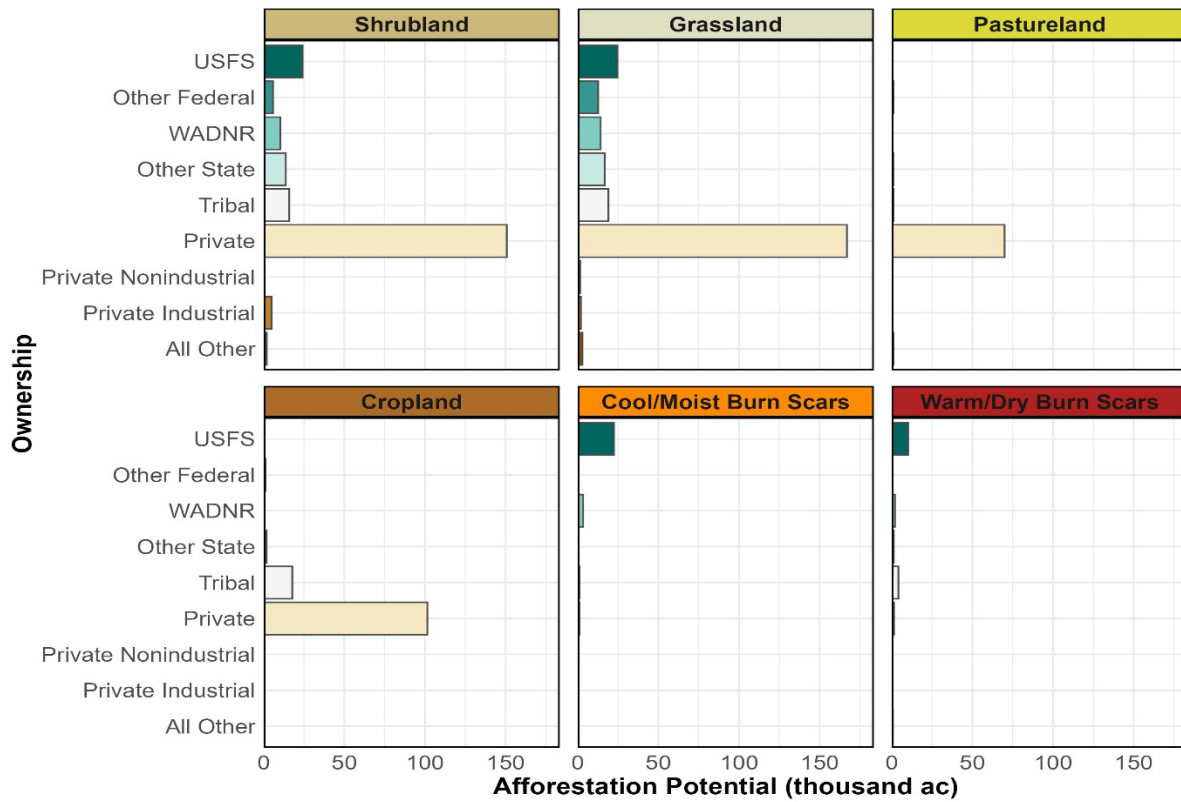


Figure 2: Potential afforestation by ownership and current land cover type for Washington. All ownerships had afforestation potential in each cover type, though some are not easily visible on the graph.



In evaluating afforestation potential by ownership, we found that private land had the most potential for grassland, shrubland, pastureland, and cropland. Additionally, private landowners (including industrial and nonindustrial), represented 68% of all afforestation potential. Meanwhile, the Forest Service had the most potential on burn scars (Fig. 2).

We also evaluated BpS forest types and more broadly BpS groups, which are used by LANDFIRE to categorize potential forest types based on historical condition. Most afforestation potential was in the Conifer (360,831 ac) and Riparian (323,132 ac) BpS groups (Fig. 3). The Hardwood and Hardwood-Conifer BpS groups each had around 100 acres of afforestation potential. Conifer forest was the majority BpS group for all land cover classes, except cropland, where Riparian represented most of the afforestation potential.

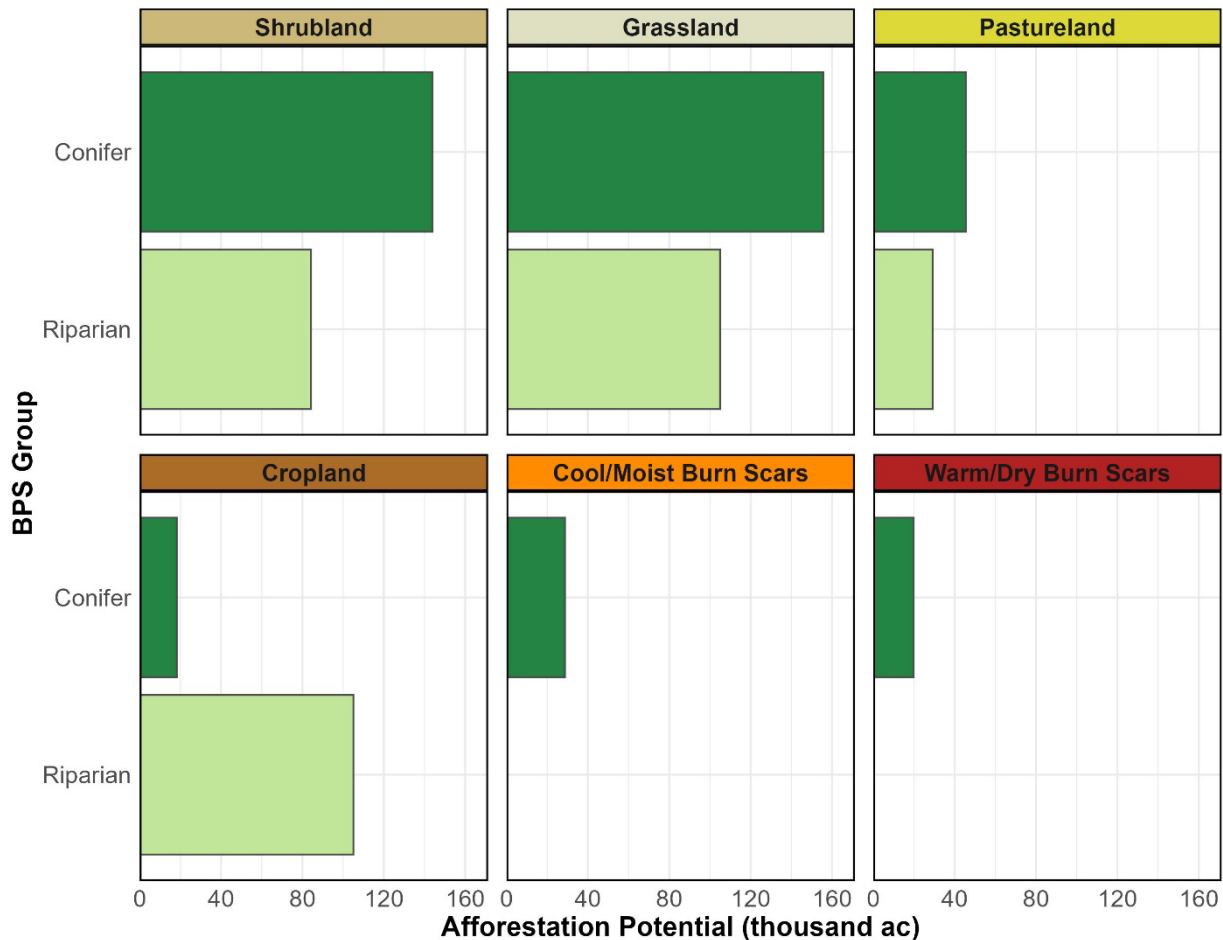


Figure 3: Potential afforestation by BpS group and current land cover type. BpS Groups not shown are Hardwood and Hardwood-Conifer, each having only around 100 acres.



The BpS forest types in the Conifer group with the most afforestation potential (Fig. 4) were Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (161,899 ac; Dominant Species: PIPO, ABGR, PSME), Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir (90,484 ac; Dominant Species: PIPO, PSME, PICO, ABGR, LAOC), and North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest (39,432 ac; Dominant Species: PSME, TSHE, THPL). A crosswalk between dominant species USDA plant codes, scientific name, and common name is shown in Table 1. BpS model codes in Appendix A can be used to look up dominant species and other [BpS descriptions](#) (accessed June 2025).

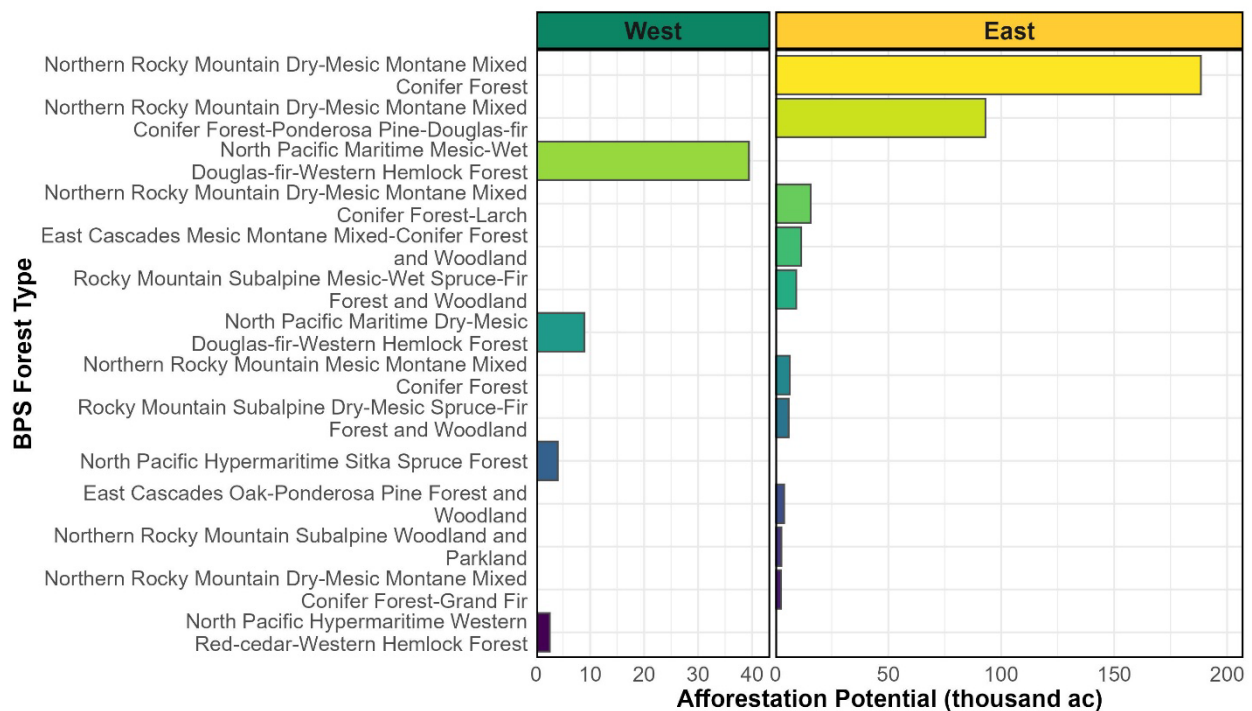


Figure 4: Potential afforestation by region and BpS forest type (Conifer group only). Forest types with less than 1,000 ac are not shown.

Four Riparian group BpS Forest types had greater than 1,000 ac of afforestation potential (Fig. 5). These were Inter-Mountain Basins and Montane Riparian Systems (215,451 ac; Dominant Species: POPUL, SALIX, ALNUS, BETUL, CORNU), Rocky Mountain Montane Riparian Systems (68,159 ac; Dominant Species: POPUL, SALIX, COSE16, BEOC2), North Pacific Lowland Riparian Forest and Shrubland (33,467 ac; Dominant Species: ACMA3, ALRU2, POBAT, COSE16, FRLA, THPL), and North Pacific Montane Riparian Woodland and Shrubland-Wet (1,168 ac; Dominant Species: ALRU2, ACMA3, ACCI, THPL, PSME, SASI2)



Table 1: USDA plant codes lookup table. Species listed are in the BpS forest types with the most afforestation potential.

USDA Plant Code	Scientific Name	Common Name
ABGR	<i>Abies grandis</i>	Grand fir
ACCI	<i>Acer circinatum</i>	Vine maple
ACMA3	<i>Acer macrophyllum</i>	Bigleaf maple
ALNUS	<i>Alnus sp.</i>	Alder
ALRU2	<i>Alnus rubra</i>	Red alder
BEOC2	<i>Betula occidentalis</i>	Water birch
BETUL	<i>Betula sp.</i>	Birch
CORNU	<i>Cornus sp.</i>	Dogwood
COSE16	<i>Cornus sericea</i>	Redosier dogwood
FRLA	<i>Fraxinus latifolia</i>	Oregon ash
LAOC	<i>Larix Occidentalis</i>	Western larch
PICO	<i>Pinus contorta</i>	Lodgepole pine
PIPO	<i>Pinus ponderosa</i>	Ponderosa pine
POBAT	<i>Populus balsamifera</i>	Black cottonwood
POPUL	<i>Populus sp.</i>	Cottonwood
PSME	<i>Pseudotsuga menziesii</i>	Douglas-fir
SALIX	<i>Salix sp.</i>	Willow
THPL	<i>Thuja plicata</i>	Western redcedar
TSHE	<i>Tsuga heterophylla</i>	Western hemlock

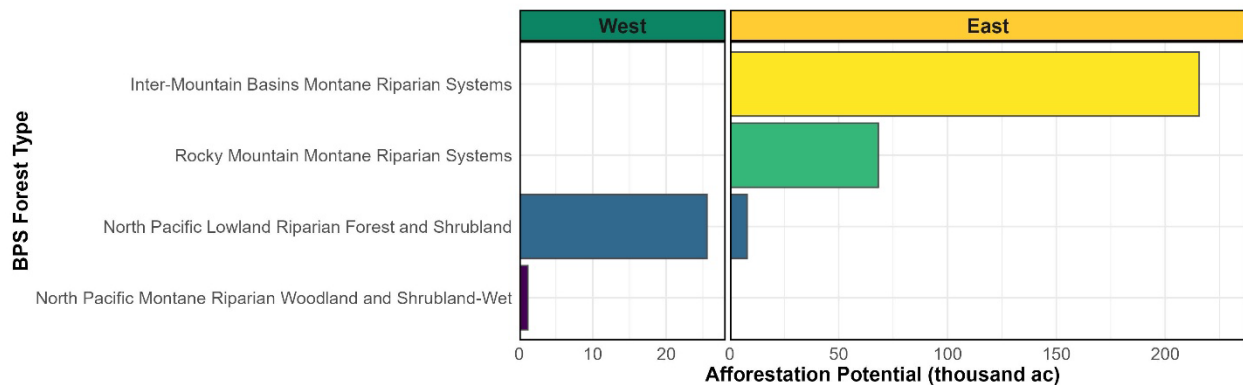


Figure 5: Potential afforestation by region and BpS forest type (Riparian group only). Forest types with less than 1,000 ac are not shown.

Climate-Socioeconomic Vulnerability

Yakima County had the highest overall CVI scores for Shrubland (1), Grassland (1), Pastureland (1), Cropland (1), Cool-Moist burn scars (1), and Warm-Dry burn scars (1). In



contrast, Skamania County had the lowest CVI scores for Shrubland (0), Grassland (0), Cool-Moist burn scars (0), and Warm-Dry burn scars (0). Wahkiakum County has the lowest CVI for Pastureland (0), and King County had the lowest CVI for Cropland (0). An example of all the scores from the CVI and CCVI climate exposure layers for Yakima County can be found in Table 2 and Skamania County in Table 3. All CVI and CCVI scores by county can be found in Appendix B. Appendix C contains the same information, but in a more useful format for future analysis.

Table 2: The mean U.S. Climate Vulnerability Index, domain scores, and NatureServe climate exposure scores in Yakima County for potential afforestation areas by National Land Cover Database type and burn scars (>10 years)

<i>Climate Vulnerability Scores</i>	<i>Shrubland</i>	<i>Grassland</i>	<i>Pasture</i>	<i>Cropland</i>	<i>Cool/Moist*</i>	<i>Warm/Dry*</i>
<i>Potential Afforestation Acres</i>	8198	8852	681	28907	853	217
<i>Overall</i>	1	1	1	1	1	1
<i>Overall Baseline Vulnerability</i>	1	1	1	1	1	1
<i>Baseline Vulnerability Health</i>	1	1	1	1	0.85	0.83
<i>Baseline Vulnerability Socioeconomic</i>	0.89	1	1	1	1	0.91
<i>Baseline Vulnerability Infrastructure</i>	0.84	0.9	0.83	0.87	0.87	0.86
<i>Baseline Vulnerability Environment</i>	0.58	0.77	0.99	0.97	1	0.73
<i>Overall Climate Change Risk</i>	0.91	0.92	0.92	0.89	1	0.89
<i>Climate Change Risk Health</i>	0.43	0.44	0.47	0.45	0.72	0.49
<i>Climate Change Risk Socioeconomic</i>	0.66	0.6	0.59	0.6	0.6	0.62
<i>Climate Change Risk Extreme Events</i>	1	1	0.91	0.87	1	1
<i>Climate Change Exposure RCP4.5</i>	0.81	0.85	0.89	0.9	0.41	0.59
<i>Climate Change Exposure RCP8.5</i>	0.78	0.81	0.87	0.91	0.44	0.61

*These scores are for cool/moist (low-priority) and warm/dry (high-priority) areas in burn scars older than 10 years.

**Score for other counties with potential afforestation areas are found in Appendix B.



Table 3: The mean U.S. Climate Vulnerability Index, domain scores, and NatureServe climate exposure scores in Skamania County for potential afforestation areas by National Land Cover Database type and burn scars (>10 years)

<i>Climate Vulnerability Scores</i>	<i>Shrubland</i>	<i>Grassland</i>	<i>Pasture</i>	<i>Cropland</i>	<i>Cool/Moist*</i>	<i>Warm/Dry*</i>
<i>Potential Afforestation Acres</i>	204	385	36	2	3	3
<i>Overall</i>	0	0	0.2	0.26	0	0
<i>Overall Baseline Vulnerability</i>	0	0	0.08	0.28	0	0
<i>Baseline Vulnerability Health</i>	0.13	0.14	0.06	0.26	0.19	0
<i>Baseline Vulnerability Socioeconomic</i>	0.15	0.12	0.17	0.41	0.08	0
<i>Baseline Vulnerability Infrastructure</i>	0	0	0.25	0.11	0	0
<i>Baseline Vulnerability Environment</i>	0.24	0.25	0.52	0.44	0.37	0.23
<i>Overall Climate Change Risk</i>	0.45	0.43	0.7	0.6	0.57	0.46
<i>Climate Change Risk Health</i>	0.43	0.44	0.38	0.38	0.75	0.51
<i>Climate Change Risk Socioeconomic</i>	0.05	0	0.13	0.1	0.13	0
<i>Climate Change Risk Extreme Events</i>	0.72	0.62	0.99	0.85	0.7	0.69
<i>Climate Change Exposure RCP4.5</i>	0.48	0.44	0.21	0.17	0.22	0.28
<i>Climate Change Exposure RCP8.5</i>	0.46	0.44	0.22	0.18	0.27	0.33

*These scores are for cool/moist (low-priority) and warm/dry (high-priority) areas in burn scars older than 10 years.

**Score for other counties with potential afforestation areas can be found in Appendix B.

Assumptions and Limitations

We removed around 2.7 million acres from the baseline afforestation potential derived from the Reforestation Hub. We were intentionally conservative regarding areas that had >10% canopy cover at some point since 2000. These areas make up about 1.3 million acres, and although we observed many cases where the baseline potential was incorrectly classified, there is likely some afforestation potential that was omitted. These may include other disturbances that could have occurred since 2000 which we did not account for such as insects, disease, blowdowns, and mass wasting, or sparsely forested areas, where planting could be ecologically useful. A significant limitation is that the baseline data uses LANDFIRE BpS, a reference to historical vegetation cover, to determine suitable forestland. We did not assess the probability of success of afforestation under a changing climate. Some areas theoretically suitable for afforestation are on the trailing edge of the current forest and may prove challenging for planting. Consideration of potential success, ecological benefits, social ramifications, and other factors relevant to afforestation outcomes must be considered before afforestation of any specific land areas, but these considerations are beyond the scope of this assessment.

The highest resolution of the CVI is the US Census tract, which vary in size. Many of the CVI indices relate to statistics about the underlying human population (e.g., health risk, economic data, ethnic makeup and distribution). In sparsely populated census tracts, or those where majority of the population lives in an urban center, these statistics may not be as applicable as



those where the population is coincident with the potential afforestation area. We resampled the data using nearest neighbor interpolation to match the resolution and extent of the potential afforestation area defined by the Reforestation Hub. However, some counties contained only a few qualifying tracts, resulting in limited spatial variability in the CVI.

Discussion and Conclusion

This analysis identifies 736,350 acres of afforestation potential in Washington State. These are currently non-forested lands that could support forest based on historical conditions. The methodology was intentionally conservative compared to results from the Reforestation Hub, ensuring that the included areas are unlikely to naturally reforest without intervention and reducing false positives common in prior estimates. However, additional suitability and feasibility analysis is needed to determine if afforestation is beneficial. This could include determining where afforestation could be successful under climate change, quantifying the net gain in carbon sequestration from afforestation versus existing shrubland and grassland systems, and consideration of where the social motivation to afforest exists, particularly for private landowners who make up 68% of the total afforestation potential.

Among land cover types, grasslands (261,055 ac) and shrublands (228,291 ac) make up the largest portion of afforestation potential. These ecosystems often occur in transitional zones where historical forest cover has been lost due to fire exclusion, grazing, or land conversion. Reforesting these areas may offer carbon benefits and habitat connectivity but will require careful consideration of competing conservation values, such as biodiversity in native shrub-steppe or fire-adapted rangelands. In some cases, managing resilient shrubland or grassland systems may be preferable to afforestation depending on local priorities. Pasturelands (74,789 ac) and croplands (123,410 ac) with marginal soils represent opportunities for climate-informed land use transition, particularly on private lands where carbon market incentives could drive afforestation aligned with economic goals. On pastureland in particular, silvopasture (the low-density planting of trees in active pastureland without disrupting its pastureland use), may be more desirable to implement, and can come with additional benefits including improved quality and density of livestock forage, or diversified income stream from timber sales (Smith et al., 2022; Angima, 2009; Garrett et al., 2004).

Opportunities on older burn scars (prior to 2014), particularly on warm/dry sites, offer targeted afforestation potential where natural regeneration has likely failed. These landscapes may require drought-tolerant planting stock and intensive site preparation but also present high-value interventions for stabilizing post-fire carbon loss and reducing future wildfire severity. Careful consideration should be given to promote fire-resilient forest structure and composition in dry mixed conifer forests as to avoid creating unstable carbon sinks (Prichard et al., 2021). Conversely, cool/moist burn scars represent lower-risk planting zones where success is more probable. Across non-wildfire cover types, private ownership dominates the opportunity



landscape, suggesting that incentives, outreach, and carbon financing mechanisms will be central to implementation.

The climate vulnerability overlay reinforces the importance of integrating afforestation with broader climate adaptation efforts. Counties such as Yakima, which have both high climate vulnerability scores and substantial afforestation potential in shrubland, grassland, and cropland areas, could benefit from investments that simultaneously enhance ecosystem function and community resilience. In contrast, counties like Skamania, with lower vulnerability and high forest regeneration potential, may serve as demonstration zones for effective afforestation under changing climate conditions, although the potential afforestation opportunity to make a largescale impact is limiting. This dual approach to vulnerability that includes biophysical feasibility and social vulnerability, supports differentiated strategies that can align ecological opportunity with equitable climate outcomes.

Together, these findings provide a spatial framework for prioritizing afforestation across Washington State. By integrating land cover, ownership, historical disturbance, and climate-socioeconomic vulnerability, the dataset supports WADNR's efforts to assess carbon market opportunities, target outreach, and coordinate seedling supply for maximum ecological and social return on investment. Although, additional analysis will be required to develop and implement afforestation projects. Future iterations of these analyses would also benefit from incorporating finer-resolution regeneration failure data, urban expansion projections, or dynamic prioritization based on patch size, riparian proximity, or biodiversity corridors.

These results also align with broader regional climate strategies emerging across the Pacific Northwest, where afforestation and reforestation are increasingly recognized as tools for meeting emissions reduction targets, enhancing watershed resilience, and supporting rural economies. Washington's Climate Commitment Act and similar frameworks in neighboring states create policy momentum and potential funding mechanisms for scaling natural climate solutions. As wildfire risk, drought stress, and land use pressure intensify across the region, the spatially explicit identification of afforestation opportunities presented here offers a timely contribution to integrated climate adaptation and mitigation planning.

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Chapter 5

Primer on Carbon Project Feasibility & Development for Washington DNR



Primer on Carbon Project Feasibility & Development for Washington DNR

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Abstract

Based on American Forests assessments of both reforestation need and potential eligibility for reforestation carbon crediting methodologies, we estimate that ~16,600 acres of Washington State Trust Lands could be eligible for reforestation carbon projects. An additional ~20,600 acres could be eligible for afforestation carbon projects (in which currently non-forested lands such as non-irrigated farmland would be planted with historically occurring tree species).

Preliminary financial feasibility estimates suggest reforestation carbon projects in such areas should be more feasible at more productive, larger (over 1,000 acre) sites. Lower-productivity sites such as the Carlton Complex fire scar are less well suited for using solely carbon financing to pay for reforestation, because these sites can sustain fewer trees (and carbon) per acre, making it more difficult to cover all site prep, planting, verification, validation, and registration costs from carbon credit revenues. In contrast, a more productive site like the Jolly Mountain fire scar would be more suitable for carbon project development, such that revenues from carbon credit sales over the first forty years of crediting would be more likely to cover reforestation activity costs.

Based on these results, American Forests recommends that WA DNR cautiously proceeds with reforestation carbon project development in higher-productivity areas of Eastern Washington. If WA DNR chooses to pursue reforestation carbon project development, we recommend that WA DNR conducts a competitive request for proposal (RFP) process for a project development partner.

As of June 2025, we believe that WA DNR land management constraints align best with Afforestation, Reforestation, and Revegetation (ARR) carbon crediting methodologies created by the registries Gold Standard, ACR, and Isometric. Choosing a target registry and methodology can help guide project design and development. In the event WA DNR decides to pursue afforestation carbon project opportunities in particular, the methodology from the Gold Standard registry may be best aligned.

WA DNR is one of several state agencies to consider carbon project development on state lands across the U.S. While early projects faced hurdles to selling credits, state agencies like those in Colorado and Hawai'i are increasingly, and successfully, developing reforestation carbon projects as well.



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Contents

Abstract.....	2
I. Background and context.....	5
II. Overall recommendations for WA DNR	6
III. Carbon credit principles.....	10
IV. Types of forest carbon projects	13
V. Carbon credit ecosystem & key players	16
VI. Reforestation carbon project methodologies	23
VII. Carbon project development cycle.....	27
VIII. Trends in carbon markets	29
IX. Precedence of carbon projects on state lands	37
X. Risks, benefits, and other considerations for carbon projects on state lands	39
XI. Decision support tools.....	40
XII. Findings from preliminary carbon feasibility assessments of two fire scars	50
XIII. Ecosystem services markets beyond carbon	52
XIV. Case studies of forest carbon projects on state lands	52
A. Michigan.....	52
B. Oregon	53
C. Colorado.....	54
D. Hawaii.....	55
E. California.....	55
XV. Conclusion.....	57
XVI. Literature Cited.....	58



I. Background and context

Healthy working lands and forests are a critical part of Washington State’s climate mitigation strategy. In particular, the Washington State Climate Commitment Act of 2021 (Commissioner’s Order 202202) promotes the maintenance and enhancement of the State’s ability to sequester carbon through working lands and forests, with the production of forest products a key component of the state’s strategy for enhancing carbon sequestration.¹

The Washington Department of Natural Resources (WA DNR) manages over five million acres across Washington State, including 2.4 million acres of forested land. Among other objectives, WA DNR is legally required to manage trust lands to generate revenues for Washington public services, with timber harvest the largest contributor to WA DNR revenues.²

To ensure continued timber revenues, lands must be reforested after harvest, and considered after fire, or other disturbances. Washington State has been experiencing increased fire extent and severity, with the largest fire years on record taking place in the past decade.³ As a result, there is a growing, unmet post-fire reforestation need in Washington due to increased high-severity burn acreage, limited reforestation budget, and high costs for salvage and site prep prior to planting.

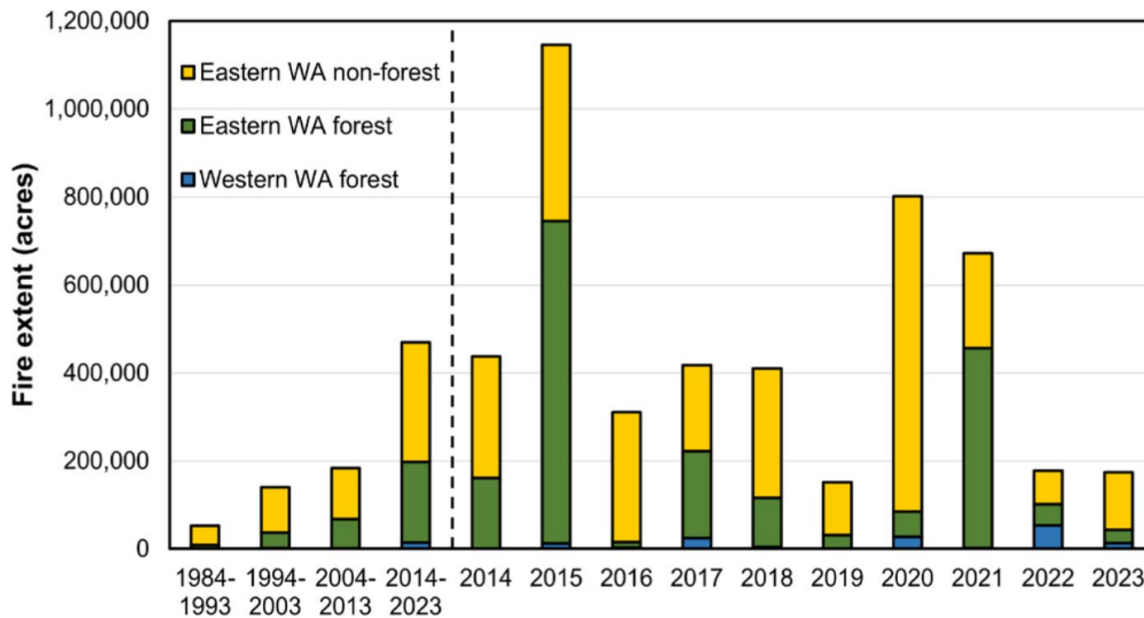


Figure 1: Total fire extent (acres) across Washington State from 1984 to 2023 by decadal average and individual year (2014-2023) as compiled by WA DNR.

¹ Revised Code of Washington § 70A.45.005 (2024). <https://app.leg.wa.gov/RCW/default.aspx?cite=70A.45.005>.

² Washington State Department of Natural Resources. (2024). *2023 Annual Report*. https://www.dnr.wa.gov/publications/em_annual_report_2023.pdf.

³ Washington State Department of Natural Resources. (2024). *Wildfire Season 2023 - Work of Wildfire Assessment*. https://www.dnr.wa.gov/sites/default/files/publications/rp_workofwildfire_0624.pdf.



Reforestation need is most acute in eastern Washington (east of the Cascade Mountains Crest) after recent fires. Precipitation and forest productivity are lower here, and the financial returns from replanting burned areas for timber are not always sufficient to compensate for site preparation and planting costs. As a result, some burned areas remain unplanted and with limited natural regeneration even decades after fire.

WA DNR is now considering developing reforestation carbon projects on WA DNR-managed lands, either directly or through partnerships with carbon project developers. Carbon credit revenues have the potential to both generate state trust revenue and help pay for reforestation projects that may not otherwise get prioritized, such as on fire scars in eastern Washington—and ultimately help contribute to meeting state climate objectives.

II. Overall recommendations for WA DNR

a. Geospatial analysis identifying WA-DNR lands that meet core carbon eligibility criteria

Our analysis identified ~16,600 acres of reforestation need and ~20,600 acres of afforestation opportunity across Washington State Trust Lands. Afforestation refers to replanting trees on lands that were forests within the past century but have been converted to other land uses, while reforestation refers to replanting trees on severely burned or otherwise degraded lands that were recently standing forests (i.e. within the past decade). The overwhelming majority of these acres (98%) were in Eastern Washington, defined as east of the Cascade Mountains crest. Seed Transfer Zones 600, 611, and 613 were among the top five seed zones for both greatest afforestation opportunity and greatest reforestation need and had the greatest overall tree-planting opportunity. For more information on this analysis and its results, see section XI-d or Appendix A.

b. Project design and structure

If WA DNR decides to develop a carbon project on WA DNR-managed lands, we recommend focusing on burned areas in Eastern Washington with relatively moderate to high precipitation and productivity, such that the sites would be able to support Douglas fir and other species, rather than solely ponderosa pine. This would improve the carbon sequestration rate of a project, and therefore the likelihood that it would be financially feasible and likely for carbon revenues to cover planting and other reforestation costs.

As of June 2025, we recommend that WA DNR lease or otherwise create an easement to effectively lease WA DNR-managed lands to a third-party carbon project development partner. This would likely result in one of two contract structures. For information on carbon project developers, see section V-a, and section VII for context on the project development cycle and a developer's typical responsibilities in that process.



The first option, akin to the partnership structure between Land Life and the Colorado State Land Board for their reforestation carbon project, would be more similar to any other WA DNR lease agreement, whereby WA DNR receives lease proceeds (and repayment of planting and management costs from the developer's carbon revenues or the developer paying for replanting costs) in exchange for the developer's right to develop a reforestation project and receive the bulk of revenue from carbon credit sales. The second structure, which is similar to the agreement between Michigan DNR and Anew for Michigan's carbon project, would not include any lease payments, and would entail that all carbon credit revenues are shared. In this structure, the developer takes a portion of revenues to account for their share of effort (typically 20-60% of net revenues), and WA DNR would be entitled to the rest of the shares to cover planting and other costs. For more information on forest carbon projects in other U.S. states, see section IV; section XIV contains more detailed case studies for each state.

In the case that an easement structure is more advantageous than a traditional lease arrangement with a third-party project developer, easement creation is not expected to be detrimental to carbon project development. In fact, it is often looked upon favorably by registries, methodologies, and carbon credit buyers because of its added assurance of consistent, and often protected, land use. For example, Climate Action Reserve's Forest Protocol says "Qualified Conservation Easements or Qualified Deed Restrictions may be voluntarily employed with any project type. Projects that choose to employ Qualified Conservation Easements or Qualified Deed Restrictions have reduced obligations to the Reserve's CRT Buffer Pool."⁴

c. *Methodology selection*

As of June 2025 and based on the versions of carbon methodologies currently publicly released, we anticipate that Afforestation, Reforestation, and Revegetation (ARR) reforestation methodologies released by the registries ACR, Gold Standard, and Isometric will be best suited to WA DNR's land management constraints (including a maximum project commitment of 99 years due to lease term limits, and the ability to remove standing dead wood and other fuels as part of site preparation). These registries are approved as compliant with the ICVCM's Core Carbon Principles, and are also pre-approved for project submission to prominent buyer coalitions, including Symbiosis Coalition and Watershed. For more information on registries, see section V-b; for context on specific ARR methodologies and their tradeoffs, see section VI.

All three of these registries' ARR methodologies are ex-post, meaning that they only issue carbon credits after an independent verifier determines that a specific quantity of carbon storage has occurred after planting. We do not recommend the use of ex-ante methodologies such as CAR's Climate Forward reforestation protocol at this time due to

⁴ Climate Action Reserve. (2023). *Forest Protocol v 5.1*. https://climateactionreserve.org/wp-content/uploads/2023/07/Final_Forest_Protocol_V5.1_7.14.2023.pdf.



strong buyer preference for ex-post credits; ex-ante methodologies are currently not allowed to be used for offsetting purposes and are considered higher-risk than ex-post methodologies. Please see section VI-a for more information.

d. Project developer criteria and responsibilities

We recommend that WA DNR partner with a credible carbon project developer to ensure successful navigation of the project development process, and successful carbon credit sales.

Active afforestation and reforestation carbon project developers in the US most relevant for WA DNR reforestation projects include [Anew Climate](#), [Boreal Carbon Corporation](#), [Climate Impact Partners](#), [Land Life](#), and [The Climate Trust](#). For afforestation projects in particular, [Chestnut Carbon](#), and [GreenTrees](#) may also be relevant.

We recommend using a comprehensive set of criteria as part of a competitive Request for Proposals (RFP) process to choose a qualified, high-integrity carbon project development partner. These criteria can include:

a. Project development experience:

- a. Experience successfully developing reforestation carbon projects in the U.S.
- b. Track record of developing multiple carbon crediting projects that have received ratings from multiple carbon rating agencies of B+ or better
- c. Experience working with municipalities, state agencies, federal agencies, or other government entities, either for carbon credit project development or through other partnerships

b. Carbon credit sales experience:

- a. Track record of successfully selling carbon credits to large premium carbon buyers, particularly through prepurchase and other offtake mechanisms
- b. Familiarity with and experience in successfully applying to and selling carbon credits to carbon buyer coalition Requests for Proposals (RFPs), such as Symbiosis Coalition

c. Partnership structure:

- a. All WA DNR reforestation carbon project costs (site prep, planting labor, seedlings, etc.) are covered by the carbon revenues from the project ⁵
- b. Ideally WA DNR is able to generate net revenues for the state from the project beyond covering costs

⁵ Some project sites, such as those with low site productivity, may not generate enough carbon revenue to offset all planting and other reforestation costs. In those cases, we recommend that WA DNR either reach an agreement with a developer to partially subsidize the cost of reforesting these sites through WA DNR budgets, or consider non-carbon ecosystem services markets, such as those for watershed health, to pay for project activities instead. If the subsidy constitutes the majority of all project activity costs, it may raise questions of additionality during the carbon project registration process. For more information on non-carbon ecosystem services markets, see section XIII.



In terms of division of roles and responsibilities over the course of a carbon project’s development, we recommend that WA DNR be responsible for the steps that are most aligned with existing strengths and capabilities across the organization (see Figure 2 below). These steps include initial site identification; project design (in coordination with a project developer); financing of the planting, site prep, and other up-front costs; and implementation of the planting and other field-based project activities. After a project is registered and begins to issue credits, WA DNR would be responsible for monitoring the site, and should allow access to independent VVBs to verify carbon storage by trees as they grow. WA DNR will also be responsible for forest management and eventual monitoring of the project after the full crediting period concludes, to ensure the project does not completely re-burn or otherwise experience a reversal.



Figure 2: Illustrative flowchart showing key steps in carbon project design. The steps best suited for WA DNR implementation are those denoted in blue.

e. *Project development timelines*

A landowner should expect that a reforestation carbon project will take between 1-6 years to design, establish a baseline, register, implement reforestation activities for, and get validated. For all ex-post methodologies, carbon credits are issued after verification (to ensure that plantings have survived and are growing and sequestering a meaningful amount of carbon, i.e. more than 100 tons of CO₂-equivalent). The resulting carbon credits can be pre-sold to large buyers before they are issued, or sold in smaller increments after they are issued, but in both cases the majority of payments and revenues will correspond to the timing of actual carbon sequestration by the planted trees. For native conifer species like Douglas fir and ponderosa pine, this will take several decades (see Figure 3). As a result, WA DNR should expect that it would not receive enough carbon revenues to offset planting costs for at least 10-20 years after planting.

Exceptions in which WA DNR could be repaid earlier can include agreements with project developers where the developer pays for all reforestation costs up-front, and agreements with large carbon buyers for long-term purchases (i.e. bulk purchases for all credits issued over 10-15 years) where the buyer agrees to pay for reforestation costs as a pre-payment much earlier than the carbon credits themselves are issued.

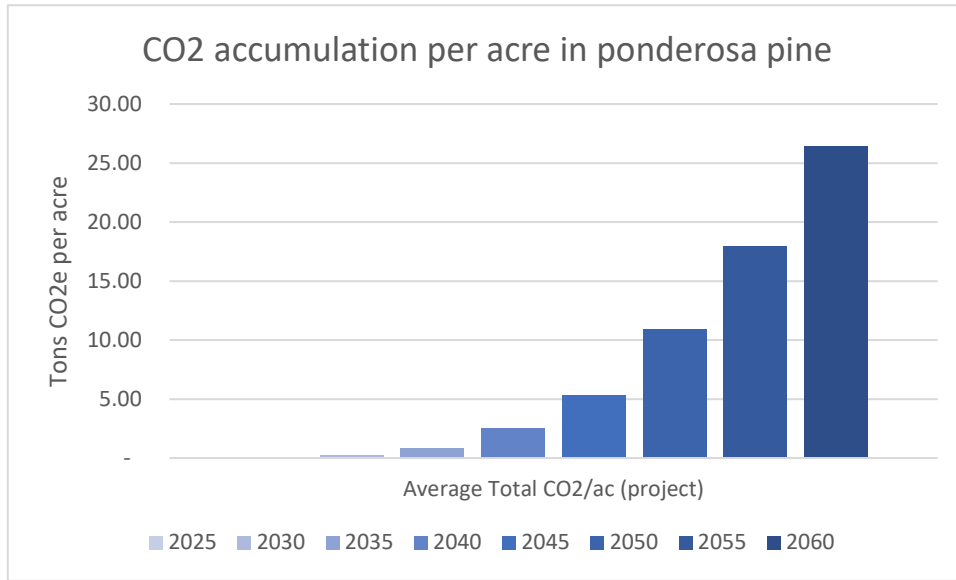


Figure 3: Expected CO2 accumulation per acre over time for the first 35 years after planting, assuming planting of 200 trees per acre of solely ponderosa pine, based on Isometric methodology. Source: American Forests preliminary analysis.

f. Setting up a project for success

We recommend that WA DNR and its developer partner engage with potential buyers, buyer coalitions, and credit rating agencies at the stage of project design if possible (prior to validation but after completion of a project design document (PDD)). For more information on the project development process, see section VII.

g. Full-cycle project development by WA DNR

If clarity is gained on WA DNR’s statutory ability to develop and sell carbon credits from project activities on the land areas it manages, the most important skillsets to develop within WA DNR will be sales expertise and cultivation of relevant relationships with large corporate buyers, buyer coalitions, and carbon brokers. For more information on buyers and other stakeholders, see sections V and VIII.

III. Carbon credit principles

Carbon credits evolved as a way to pay for greenhouse gas pollution, as an alternative and sometimes complementary mechanism to carbon taxes. Carbon taxes and credits can achieve the same outcome: by putting a price on carbon emissions, they make polluting more expensive and therefore align incentives to reduce emissions. As of 2024, carbon taxes and government-regulated carbon emissions trading schemes existed in over 40 countries. These cover ~24% of global emissions by area, but only ~1% in absolute emissions because they typically include only the largest companies and a small subset of emitting sectors and sources in each country. In addition, high regulated carbon prices are politically challenging to pass, and as a result, most



carbon taxes and regulated carbon emissions trading schemes are priced too low to change behavior and significantly reduce emissions.⁶

a. *Compliance vs. voluntary carbon credit markets*

Compliance markets for carbon typically operate through a “cap and trade system” of pollution allowances, in which large companies in certain industries must not emit greenhouse gases above a certain amount each year. If they do, they can buy allowances or carbon credits for emissions up to a small proportion above the capped amount. Allowances are sold by polluters that did not emit the full amount they had been allowed, while eligible carbon credits are those that were certified as suitable for that compliance market, and can only be from certain registries. In the US, the main compliance markets are those managed by the California Air Resources Board (CARB), Washington Dept. of Ecology, and Regional Greenhouse Gas Initiative (RGGI) in the Northeast.

In addition to compliance (regulated & mandatory) carbon credit markets, there are also voluntary carbon markets. Voluntary carbon markets arose to augment and complement the coverage of compliance markets. In both compliance and voluntary markets, carbon credits represent monetary payment in exchange for measurable climate outcomes. More specifically, carbon credits enable Stakeholder 1 to pay Stakeholder 2 to do an action that is independently verified to avoid, reduce, or remove the equivalent of one ton of CO₂. Carbon credits are meant to pay for projects with climate impacts that would not otherwise occur.

In voluntary carbon markets, buyers of carbon credits are typically either companies or individuals (and occasionally sovereign governments). Credits are issued by an independent registry after third-party project review, and can be traded and re-sold until they are “retired” by the registry and counted toward an entity’s emissions, at which point the credits cannot be resold or reused. In many cases, the same carbon crediting methodologies are used for compliance and voluntary carbon credits (such as those listed on the CARB system.)

b. *Principles for high-quality carbon projects*

All high-quality carbon crediting projects abide by a set of basic common principles. They help ensure that a project creates the positive climate impacts that it claims to generate, that there are no unintended consequences, and that the reputational risk from both selling and buying the project’s credits is low.

These principles are codified in globally agreed-to principles on carbon credit integrity, including the [Oxford Offsetting Principles](#) established by a consortium based at Oxford University (also called the Oxford Principles for Net Zero Aligned Carbon Offsetting), and the [Core Carbon Principles](#) outlined by the Integrity Council for the Voluntary Carbon Market.

- **Additionality** – the project achieves emissions reductions that would not have occurred in the absence of the project

⁶ World Bank. (2024). Executive Summary: State and Trends of Carbon Pricing 2024. <https://openknowledge.worldbank.org/server/api/core/bitstreams/d14ff4b1-823f-4d70-927c-456449772089/content>.



- **Leakage** – making sure the project does not result in unintended increases in emissions outside of the project area due to reduced market supply, such as land being cleared for agriculture outside the project boundary if productive agricultural areas are reforested as a result of the carbon project
- **Durability** – the project maintains emissions reductions for a sufficient amount of time to be meaningful on human time scales (i.e. 100 years or more); geological storage often aims for 1,000 years of storage to have impact on planetary timescales
- **Permanence** – the project mitigates against the risk of total destruction (“project reversal”) of the originally-intended climate impact (such as due to wildfire). Projects (or the registries they are listed on) typically need to set aside a buffer pool of credits in case of disaster, to fill in for those projects that fail
- **Independent verification** – credits are issued by a 3rd party and the project is monitored in a transparent, robust way
- **Benefit sharing** – sharing the economic benefits (revenues) from a carbon credit project with landowners, Tribal nations, and other relevant beneficiaries
- **Co-benefits** – physical benefits from a carbon crediting project [additional to carbon], such as increased biodiversity, improved water quality and retention, cleaner air, improved resilience to extreme weather; as well as respect for, inclusion in decision-making, and economic benefits shared with indigenous peoples and other local communities; and improvement of social outcomes and cultural values (such as from project-related employment, or greater access to improved historic hunting and fishing habitat)

c. *Carbon removal vs. reduction vs. avoidance credits*

There are three types of climate impacts stemming from carbon projects: emissions avoidance, reduction, and removal.

- a. **Emissions avoidance** projects fund prevention of a greenhouse gas-emitting activity as compared to projected scenarios, such as by paying to prevent deforestation or paying to prevent megafires.
- b. **Emissions reduction** projects fund activities that decrease the emissions of greenhouse gases compared to a baseline year, such as from combusting methane generated by landfills or destroying high-potency refrigerants.
- c. **Carbon removal** projects physically remove carbon dioxide from the atmosphere and lock it away for periods ranging from decades to millennia, such as through reforestation or direct air capture and storage.

One of the persistent criticisms of carbon crediting projects over the past 20 years has been that it is often difficult to know if the impact was “real” and that the counterfactual is credible. The first registered carbon crediting projects were avoidance and reduction projects, and these have made up the vast majority of all carbon credits sold by volume (see section VIII). Avoidance projects have faced the greatest media and scientific scrutiny due to a frequent lack of



additionality⁷ (e.g., REDD+ projects meant to stop deforestation that experienced similar rates of deforestation as non-enrolled surrounding areas), leakage concerns (e.g., increased harvest outside project boundaries to compensate for reduced harvest within the project area), reversals⁸ (e.g., wildfires after reforestation or forest protection), and exploitative practices, particularly with indigenous communities⁹ (such as with projects in the Brazilian Amazon,^{10, 11} Kenya,¹² and Cambodia¹³).

As a result of this scrutiny by the scientific community and the media, carbon removal projects have become favored by many corporate buyers to reduce their reputation risk. Although all three approaches to emissions reductions can yield high-quality projects and are necessary for planetary-scale climate mitigation, carbon removal projects are now considered the “gold standard” because they can most clearly demonstrate additionality, in that the carbon sequestration typically would not have happened otherwise.

IV. Types of forest carbon projects

There are five types of carbon projects directly relating to forest management. The two most relevant to WA DNR (afforestation and reforestation) are often combined into a joint project type for the purposes of carbon accounting methodologies.

a. Afforestation

Afforestation refers to planting trees on land that was not forested within the past 10 years, but which did historically support forests (i.e. farmland, rangeland, or mineland). Peatlands, bogs, and other carbon-rich, saturated soils typically do not qualify for afforestation projects. Afforestation is well-established as a carbon credit generation method both within the US and

⁷ Greenfield, P. (2023, January 18). Revealed: more than 90% of rainforest carbon offsets by biggest certifier are worthless, analysis shows. *The Guardian*. <https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe>.

⁸ Webster, S. (2024, August 12). Carbon credits are literally going up in smoke as wildfires threaten California's forest offset projects and buffer pool. *Fortune*. <https://fortune.com/2024/08/12/carbon-credits-california-wildfires-park-fire-forest-offset-projects-buffer-pool/>.

⁹ Redvers, N., Chan, J., Odochao, S., Pratt, V., Sim, J., Gougsa, S., Kobei, D. M., & Willetts, L. (2025, May). Carbon markets: A new form of colonialism for Indigenous Peoples? *Lancet Planetary Health*, 9(5), e421–e430. [https://doi.org/10.1016/S2542-5196\(25\)00086-5](https://doi.org/10.1016/S2542-5196(25)00086-5).

¹⁰ McCoy, T., J. Ledur, and M. Dias. (2024, July 24). How ‘carbon cowboys’ are cashing in on protected Amazon forest. *Washington Post*. <https://www.washingtonpost.com/world/interactive/2024/brazil-amazon-carbon-credit-offsets/>.

¹¹ Bispo, F. (2023, November 14). Shell affiliate accused of violating Indigenous rights in carbon credit contracts. *Mongabay*. <https://news.mongabay.com/2023/11/shell-affiliate-accused-of-violating-indigenous-rights-in-carbon-credit-contracts/>.

¹² Kimeu, C. (2025, May 13). Netflix and Meta's Carbon Credits Snared in Dispute With Maasai Herders. *Wall Street Journal*. https://www.wsj.com/us-news/climate-environment/netflix-and-metas-carbon-credits-snared-in-dispute-with-masai-herders-4f01a59f?gaa_at=eafs&gaa_n=ASWzDAi79YQVBov0PUY99sdcOgUEInVaN8JSFMgGGyGKGEsemqhDilQfJO7cWlB7g%3D%3D&gaa_ts=68548725&gaa_sig=2L-BTKHGf14aOHme0PiBSVImZfa0DUkrsu-d30_XpwpPbubaWeyDwLxCKYG1hWHQNwezC51Imipp2pS5YHUpQw%3D%3D.

¹³ Téllez Chávez, L. (2024, February 28.) Carbon Offsetting's Casualties: Violations of Chong Indigenous People's Rights in Cambodia's Southern Cardamom REDD+ Project. *Human Rights Watch*. <https://www.hrw.org/report/2024/02/29/carbon-offsettings-casualties/violations-chong-indigenous-peoples-rights>.



internationally, though it only represents ~3-5% of all carbon credits issued from registered forest carbon projects in the US currently.¹⁴ It also poses a few challenges, including the replacement and reduction of productive farmland with forest, and occasional afforestation with non-native species (such as eucalyptus in Latin America.)

b. Reforestation

Reforestation refers to planting native trees where there had previously been forest within the last ten years. Like afforestation, it is well-established and well-understood by carbon credit buyers. Reforestation projects account for ~5% of all US forest carbon credits.¹⁵ Reforestation typically results in longer payback periods and lower returns than low-input project activities like IFM, but has other benefits such as water quantity and quality improvements, and habitat restoration for biodiversity.

c. Improved forest management (IFM)

Improved Forest Management (IFM) is the most common forest carbon project type in the US (~86-88% of all carbon credits issued from forest-related projects).¹⁶ Unlike afforestation or reforestation, this project type capitalizes on an existing forest's capacity to store and sequester additional carbon dioxide. This project type uses carbon credit revenue to pay a landowner to delay their timber harvest or otherwise extend rotation lengths and therefore increase the carbon sequestered by the trees before they are cut down. IFM's popularity with landowners and carbon credit project developers rests largely on its – comparatively – minimal startup costs and its ability to yield avoided emissions credits and carbon removal credits on much shorter timelines than afforestation or reforestation project types. This carbon crediting method is well-established, though many projects are considered to be of lower-quality by buyers because it can be difficult to prove additionality and permanence. For example, it is hard to prove a harvest would have happened in any given year, and therefore that the carbon credits changed any logging behavior. Further, the climatic benefit of delaying harvests is far from certain given tradeoffs associated with decreased carbon storage in harvested wood products, substitution effects, and global market leakage risks.

d. Reduced emissions from deforestation and forest degradation (REDD+)

Avoided conversion projects are less common in the US but are the most common forest carbon projects globally, and were historically one of the largest categories of all carbon projects globally aside from renewable energy carbon credits. These are also known as “reduced emissions from deforestation and forest degradation” or REDD+ projects; they are meant to prevent forests at risk of conversion from being deforested by using carbon credit revenues to pay communities to keep forests intact. These projects must have a demonstrably high likelihood of loss, and like IFM projects, often have difficulty demonstrating their additionality

¹⁴ Kreye, M. et al. (2023, August 24). How a Forest Carbon Offset is Made and Sold. *Forest Owner Carbon and Climate Education (FOCCE), PennState Extension*. <https://extension.psu.edu/how-a-forest-carbon-offset-is-made-and-sold>.

¹⁵ Kreye, M. et al. (2023, August 24). How a Forest Carbon Offset is Made and Sold. *Forest Owner Carbon and Climate Education (FOCCE), PennState Extension*. <https://extension.psu.edu/how-a-forest-carbon-offset-is-made-and-sold>.

¹⁶ Reis, G. and S. Evans. (2025, April 1). Resilient growth in US forest carbon markets. *Fastmarkets*. <https://www.fastmarkets.com/insights/resilient-growth-in-us-forest-carbon-markets/>.



because it can be hard to prove the counterfactual, that a lack of deforestation was due to carbon payments. More importantly, many REDD+ projects have faced controversy due to potential coercion and insufficient compensation of forest-dependent communities, including indigenous groups, as well as ineffective projects that did not ultimately protect forests from deforestation.¹⁷ In the best cases, REDD+ can help drive alternative economic activities to reduce deforestation pressures (such as by paying for honey or cocoa production, or ranger patrols and ecotourism). These represent ~4% of forest carbon credits in the US but >50% in the Global South.¹⁸

e. *Reduced emissions from megafires*

Reduced emissions from megafires projects are meant to incentivize fire risk reduction through fuel treatments. This type of carbon project assumes that fuel reduction and forest health treatments such as prescribed fire and silvicultural treatments that reduce fuels and increase forest vigor would then lead to a reduced risk of large, catastrophic wildfire. The carbon credits would then be issued for the difference in emissions between the theoretical future megafire risk in the absence of forest health interventions, and the estimated remaining fire risk after intervention. As of June 2025, only one registry (Climate Action Reserve or CAR) has publicly released a methodology for estimating and issuing carbon credits related to reduced emissions from megafires.¹⁹ These would be ex-ante credits issued through CAR's Climate Forward protocol. While no projects have been registered as of May 2025, several projects are in development by groups such as [Blue Forest](#). Importantly, with this project type it is difficult to prove the counterfactual that a fire would have happened in a given area without the intervention. In addition, current fire risks aren't accounted for in historical data so modeled crediting yields have been lower than desired.

In addition to these explicitly tree-focused project categories, several other types of carbon crediting projects may be complementary to reforestation carbon, and worth considering, including: fungal inoculation, biochar, and biomass burial.

f. *Fungal inoculation*

This carbon project approach uses naturally occurring microbial strains to inoculate seedlings and thereby enable greater tree growth. The difference in biomass between inoculated and uninoculated trees is then used as the basis for issuing carbon credits under a modified IFM methodology. [Funga](#) is the main carbon project developer using fungal inoculation techniques; it has been developing carbon projects in the Southeastern US using loblolly pine and is considering expansion to the western US.

g. *Biochar and bio-oils*

¹⁷ McCoy, T., Ledur, J., & Dias, M. (2024, July 24). *How 'carbon cowboys' are cashing in on protected Amazon forest*. *The Washington Post*. <https://www.washingtonpost.com/world/interactive/2024/brazil-amazon-carbon-credit-offsets/>.

¹⁸ Kreye, M. et al. (2023, August 24). *How a Forest Carbon Offset is Made and Sold*. *Forest Owner Carbon and Climate Education (FOCCE), PennState Extension*. <https://extension.psu.edu/how-a-forest-carbon-offset-is-made-and-sold>.

¹⁹ Climate Action Reserve. (2023, March 7). *Reduced Emissions from Megafires (REM) Forecast Methodology (Version 1.0) [PDF]*. *Climate Forward*. <https://climateforward.org/wp-content/uploads/2023/03/Reduced-Emissions-from-Megafires-Forecast-Methodology-v1.0.pdf>.



Biochar converts wood and other kinds of biomass into carbon-dense, porous char through pyrolysis (high temperature, low-oxygen burning). The resulting biochar can then be used for various applications, including application to agricultural soils, use in water filtration, and as an input to steel manufacturing. Biochar has been used for millennia to improve soil fertility (i.e. “terra preta” in the Amazon) and pyrolysis technologies to create biochar are relatively mature, apart from mobile (offroad) pyrolysis units. Biochar carbon credits are also relatively mature as a project type. [Puro Earth](#) is the dominant registry for biochar carbon projects, though other registries also offer biochar methodologies. Importantly, although biochar carbon credits often garner prices of \$100 per ton or more and the technology is well-developed, demand for biochar itself is still low.

Bio-oil uses a similar process of pyrolyzing waste biomass; however, this is done at lower temperatures to create a liquid similar to gasoline. The bio-oil is typically injected underground into EPA-permitted wells, such as spent oil and gas wells. [Charm Industrial](#) is the largest bio-oil project developer, and uses waste wood from British Columbia for its bio-oil production in the US (in addition to corn stover and other biomass inputs.)

h. Biomass burial

Biomass burial sequesters waste woody biomass (such as unmerchantable wood in a fire scar) that would have otherwise been pile-burned or landfilled (where it would typically emit methane). The wood is then either buried underground in lined pits or unlined pits with high clay content, or otherwise buried in an encasing structure above ground, with the goal of preventing decomposition. Biomass burial is nascent as a carbon crediting approach, and not yet fully proven scientifically.

[Mast Reforestation](#), [Carbon Lockdown](#), and [Graphyte](#) are the main project developers of biomass burial projects. Mast Reforestation and Carbon Lockdown bury large logs of wood waste underground. Graphyte has a similar approach of taking wood waste, drying it, and shaping the residues into polymer-sealed bricks that then get buried in polyethylene-lined pits similar to landfills. Still others are experimenting with salting wood residues prior to burial.

V. Carbon credit ecosystem & key players

When a landowner enrolls their land in a carbon project, they enter a complex ecosystem of carbon market participants including project developers, registries, credit-buyers, rating-agencies, and more. Each of the types of stakeholders covered in this chapter have an essential role to play in the modern carbon market. However, aside from landowners themselves, project developers, registries, and buyers are the most important decision makers in the carbon credit ecosystem.

a. Project developers

Project developers are typically responsible for designing, financing, and registering projects, and selling the resulting carbon credits. As of June 2025, active afforestation and reforestation carbon project developers in the U.S. include [Anew Climate](#), [Boreal Carbon Corporation](#)



(formerly Finite Carbon), [Bosland Growth](#), [Chestnut Carbon](#), [Climate Impact Partners](#), [GreenTrees](#) (owned by ACRE Investment Management), [Land Life](#), [Living Carbon](#), [National Indian Carbon Coalition](#), and [The Climate Trust](#). Note that this is a comprehensive but an exhaustive list of project developers, and that inclusion here does not constitute an endorsement by American Forests.

A number of other forestry-oriented project developers exclusively develop IFM projects (IFM projects require far less up-front investment, are easier to develop, have shorter timelines to financial breakeven points, and are thus considered more lucrative), such as [NativState](#) and [Spatial Informatics Group](#) and its Greenline Climate subsidiary. American Forest Foundation's [Family Forest Carbon Program](#) has historically developed IFM projects and is beginning to support private landowners in the Southeastern U.S. on reforestation projects as well. [TerraCarbon](#) provides some of the services that a carbon project developer would provide (such as project feasibility testing, project design and validation, and support with monitoring and verification), but does not finance projects, register projects, or sell carbon credits.²⁰

As of June 2025, Living Carbon and Bosland Growth are predominantly focused on mineland restoration projects; Living Carbon specializes in ecosystem restoration and remediation with genetically modified trees. Chestnut Carbon and GreenTrees are predominantly focused on afforestation on degraded agricultural lands, particularly in the Southeastern U.S. Land Life started as a restoration project developer and is beginning to develop expertise in carbon crediting projects, with most of its previous projects in Europe and Australia and its first U.S. project in Colorado.

Boreal Carbon Corporation is a generalist forest carbon project developer. Anew and Climate Impact Partners are generalist carbon credit project developers that develop various kinds of forest and non-forest carbon projects.

National Indian Carbon Coalition and The Climate Trust are nonprofit project developers, and National Indian Carbon Coalition works exclusively with Tribal Nations.

b. Registries

At the simplest level, registries are entities that create and retire carbon credits. Registries are responsible for writing methodologies (also called protocols) for how to measure carbon emissions and savings from a certain type of activity, such as reforestation or biochar production. Based on these methodologies, registries issue credits to a project that complies with a given methodology. Registries assign credits all have a serial number and must make the credits visible on a public ledger. The registries then retire those credits after they are purchased and counted against a buyer's emissions footprint, to make sure they cannot be used multiple times and double-counted.

There are at least six major carbon registries, each with their own reputations, processes, and methodologies. Afforestation and reforestation methodologies from some - but not yet all - of the



registries listed below have been approved with a Core Carbon Principles (CCP) label by the Integrity Council for the Voluntary Carbon Market, meaning that the methodologies themselves are considered to be high-integrity.

The most relevant registries for WA DNR afforestation and reforestation projects are:

- **ACR:** ACR is the oldest greenhouse gas registry (founded in 1996) and was initially called “Ambitious Climate Results” before its rebranding in 2008 to “American Carbon Registry” and now simply ACR. It is managed by Winrock International, a non-profit predominantly focused on international development and had been funded largely by the U.S. Agency for International Development (USAID) prior to the effective dissolution of USAID and its funding in 2025. It is one of the few carbon credit registries approved for CARB’s compliance market. As of the time of writing, ACR’s current ARR methodology is [Afforestation & Reforestation of Degraded Land v 1.2.](#)
- **Climate Action Reserve (CAR):** CAR was initially established in 2001 as the California Climate Action Registry. Its listed projects have expanded beyond California, though are still predominantly in North America. Like ACR, it is one of the few registries whose projects are eligible for offsetting through CARB. CAR has a variety of methodologies and project types; in addition to a standard afforestation and reforestation methodology (included within its [Forest Protocol 5.1](#)), CAR created the Climate Forward Reforestation Forecast Methodology Version 2.0, a methodology that is meant to issue credits from reforestation projects much sooner than with typical timelines. For more information about this Climate Forward methodology, see section V-a.
- **Gold Standard:** The Gold Standard registry was founded in 2003 by WWF and other environmental non-profits, and has maintained a strong reputation for quality. It has a focus on the Sustainable Development Goals (SDGs) and project co-benefits. It has registered projects from 100+ countries and includes a range of project types. Its afforestation & reforestation methodology is [Methodology For Afforestation/Reforestation \(A/R\) v2.1](#); the next version of it is expected to be released in October 2025.
- **Verra:** Verra, previously called the Verified Carbon Standard, was founded in 2007 and is a well-established, non-profit registry. Verra is the world’s largest registry in terms of the number of projects listed, and registers diverse project types, with a focus on nature-based carbon projects. Verra was historically the largest registry for REDD+ projects, and both the REDD+ projects and Verra were subject to intense media scrutiny²¹ as a result of the projects’ poor quality and ratings. Beyond the REDD+ methodologies, Verra generally has rigorous carbon crediting methodologies, but is known for very slow project registration timelines. The current afforestation & reforestation methodology is [VM0047 Afforestation, Reforestation, and Revegetation, v1.1.](#)

²¹ Greenfield, P. (2023, January 18). Revealed: more than 90% of rainforest carbon offsets by biggest certifier are worthless, analysis shows. *The Guardian*. <https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe>.



- **Isometric:** Isometric was founded in 2022 and is still the “new kid on the block” relative to the four legacy carbon registries listed above. Nonetheless, Isometric-listed projects have attracted many of the largest multi-million-dollar carbon credit purchases since their founding, and Isometric’s projects garner higher prices per ton than other registries due to multiple differentiating factors. Its relevant methodology ([Reforestation Protocol 1.0](#)) was released in 2024, and an updated version will be released in the second half of 2025.

Isometric has focused mainly on developing methodologies for carbon removal projects, thereby avoiding more controversial carbon avoidance project types (where additionality is more difficult to prove). Isometric also structures their payments differently to avoid conflicts of interest: carbon buyers pay Isometric a flat fee to conduct verification and validation, rather than the legacy system of project developers themselves choosing Validation and Verification Bodies (VVB), with registry fees often scaled to the number of credits issued. Finally, Isometric has incorporated lifecycle assessment (LCA) approaches into their methodologies to yield a more robust and realistic picture of climate outcomes for each project.

- **Plan Vivo Foundation (Plan Vivo):** Plan Vivo was founded in Scotland and first issued credits in 1997. Despite its long history, it has not yet risen to the level of prominence, scale of credit issuance, and market acceptance by corporate buyers that Verra, Gold Standard, ACR, and CAR have achieved. Plan Vivo focuses solely on nature-related projects, primarily in developing countries, and with a strong focus on community engagement and safeguards. For instance, 60% of carbon revenues from the sale of Plan Vivo credits must go back to community participants. No projects have been registered from North America to date, and ~35 projects have been registered on Plan Vivo in total as of June 2025 (compared to thousands on the four major registries). Its main reforestation methodology is contained within [PV Climate v5](#). Plan Vivo also recently created a biodiversity credit standard called [PV Nature](#).
- **Open Forest Protocol (OFP):** OFP was founded in 2021 and is still developing its project and buyer base. This registry is focused entirely on forest-related carbon projects under its [Afforestation, Reforestation, and Revegetation methodology](#), with other forestry-related methodologies being developed. OFP requires photo-based verification of planting activities and is most suitable for small landowners and projects in developing countries.
- **Ecosystem Restoration Standard (ERS):** ERS was founded in France in 2020 to focus solely on carbon credit issuance from science-based ecosystem restoration projects. Like OFP, it is still relatively nascent in being considered credible by carbon credit buyers. As of spring 2025, ERS publicly lists 17 projects in various stages of development under its [M001: Methodology for Terrestrial Forest Restoration methodology](#), with ~37 projects at initial qualification stages. No projects have been registered from North America to date.



c. *Validation and verification bodies (VVBs)*

Carbon credits are issued based on a carbon project's independently verified climate outcomes. More specifically, independent auditors are contracted by either the project owner/developer or the registry, and are called "validation and verification bodies" (VVBs).

Validation occurs *before* a carbon project is ever registered or implemented. It refers to the process of making sure that the project plans and design will meet all rules and requirements for a given registry and methodology. If a project successfully completes validation, the project proponent can submit the project for registration.

Verification occurs *after* project activities and registration have occurred. It confirms that the outcomes set out in the project plan have been achieved and quantified according to the requirements of the chosen methodology.

Similar to other kinds of auditors, VVBs must typically comply with relevant ISO standards, such as [ISO 14064-3](#) and [ISO 14065](#). Each registry typically certifies a group of "accredited" VVBs that are considered proficient in the registry's specific methodologies and project types; only these accredited VVBs can be contracted for VVB services. Examples of active VVBs as of June 2025 include [SustainCert](#), [Ecolance](#), [TUV SUD America](#) (formerly Ruby Canyon Environmental), [TUV Rheinland](#), [Aster Global](#), [S&A Carbon](#), and [SCS Global Services](#).

d. *Monitoring, reporting, and verification providers (MRV)*

Beyond project developers, registries, and VVBs, there is a further universe of newer stakeholders that developed in the wake of media scrutiny about poor-quality carbon projects with little or no positive climate impacts. These additional stakeholders make independent assessments of project progress, quality, and risk to provide carbon credit buyers with additional assurance. They include monitoring, reporting, and verification companies; carbon credit rating agencies; and carbon credit insurers.

Monitoring, Reporting, and Verification (MRV) providers help independently assess that projects continue to have the impact that projects initially intended to have at their outset. VVBs perform a very similar role to MRV providers (especially in terms of verification every few years following the initial project registration), and in some cases VVB providers also provide MRV services.

MRV is more helpful for tracking a project in near-real time, especially in between verification periods and during the post-crediting monitoring period when third-party verification no longer occurs. Forest-focused MRV providers include, but are not limited to, [Pachama](#), [Nadar](#), [Gaia AI](#), [Treefera](#), [Upstream Tech](#), and [Terra Pulse](#).

- A. **Monitoring** refers to systemic data collection to determine the performance and impact of a project over time. Traditionally, this has looked like field measurements of forest biomass; increasingly, monitoring also includes analysis of satellite imagery and LIDAR to complement or supplant in-person measurements. This use of remote sensing and other digital technologies (including artificial intelligence and machine learning) is often referred to as dMRV.



- B. **Reporting** entails compiling project data into reports detailing the methodologies used to calculate emission reductions, combined with a project's performance and impact to date, to be shared with registries, buyers, and other stakeholders (investors, project proponents, regulatory bodies, the general public, etc.)
- C. **Verification** refers to the third-party review and verification of reported project data, conducted by an independent third-party auditor (typically a VVB) to ensure that the project's claimed emission reductions are accurate and compliant with the relevant methodology. This can involve site visits, data cross-checking, and validation of methodologies.

e. *Rating agencies*

There are currently five main carbon credit rating agencies. Each of these rating agencies have their own methodologies and at times, biases, to quantify project quality and risk, but all strive to provide their own (relatively independent) views on carbon credit quality. The most important role of carbon credit rating agencies is to conduct deeper due diligence on a variety of carbon projects, and help corporate and other buyers to have confidence and trust in the projects from which they purchase carbon credits. Their ultimate goal is to help guide more funding to high-quality carbon projects, rather than merely the lowest-cost carbon projects.

The four main carbon credit rating agencies are [BeZero](#), [Sylvera](#), [Calyx Global](#), and [Renoster](#). [MSCI Carbon Project Ratings](#), a fifth rating provider and part of the broader MSCI financial data platform, is newer and not yet staffed with carbon market experts. Renoster and Sylvera have historically specialized in forest-related carbon projects and ratings based on their expertise in satellite-based analysis and monitoring. BeZero and Calyx Global rate a broader range of project types; Calyx Global is considered the most stringent and often perceives forest-related projects as lower-quality (and therefore lower-rated) than engineered carbon removal projects.

f. *Insurers*

Carbon credit insurers offer insurance coverage to carbon credit buyers, and particularly to those corporations that aim to meet specific emissions reductions targets or requirements. Buyers typically purchase a project-specific insurance policy, and the insurer independently assesses the risk that the project will experience reversal or under-delivery of carbon credits within a certain timeframe. If a policy is activated, the insurer can then compensate the buyer with a full reimbursement of carbon credit purchase costs, or with equivalent carbon credits from a different project of the same project type and quality. Carbon credit insurers include [Kita](#), [Oka](#), and [CarbonPool](#).

g. *Brokers*

Brokers are intermediaries that trade and sell unretired carbon credits between project developers, commodity traders and speculators, and corporate buyers. Brokers often charge a service fee of 5-20% on trades, and are typically part of commodity trading houses like [Trafigura](#), [Karbone](#), [ICT \(International Commodity Traders\)](#), [OTC Flow](#), [ACT Commodities](#), and [STX Group](#).

h. *Quality standard setting bodies*



As a further result of frequent media and scientific scrutiny and skepticism about carbon markets, multiple organizations sprang up to set minimum quality standards—both on the “supply side” of carbon credit projects, and the “demand side” to dictate whether and how companies could use carbon credits to claim that they reduced their emissions footprints.

The [Integrity Council for the Voluntary Carbon Market](#) (ICVCM) defines quality for all voluntary carbon crediting projects through its ten Core Carbon Principles (CCPs). The CCPs include principles on good governance (effective governance, tracking, transparency, and independent 3rd party validation and verification); emissions impact (additionality, permanence, robust quantification of reductions and removals, and no double counting); and finally, sustainable development (safeguards and sustainable development benefits, as well as contributions to the net zero transition). These ten CCPs are meant to help potential buyers of carbon credits to identify high-integrity projects and reduce their reputation risk. More broadly, the ICVCM aims to build trust among companies, investors, and governments that are considering participation in the voluntary carbon market. The ICVCM is an independent non-profit, funded by philanthropic institutions and the UK Government.



Figure 4: ICVCM's 10 Core Carbon Principles for high-integrity carbon projects.

Complementary to the ICVCM, the [Science-Based Targets Initiative](#) (SBTi) and [Voluntary Carbon Markets Integrity Initiative](#) (VCMI) both establish guidelines for companies on when to use carbon credits to avoid greenwashing and reputational risks. More specifically, both groups issue guidance to determine if and when it’s advisable to purchase carbon credits relative to investing in the decarbonization of a company’s own operations and supply chains. SBTi guidelines are sector-specific and scientifically vetted, but have often been seen as more aspirational, complex, and at times unrealistically rigorous relative to company willingness to invest in decarbonization. SBTi also historically advised against purchasing carbon credits, until changes in 2024-25. VCMI guidelines were considered slightly less rigorous, but also more



realistic and favorable to the use of carbon credits for making emissions reduction claims. Ideally, buyers of any WA DNR carbon credits would adhere to at least the VCMI standards in making emissions reduction claims (to reduce WA DNR's own reputational risks).

As of May 2025, the guidance from VCMI's [Claims Code of Conduct](#) requires that companies (1) set science-based near-term emission reduction targets, (2) publicly commit to reaching net zero emissions no later than 2050, and (3) purchase high-quality carbon credits representing emissions reductions or removals from outside their company's value chain (rather than "insetting" credits from projects within their own supply chains). This allows companies making VCMI Claims to "demonstrate their contribution to the collective global effort to reach net zero."²²

For SBTi, the draft guidance as of May 2025 (based on Corporate Net-Zero Standard Version 2) is to allow companies to only use carbon removal credits to account for emissions originating beyond their value chains (similar to VCMI) and residual emissions.²³

VI. Reforestation carbon project methodologies

Each carbon registry has its own standards and methodologies for estimating emission reductions or removals. Standards are documents that outline overarching processes and rules for all methodologies – also known as protocols – developed by a given carbon registry. The methodologies describe the carbon accounting methods by which climate benefits derived from any given project are determined. Methodologies can cover anything from methane destruction to direct air capture of carbon dioxide to emissions benefits from forestry-related programs (i.e., ARR or IFM). Registry methodologies vary considerably and are updated regularly to account for new scientific understanding and measurement tools like LiDAR. Below, we discuss key attributes of the most widely used and accepted ARR carbon methodologies.

a. *Ex-post vs. ex-ante projects*

One of the biggest challenges of reforestation carbon projects is the relatively long payback period on up-front costs from site prep, planting, validation, verification, and registration. In typical carbon projects, carbon credits are only issued after ("ex-post") the actual carbon sequestration from tree growth has occurred, and been independently verified. Given that many tree species take decades to grow and reach a high rate of carbon storage, the carbon issuance and resulting payback can take 20 years or more.

A handful of registries have attempted to solve this problem by developing methodologies for *ex-ante* carbon credit issuance. Two notable examples come from Verra and CAR. These registries attempted to improve access to financing for carbon project proponents and reduce

²² Voluntary Carbon Markets Integrity Initiative. (2025). Claims Code of Practice. <https://vcmintegrity.org/vcmi-claims-code-of-practice/>.

²³ Science Based Targets Initiative. (2025). SBTi Corporate Net-Zero Standard Version 2.0 - Initial Consultation Draft with Narrative. <https://files.sciencebasedtargets.org/production/files/Net-Zero-Standard-v2-Consultation-Draft.pdf?dm=1742292873>.



the payback period by creating an option for developers to have credits issued soon after the project implementation activities, rather than waiting many years for actual carbon sequestration. However, Verra's Projected Carbon Unit (PCU), anticipated to be available for registration in 2022, was never moved forward as an option.

CAR's ex-ante Climate Forward reforestation methodology continues to exist. It has successfully registered projects that issued ex-ante "forecast mitigation units" (FMUs), to differentiate from standard carbon credits that are issued ex-post. The Climate Forward reforestation methodology preemptively issues these FMU carbon credits after a one-time verification within 1-3 years after planting (rather than multiple verifications of planting survival and growth over time). The amount of FMUs issued is discounted relative to the total potential credit issuance from a standard (ex-post) reforestation methodology, to account for potential project reversals that will not be verified in the future.

In the US, Mast Reforestation notably developed multiple post-wildfire reforestation projects registered under the Climate Forward protocol. However, Mast and other developers have struggled to sell their projects' FMUs from the Climate Forward protocol because the Climate Forward methodology and its resulting FMUs are not recognized as credible by standard-setting bodies like ICVCM, and thus FMUs cannot be used for offsetting purposes. After only issuing FMU credits using the Climate Forward methodology for several years, Mast Reforestation decided in 2024 to leave the reforestation carbon business completely because the sales of FMUs were insufficient to cover project costs. Though it has not formally announced its exit from ARR projects, the only project listed on its website is now a [woody biomass burial project](#).

b. Dynamic vs. static baselines

In a carbon project, baselines determine what the project activity gets compared to, to determine its climate impact and the amount of carbon credits to eventually issue. There are two main kinds of baseline measurement approaches: static and dynamic. Both are currently still accepted.

Initially, all registries and methodologies used a "static" baseline, meaning that historical data and assumptions about both the project site and surrounding areas was gathered at the beginning of a project and remained unchanged throughout the project duration. That data was then used to model the assumed future outcome (such as the harvest rate or natural regeneration rate at the project site relative to the project not occurring), which might not accurately reflect the actual project situation over time. Static baselines can therefore both under- and overestimate project benefits.

In contrast, "dynamic" baselines update periodically to account for changes in policy, land use changes, and other factors. A dynamic baseline is adjusted periodically (typically annually) and continuously updates its comparison point based on real-time data, rather than remaining fixed throughout a project's duration. Dynamic baselines are considered more accurate in capturing the constantly evolving nature of land use and other factors influencing carbon sequestration. Only two registries (Verra and Isometric) currently use dynamic baselines for their reforestation methodologies, but more registries are likely to begin adopting them in the future.



c. Key differences between reforestation carbon methodologies

Registry & Protocol	Project length	Baseline approach	Planting Restrictions	Management Restrictions	Market Acceptance
Verra - VM0047 v1.1	<ul style="list-style-type: none"> Maximum crediting period of 40 years Additional monitoring period of 40 years after crediting period 	<ul style="list-style-type: none"> Dynamic baseline Allow for use of LiDAR or third-party biomass maps 	<ul style="list-style-type: none"> No planting in tidal wetland areas (others allowed with exemption) Native species only 	<ul style="list-style-type: none"> Removal of shrubs as well as dead wood during site prep penalized (deducted from carbon credit total) 	<ul style="list-style-type: none"> Approved by CCP²⁴ Accepted by Watershed and Symbiosis Coalition if with ABACUS label
CAR – U.S. Forest Protocol v5.1	<ul style="list-style-type: none"> Maximum 100-year crediting period (no minimum) Additional 100-year monitoring period after crediting period 	<ul style="list-style-type: none"> Static baseline 	<ul style="list-style-type: none"> Project sites should have <25% existing canopy cover No planting in wetland areas Must be 95% native species and composition of no single species may exceed region-specific limits defined in Assessment Area Data File 	<ul style="list-style-type: none"> Harvest and other activities permitted Age class distribution requirements Reversals over a 10-year period are permitted if demonstrably in the service of forest resilience 	<ul style="list-style-type: none"> Approved by CCP Accepted by Symbiosis Coalition and Watershed Main registry & protocol allowed by CARB
ACR – ARR v1.2	<ul style="list-style-type: none"> 40-year crediting period No monitoring period 	<ul style="list-style-type: none"> Static baseline 	<ul style="list-style-type: none"> Planting in wetlands is permitted but intentional manipulation of the water table is not. Not more than 10% of such areas may be disturbed as a result of soil preparation 95% native species 	<ul style="list-style-type: none"> Site prep is allowed and must be accounted for, but small woody biomass (i.e. leaf litter) must remain onsite 	<ul style="list-style-type: none"> Approved by CCP Accepted by Symbiosis Coalition and Watershed
Gold Standard – AR v2.1	<ul style="list-style-type: none"> Minimum 30-year crediting period No monitoring period 	<ul style="list-style-type: none"> Static baseline 	<ul style="list-style-type: none"> No planting in wetland areas 	<ul style="list-style-type: none"> Projects can include selective harvesting, rotational harvest, agroforestry, silvopasture 	<ul style="list-style-type: none"> Approved by CCP Accepted by Symbiosis Coalition and Watershed

²⁴ The Integrity Council for the Voluntary Carbon Market. (2025). Carbon Credit Program Assessment Status. <https://icvcm.org/assessment-status/#category-status>



Isometric – Reforestation v1	<ul style="list-style-type: none"> • Variable length crediting period based on estimated time to reach maturity • Minimum 40-year monitoring period 	<ul style="list-style-type: none"> • Dynamic baseline • Allow for use of LiDAR or third-party biomass maps 	<ul style="list-style-type: none"> • No planting in wetland areas • No planting in areas with high albedo effects • Minimum of 5 species from 2 genera planted, with exemptions possible • No invasive species or plantation forestry • No afforestation 	<ul style="list-style-type: none"> • Site prep, non-commercial salvage, PCT not penalized as long as accounted for in project plan • No clear-cutting during crediting or monitoring period, and ideally not after the monitoring period ends (but not enforced) 	<ul style="list-style-type: none"> • Approved by CCP • Accepted by Symbiosis Coalition and Watershed
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d. Project developer preferences

Many carbon project developers prefer to develop new projects using methodologies and registries with which they have experience and existing relationships. Verra remains the most common registry for new ARR projects globally,²⁵ and many developers will express a preference to develop projects under the four legacy registries (Verra, ACR, CAR, and Gold Standard) due to their familiarity with their methodologies.

e. Additional certifications

Additional certifications (i.e., credit labels) are akin to “extra credit” stickers; they help identify carbon projects that conform to a minimum set of standards or confer co-benefits, durability, or perform diligence beyond what is required in a given methodology. When credits are issued to projects that satisfy these requirements, labels may be applied to each credit. Increasingly, credit buyers look for these labels to identify credits from higher-quality projects. Labels can be activity-agnostic (i.e., bestowed upon entire standards and methodologies) like ICVCM’s Core Carbon Principles (CCP) label, or can be additional requirements stacked on top of an existing methodology. All of the carbon programs we consider in this review have earned the program-wide CCP label. At the time of writing, Verra is the only main registry that has introduced additional labels applicable to ARR projects that stack atop its CCP-approved VM0047 ARR methodology. Those are the [Climate, Community & Biodiversity \(CCB\) Standards](#), [Sustainable Development Verified Impact \(SD VISta\) Standard](#), and [ABACUS](#) labels.

Verra’s CCB, SD VISta, and ABACUS labels were developed to identify projects that exceed Verra’s base standard and VM0047 methodology. The CCB label requires project developers to demonstrate additional and exceptional benefits to climate, communities in the local project area, and biodiversity beyond what is laid out in the current standard. This includes ongoing consultation with local communities during project development as well as biodiversity and community impact monitoring thereafter. SD VISta, meanwhile, identifies projects that have verifiable contributions to United Nations Sustainable Development Goals. Finally, ABACUS

²⁵ Urban, N. (2025). Unlocking High-Integrity Restoration at Scale: Early Insights from Symbiosis Coalition’s First RFP. *Symbiosis Coalition*. <https://www.symbiosiscoalition.org/perspectives/unlocking-restoration-at-scale-early-insights-from-symbiosis-coalitions-first-rfp>.



labels identify projects able to conform with more rigorous measurement and reporting guidelines (e.g., annual monitoring, dynamic baselines).

Some buyer groups, notably the Symbiosis Coalition, require adherence to ABACUS principles, though they do not necessarily require the label itself. As such, projects from other registries (e.g., Isometric Registry or ACR) may meet buyer requirements without the Verra-specific ABACUS label.

VII. Carbon project development cycle

Developing a carbon crediting project for the voluntary carbon market typically takes 1-3 years from ideation to project registration, and often an additional 1-5 years for verification and credit issuance. The length of time often depends on the complexity of a project, the chosen registry and VVB, the speed of processing of that registry, and on whether a landowner is developing a forest carbon project with an experienced developer or on their own.

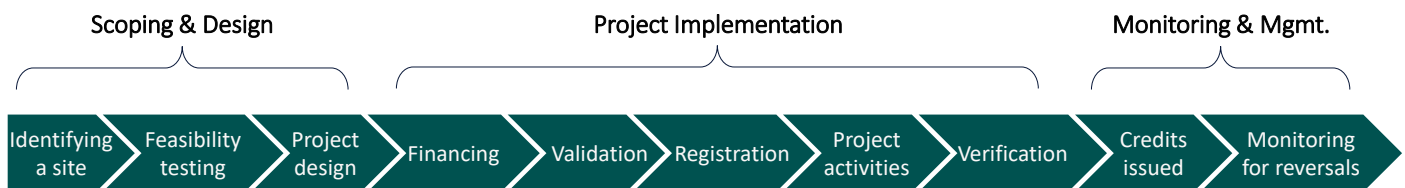


Figure 5: Flowchart of a simplified carbon project development cycle, from initial project conception through to registration, carbon credit issuance and sales, and eventual monitoring after a project’s full crediting period ends.

First, as with any other non-crediting reforestation projects, the landowner or project proponent (WA DNR) identifies one or several potential project sites and corresponding potential planting plans.

Next, the selected sites are inventoried for standing carbon and natural regeneration rates, and then tested for both carbon storage potential and financial feasibility. This feasibility testing helps determine if the sites would yield sufficiently productive forest and corresponding carbon credit yields to justify the likely effort and investment required. Feasibility testing is typically run by a project developer or other third party with experience in carbon inventories and financial modeling. This testing is also used to determine the likely financial investment required for full carbon project implementation. The cost of feasibility studies can either be paid by the landowner to a project developer through a fee-for-service model, or the costs are included within the developer’s portion of a resulting project’s credit revenues. Some project developers run feasibility studies at no charge to landowners.

If a site is deemed feasible, the landowner and a contracted project developer then co-design the project to be implemented. This includes choosing a suitable reforestation carbon methodology and registry for eventually listing the project’s credits, finalizing a planting and management plan that spans the length of the project’s crediting and monitoring periods, and compiling all relevant information into a Project Design Document (PDD). This PDD will be



submitted to the chosen registry for validation and approval. Funding and financing are also secured to pay for project implementation.

Once the PDD is submitted, a validation and verification body (VVB) that has been trained and pre-approved by the chosen registry reviews the project documents to make sure they are aligned and in compliance with the chosen ARR methodology. For instance, they must include a determination of the project's baseline, and plans to report on all carbon sources and sinks included in the methodology. They must account for any site prep and harvesting plans and ensure that they aren't in conflict with restrictions in the chosen methodology. If a VVB approves and validates the project, the project proponents can then register the project on the chosen registry. This lists the project publicly, and sets up the project to eventually issue carbon credits from that registry.

Project activities (such as site preparation, uneconomic salvage, planting, and assisted natural regeneration) begin the clock on a methodology's crediting period. Reforestation project activities can occur in parallel to the registration process, though the validation and registry approval process becomes more complex if project activities happen two or more years before validation. The crediting period is the period of time during which project activities result in measurable greenhouse gas benefits and can issue carbon credits. Most registry crediting periods last from 30-100 years. As shown in Figure 6, all ex-post carbon crediting methodologies actually have multiple crediting periods during which the forest growth would be measured and verified, and after which credits are issued for the amount of carbon that was found to be stored in the trees over that period.

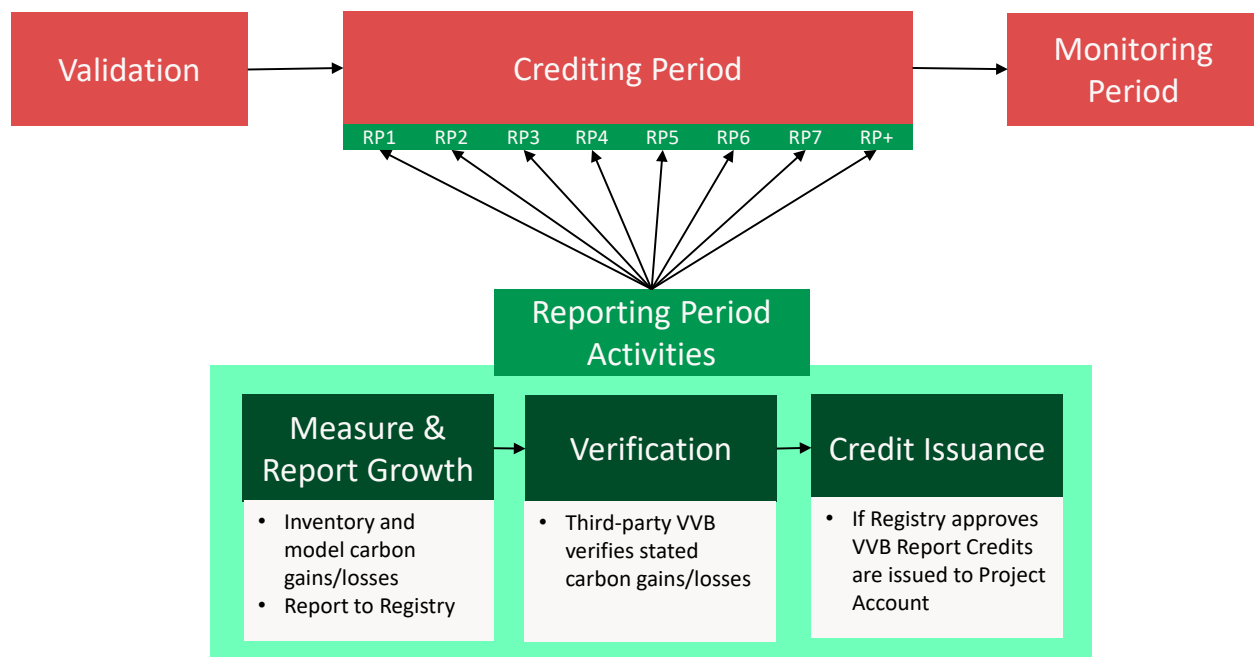


Figure 6: Diagram of a subset of the project development process, depicting the multiple iterative activities that make up the crediting period of a carbon crediting project.



Carbon credits can be sold before or after they are issued. These sales can be through bilateral pre-purchase or “forward offtake” agreements directly with a buyer or coalition of buyers on the basis of planned credit issuances (often for multiple “vintages” or 3-15 crediting years at a time), or for a certain amount of credits purchased by a broker or corporate buyer after credits are issued.

Once a buyer purchases carbon credits from a specific project, the credits are transferred from the account of the landowner (i.e. WA DNR) to the account of the buyer. The buyer then typically asks the registry to “retire” the credits, which ensures that those same credits cannot be resold and double-counted by another buyer.

After the full length of a project’s crediting period finishes, the project moves into a monitoring period (except for Gold Standard and ACR, which do not require monitoring periods following the crediting period). These monitoring periods are meant to ensure that the benefits from the project do not get reversed through fire, clear-cutting, development, or other means as soon as a project finishes issuing credits. Most registries require that projects set aside and contribute a portion of all issued credits toward a buffer pool to make up for potential losses (often these credits are automatically deducted from the issuance). Buffer pools typically require setting aside 5-30% of a project’s issuance, depending on the registry and the perceived risk of the project.

VIII. Trends in carbon markets

a. Buyers

Energy, transportation, and technology companies are the most common buyers of voluntary carbon credits. Large oil and gas companies have historically been the largest purchasers of voluntary carbon credits by volume. In 2024, Shell was the largest buyer globally, and retired three times as many credits as the next-largest buyer, Microsoft (Figure 7).²⁶ However, oil and gas companies like Shell focus more on buying a large quantity of credits than high-quality credits, and typically purchase credits that sell at lower prices per ton than buyers more focused on credit quality (like Microsoft). For example, Shell’s average price paid in 2024 was \$4.15 per carbon credit, while Microsoft paid an average of \$189 per credit.²⁷

As of 2025, corporate buyers interested in reforestation carbon credits include Microsoft, Disney, Google, Meta, McKinsey and Company, BCG, Salesforce, McLaren Racing, Airbnb, Autodesk, Takeda Pharmaceuticals, and FedEx (among many others.)

Sustainability advisory companies like [Watershed](#), [Carbon Direct](#), and [Rubicon Carbon](#) also purchase large quantities of carbon credits on behalf of customers, often as part of packaged portfolios of diverse projects.

²⁶ Giles, G. (2025, January 13). Shell and Microsoft top list of 10 biggest carbon credit buyers in 2024. *Trellis*. <https://trellis.net/article/carbon-markets-leaderboard-shell-microsoft/>

²⁷ Giles, G. (2025, January 13). Shell and Microsoft top list of 10 biggest carbon credit buyers in 2024. *Trellis*. <https://trellis.net/article/carbon-markets-leaderboard-shell-microsoft/>



Top buyers 2024

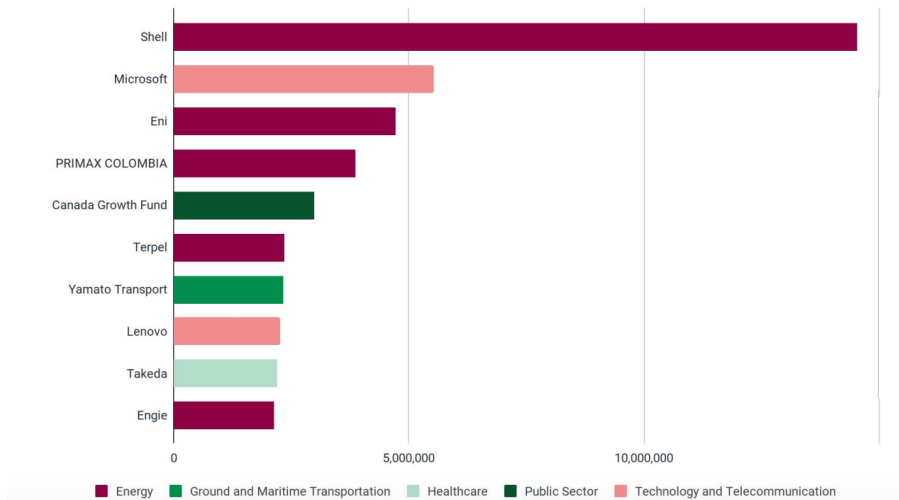


Figure 7: Chart from Allied Offsets/Trellis 2025, depicting the top buyers of carbon credits by volume of credits purchased (rather than amount spent on credits) globally in 2024.

b. Buyer motivations

The voluntary carbon market, as named, is fully voluntary in the U.S. The majority of companies that choose to purchase carbon credits are doing so for reputational and related credibility reasons, essentially maintaining a public license to operate (and pollute). At the same time, multiple studies have found that buyers of voluntary carbon credits are more likely to be reducing their companies' overall emissions faster than companies that don't purchase carbon credits.^{28,29}

Many sophisticated buyers of carbon credits have set net-zero or other emissions reductions targets in line with VCMI, SBTi, or other frameworks for corporate decarbonization. These frameworks outline how and when carbon credits can be used in addition to investments in a company's emissions reductions from its own activities, such as from switching to less polluting energy sources or changing to less emissions-intensive material inputs, such as from steel to wood. As of 2025, European corporations have more policy incentives to purchase carbon credits, though US-based companies remain among the largest carbon credit buyers globally.

Those buyers that adhere to corporate decarbonization guidelines like SBTi increasingly favor purchasing carbon removal credits (i.e. reforestation rather than IFM or REDD+ projects in the case of nature-based projects).

c. Contributions vs. offsetting

"Offsetting" has been the traditional approach to buying carbon credits. It refers to buying a specific quantity of carbon credits based on the amount of greenhouse gas emissions resulting from an individual's or a company's actions. (For instance, if an individual buys carbon credits

²⁸ Ecosystem Marketplace. (2023). 2023 All in on Climate: The Role of Carbon Credits in Corporate Climate Strategies. *Forest Trends*. <https://www.ecosystemmarketplace.com/publications/2023-em-all-in-on-climate-report/>

²⁹ Sylvera. (2023). Carbon Credits: Permission to Pollute, or Pivotal for Progress? <https://www.sylvera.com/reports/carbon-credits-and-decarbonization>



when they purchase a flight ticket to compensate for the amount that flight would emit, that is consistent with offsetting.)

Some buyers are beginning to take a “contributions” approach to buying carbon credits, meaning that they are not looking to buy a specific quantity based on their emissions footprint or their internal carbon budgeting, but rather an arbitrary amount. (In the case of buying carbon credits when purchasing a flight, this would be the equivalent of adding \$5 or \$20 to the ticket price as a token contribution to emissions reductions, even if that is less than the price of the carbon credits equivalent to one’s emissions.) This contributions approach generally reduces the demand for credits in the carbon market overall, though some academics with higher skepticism for carbon credits believe that this is a better approach; it reflects that companies are paying for climate impacts globally that are independent of their own emissions.

d. *Buyer coalitions*

One of the most promising trends in voluntary carbon credit markets has been the rise of aggregation mechanisms, including advanced market commitments and buyer coalitions. These coalitions are groups of companies that each commit to contract for large amounts of carbon credits together, typically of similar project types and through a joint process. This allows project developers and other credit suppliers to have greater visibility into corporate credit demand, and more certainty in terms of desired project types, pricing, quantities of credits, and quality criteria.

Notable buyer coalitions include [Frontier](#) (which mainly focuses on engineered carbon removal projects like biochar and direct air capture), [Carbon Direct](#) (which aggregates demand for both engineered and nature-based carbon projects), as well as the [Symbiosis Coalition](#) and [Watershed](#), both of which explicitly look to purchase credits from reforestation and other nature-based carbon crediting projects. Each coalition of buyers typically releases a request for proposals (RFP) that details eligibility criteria for projects, including the registries, types of projects, and “vintage” years (crediting periods) of interest.

In 2025, Symbiosis Coalition (which includes Microsoft, Google, Meta, Salesforce, and McKinsey & Company) issued an RFP for the first time, for the purchase of 20 million carbon credits. Watershed similarly issued an RFP of behalf of its software platform users (companies such as Airbnb, FedEx, General Motors, Visa, and Walmart) for the purchase of 1 million credits.^{30,31} Based on the publicly released outcomes of the Symbiosis RFP to date, 80% of proposed projects are over 5,000 hectares (12,355 acres) in size, and 74% of projects plan to register under Verra or Gold Standard.³² Even so, less than 25% of 228 submitted projects qualified for the “intermediate diligence” phase of the Symbiosis RFP as of June 2025, demonstrating a mismatch between buyer preferences (for large, high-quality, cheaply priced carbon projects) and the actual projects being developed.

³⁰ Symbiosis Coalition. (2025). Symbiosis Coalition RFP: Reforestation & Agroforestry. <https://rfp.symbiosiscoalition.org>.

³¹ Watershed. (2025). Guidance for Watershed’s 1 megatonne carbon credit RFP. <https://cdn.sanity.io/files/3ogo9b9g/production/8b8d288219e6e48c7b2091a791e4e7913ebf0ed1.pdf>.

³² Urban, N. (2025). Unlocking High-Integrity Restoration at Scale: Early Insights from Symbiosis Coalition’s First RFP. *Symbiosis Coalition*. <https://www.symbiosiscoalition.org/perspectives/unlocking-restoration-at-scale-early-insights-from-symbiosis-coalitions-first-rfp>.

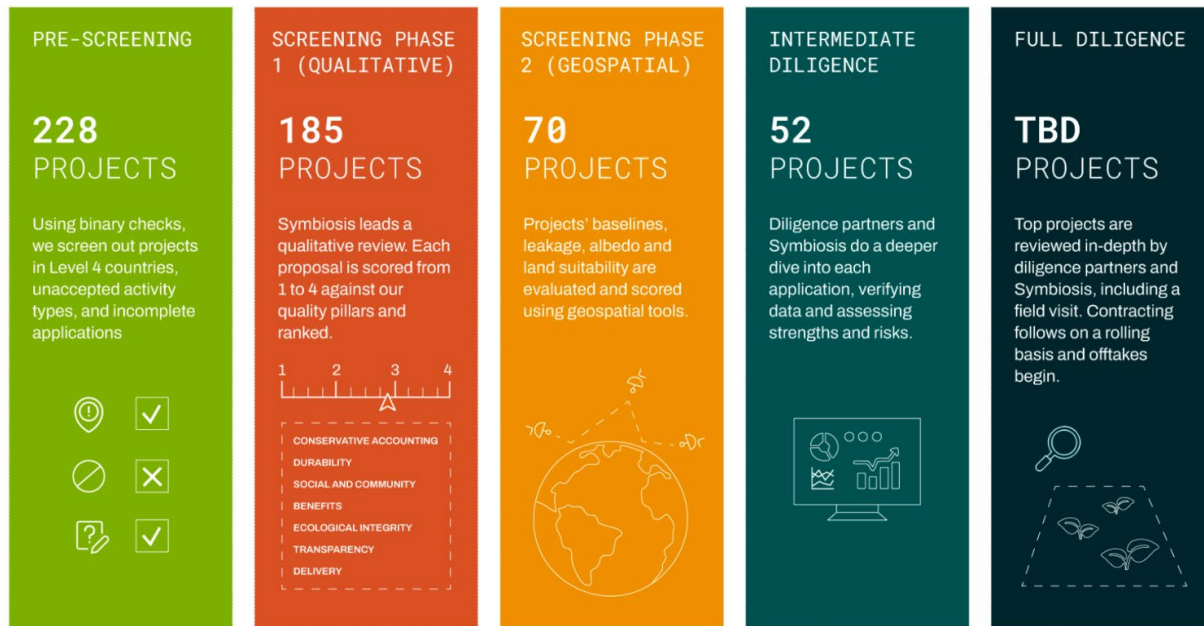


Figure 8: Published diligence pipeline for the Symbiosis Coalition RFP as of June 2025. Only 23% of projects have moved forward to “intermediate diligence.”

In addition to joint RFP and due diligence processes, buyer coalitions are beginning to develop a streamlined process for applying for project consideration. The [Beyond Alliance](#) (which includes the same buyers as the Symbiosis Coalition as well as other buyers like Amazon, Disney, Autodesk, Netflix, and Starbucks) launched a “Common Application” in 2025 for ARR projects, similar to the U.S. college admissions common application.³³

e. *Changes in carbon credit demand and supply over time*

Voluntary markets are increasingly sophisticated, diverse, and global in both their projects and buyers. There have never been as many buyers globally as in 2024 (Figure 9) and demand for carbon removal in particular (including reforestation) continues to increase (Figure 10).³⁴ The share of retired carbon removal credits from nature-based projects like reforestation has also increased as a proportion of all credit purchases (Figure 12).

³³ Beyond Alliance. (2025). Beyond Alliance Afforestation, Reforestation, and Revegetation (ARR) Common Application Questions. https://beyond-alliance.org/wp-content/uploads/2025/03/Beyond-Common-App-Questions_Clean_3.3.2025v2.pdf.

³⁴ AlliedOffsets. (2025). 2024 End of Year Report: VCM 2024 Review and Emerging Trends for 2025. <https://alliedoffsets.com/wp-content/uploads/2025/01/VCM-2024-Recap-Emerging-Trends-for-2025.pdf>.



Number of buyers retiring credits

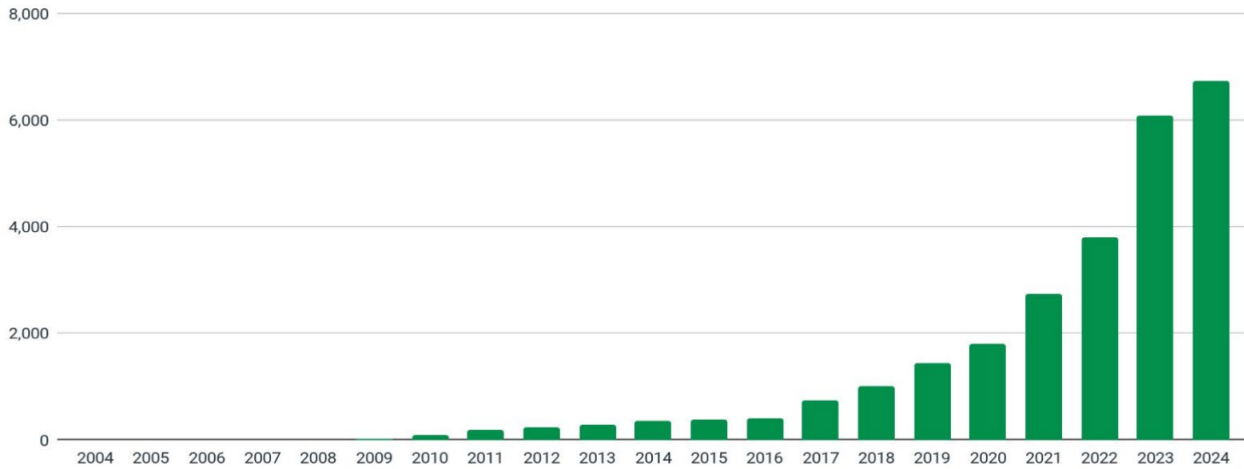
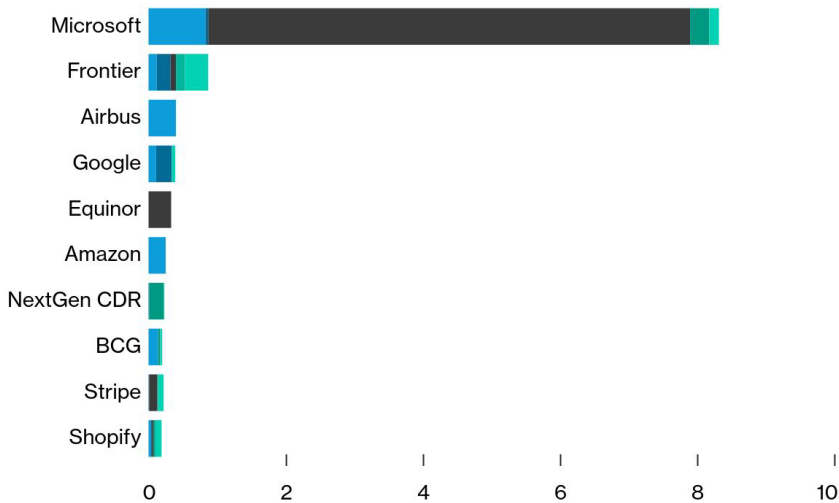


Figure 9: Number of unique buyers purchasing and retiring carbon credits by year, for the past 20 years. Source: Allied Offsets 2025.

Carbon Removal Credit Volumes to Double in 2025 After 74% Increase in 2024

Top carbon removal credit buyers

■ DAC
 ■ Enhanced Weathering
 ■ BECCS
 ■ Biochar Carbon Removal
 ■ Biomass Direct Storage
 ■ Other



Source: BloombergNEF, cdr.fyi.

Note: BECCS refers to bioenergy with carbon capture and storage, DAC refers to direct air capture.

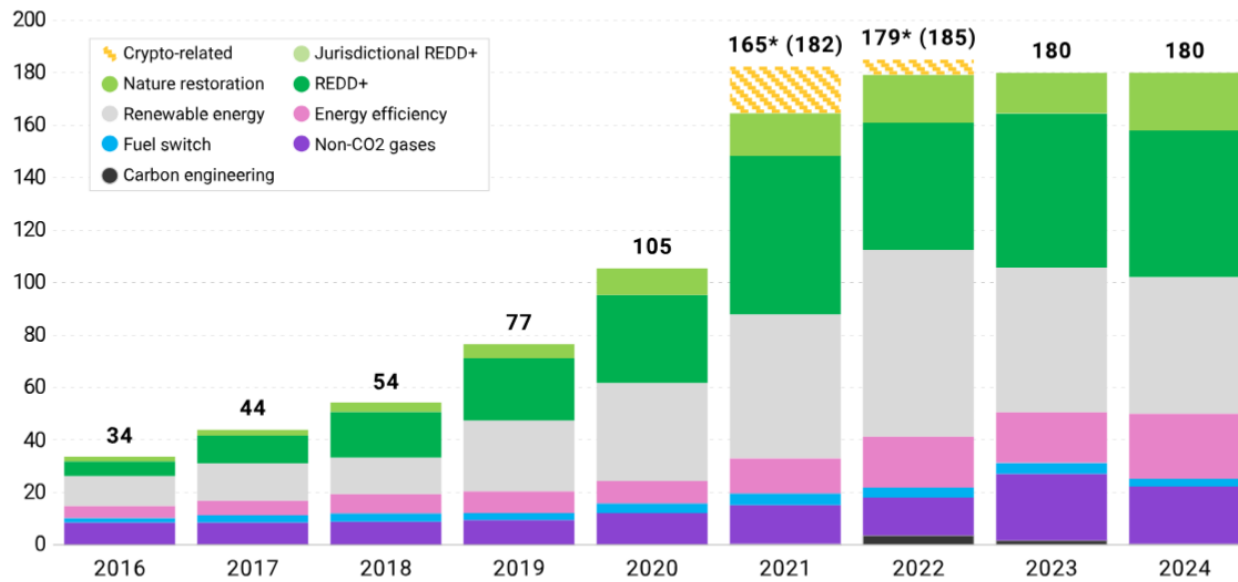
BloombergNEF

Figure 10: Purchases of carbon removal-based credits by project type for the ten largest buyers globally as of May 2025. Source: BloombergNEF 2025.



Nonetheless, the voluntary carbon market has also stagnated and even contracted in other ways over the past few years, following negative press coverage and lawsuits in 2022-2023.^{35,36} The press coverage focused on low-quality REDD+ (forest protection) and renewable energy projects, but many journalists and buyers broadened the assumption to the rest of the carbon market because these two project types historically made up the majority of all credits issued globally (Figure 11).³⁷ Registries, carbon project developers, and corporate buyers were all accused of fraud and greenwashing.

Annual retirements by project type (MtCO2e)



Data as of Dec. 31, 2024. Source: MSCI Carbon Markets. 2024 retirement excludes the 5 MtCO2e of energy efficiency credits that were retired from the market by the registry Verra due to past fraudulent over-issuance by the developer C-Quest Capital. 2021 and 2022 retirement totals are shown both including and excluding (marked with an *) retirements made for use in cryptocurrency schemes such as Toucan.

Figure 11: Change in carbon credit retirement by project type between 2016-2024. Source: MSCI Carbon Markets 2025.

For instance, Verra and South Pole, the largest registry for REDD+ projects and the largest developer of carbon crediting projects, respectively, were each accused of developing and issuing credits from faulty projects with little to no climate impact, and in some cases, negative impacts on indigenous and other local communities. The CEOs of each organization resigned,

³⁵ Greenfield, P. (2023, January 18). Revealed: more than 90% of rainforest carbon offsets by biggest certifier are worthless, analysis shows. *The Guardian*. <https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe>.

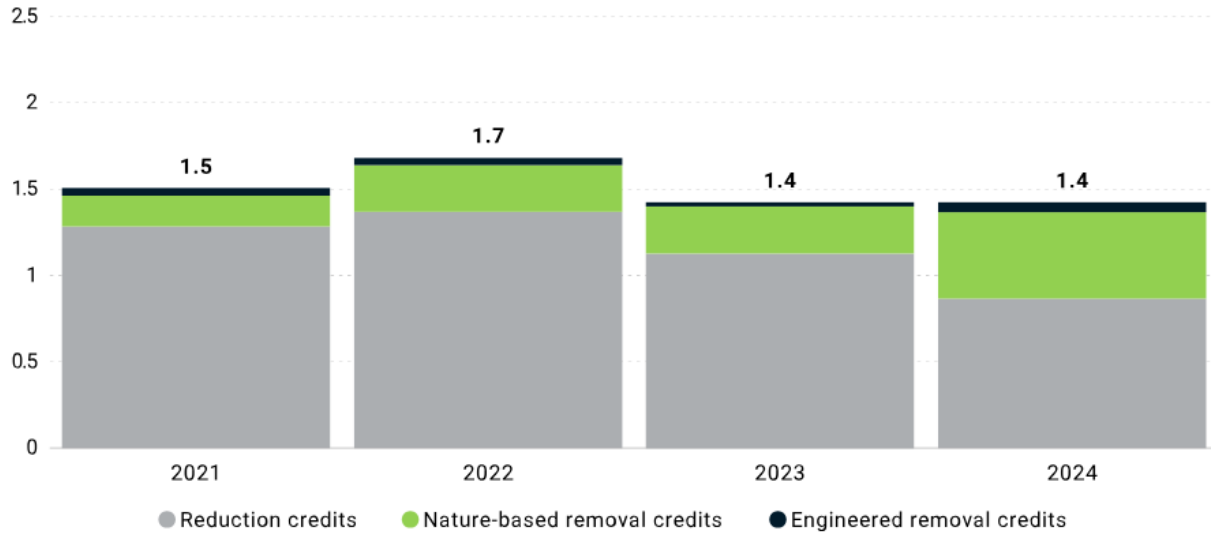
³⁶ Elgin, E., Marsh, A., & de Haledvang, M. . (2023, March 24). Faulty Credits Tarnish Billion-Dollar Carbon Offset Seller. *Bloomberg*. <https://www.bloomberg.com/news/features/2023-03-24/carbon-offset-seller-s-forest-protection-projects-questioned>

³⁷ Lakhani, N. (2023, September 19). Revealed: top carbon offset projects may not cut planet-heating emissions. *The Guardian*. <https://www.theguardian.com/environment/2023/sep/19/do-carbon-credit-reduce-emissions-greenhouse-gases>



and interest has gradually shifted toward new registries and developers that might be clear of the stigma and reputational harm now associated with those exposed by the media.

Historical market size of credits retired (USD billion, 2024 prices)



Data as of Dec. 31, 2024. Reduction credits are issued by projects that reduce/avoid emissions being released into the atmosphere (e.g., by reducing deforestation occurring in an area of tropical forest). Removal credits are issued by projects that directly remove emissions from the atmosphere, either via nature-based or engineered processes. Source: MSCI Carbon Markets

Figure 12: Credit purchases by total purchase amount (rather than volume of credits purchased) for 2021-24. Carbon removal credits from nature-based solutions have increased as a proportion of all credits purchased. Source: MSCI Carbon Markets 2025.

Similarly, Delta Airlines had made a public carbon neutrality claim in 2020, aiming to become the ‘world’s first carbon-neutral airline.’ Delta then sought to meet that claim through the purchase of carbon credits, eventually becoming the largest buyer of carbon credits globally (Figure 13). In 2022, Delta was sued in a class action lawsuit that alleged greenwashing due to purchasing faulty carbon credits.³⁸ As a result, Delta has moved away from purchasing carbon credits. Apple and Danone Waters have faced similar lawsuits in claiming their projects were carbon-neutral as a result of purchasing low-quality carbon credits.^{39,40} These greenwashing lawsuits, even more than the media coverage of poor-quality carbon projects, have led to greater corporate hesitation about purchasing carbon credits. This has also led to a much greater emphasis on project integrity and a shift towards purchasing carbon removal projects, which are generally easier to quantify in terms of their impact because they rely on specific activities rather than assumed or modeled counterfactuals.

³⁸ Davey, E. (2023, May 31). Delta Air Lines hit with lawsuit over claims of carbon neutrality. *Associated Press*. <https://apnews.com/article/delta-airlines-lawsuit-carbon-credits-carbon-neutral-469f2671010ba7f40c934cc23d62149a>

³⁹ Stempel, J. (2024, November 18). Evian maker Danone defeats lawsuit over 'carbon neutral' claim. *Reuters*. <https://www.reuters.com/legal/evian-maker-danone-defeats-lawsuit-over-carbon-neutral-claim-2024-11-18/>

⁴⁰ Stempel, J. (2025, February 27). Apple sued over 'carbon neutral' claim for watches. *Reuters*. <https://www.reuters.com/technology/apple-sued-over-carbon-neutral-claim-watches-2025-02-27/>

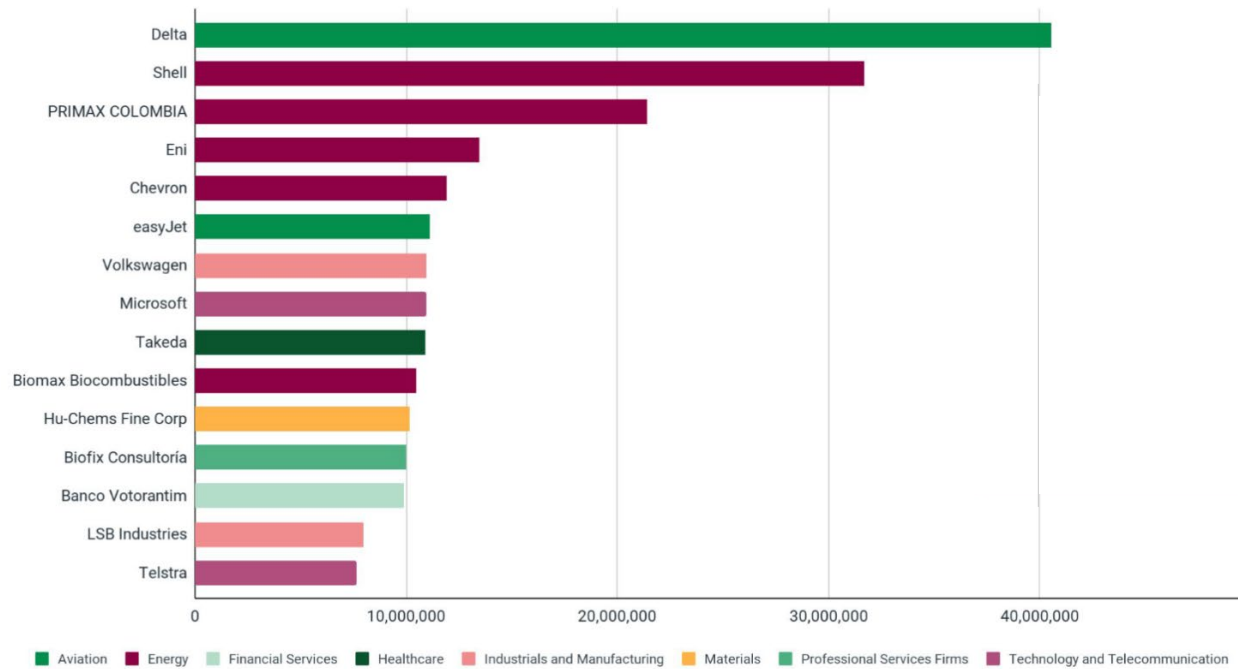


Figure 13: All-time top buyers of carbon credits (by volume of credits retired) globally as of December 2024. Source: Allied Offsets 2025.

f. *Changes in carbon credit price over time*

Prices for voluntary carbon credits have generally followed this fluctuating demand. Prices for REDD+ and renewable energy carbon credits have declined significantly, from \$12 per credit to US\$4. Prices for nature-based carbon removal credits, such as from reforestation projects, declined slightly after 2022 but have since maintained average prices of ~US\$15 per credit as of 2025.⁴¹ Prices for large, relatively high integrity projects such as Amazon reforestation projects developed by [Mombak](#) in Brazil, have garnered even higher prices. Discussions with Isometric executives revealed that recent reforestation projects registered on the Isometric registry have sold credits for \$60-\$125 per credit ton.

⁴¹ AlliedOffsets. (2025). 2024 End of Year Report: VCM 2024 Review and Emerging Trends for 2025. <https://alliedoffsets.com/wp-content/uploads/2025/01/VCM-2024-Recap-Emerging-Trends-for-2025.pdf>.



NBS removals bucked the trend



Figure 14: Chart depicting prices for nature-based carbon removal credits over time, from July 2022 to January 2025. Source: Allied Offsets 2025.

IX. Precedence of carbon projects on state lands

At least six states have considered developing forest-related carbon crediting projects over the past twenty years, including Michigan, Oregon, Hawaii, California, Colorado, and Alaska.

California was perhaps the earliest state to develop a forest-based carbon project. California's Department of Parks and Recreation registered a 5,700 acre post-wildfire reforestation carbon project at Cuyamaca Rancho State Park on the Climate Action Reserve (CAR) registry in 2009, though it never issued carbon credits from the project.

Similarly, Hawaii's Department of Land and Natural Resources Division of Forestry and Wildlife developed a 1,560-acre reforestation carbon project to issue credits through the Verra registry. Like California, Hawaii DLNR initially chose not to work with a third-party project developer, and their registration process has taken over a decade. Planting for the carbon project was completed in 2015, but the project registration, validation, and verification are only now being completed in 2025, due to significant complexities introduced by establishing a baseline after the project activities were completed (rather than prior to planting as is standard) and requirements to shift to the new VM0047 because the project was not registered using the previously accepted methodology. Credits from the project have not yet been issued as of 2025. The state legislature is still determining whether credits issued by the project can be sold to polluters not based in Hawaii, which would impact the state's greenhouse gas accounting. Hawaii DLNR is looking for additional lands to enroll in the project, which is being established as



a CCB-certified grouped project allowing for additional instances on public and private lands throughout the state.

Michigan Department of Natural Resources developed the first forest carbon project to successfully sell carbon credits. Michigan DNR contracted the project developer Anew (then called Bluesource) to lease 101,000 acres of state lands in Pigeon River Country State Forest to develop an IFM carbon project. The project was registered through the ACR registry in 2020, and all credits for the first ten years of issuance were sold to DTE Energy, a Detroit-based natural gas provider. This resulted in significant state revenues of ~\$12 million to Michigan DNR, which were then used to fund staff and projects within Michigan DNR and its forestry, clean energy, and sustainability division. The project received negative media attention for its perceived lack of additionality and poor quality (the project resulted in ambiguous climate impacts).^{42,43} Michigan DNR chose its initial project location and IFM structure for ease of project setup rather than impact, to serve as a proof of concept. Michigan DNR has since developed a second IFM carbon project listed on the ACR registry (the Anew - Michigan DNR Wolverine Copper Forestry Project), though it has had more difficulty selling carbon credits from this subsequent project.

Oregon Department of State Lands has taken a similar approach to Michigan DNR, partnering with Anew to develop an IFM project on the Elliott State Forest, also expected to be registered through ACR. This project is still in the process of registration, but received approval for enrolling the entire forest (83,000 acres) into a carbon project in 2024.

Alaska passed SB 48 in 2023, enabling Alaska's Department of Natural Resources to enroll State forests in the voluntary carbon market starting in 2025. Alaska DNR is now developing three pilot IFM projects, each approximately 75,000 to 100,000 acres, planned in Haines State Forest, Tanana Valley State Forest, and the Matanuska-Susitna region.⁴⁴ Early estimates from 2022 suggested that these projects could generate \$8 million annually in the first decade, although the projects have already faced media scrutiny over their likely poor quality (in terms of no net climate benefit from the projects due to no planned change in harvest practices).⁴⁵

Most recently, the Colorado State Land Board leased approximately 1,000 acres to a carbon project developer called Land Life, to develop a post-fire reforestation project in 2025. The project would be planted by Land Life and monitored and maintained by Colorado State Forest Service after planting, and will be registered on the Verra registry. Notably, the project is structured such that Colorado State Land Board would receive lease payments from Land Life, rather than any share of carbon credit proceeds. The result is that all planting costs are fully

⁴² Samilton, T. (2024, February 18). Critics say DTE Energy's "Natural Gas Balance" program is more marketing than emissions reducing. *Michigan Public Radio-NPR*. <https://www.michiganpublic.org/environment-climate-change/2024-02-18/critics-say-dte-energys-natural-gas-balance-program-is-more-marketing-than-emissions-reducing>.

⁴³ Cass, C. (2022, October 18). Michigan Carbon Offsets: Success or Scam?. *Great Lakes Echo*, October 18, 2022. <https://greatlakesecho.org/2022/10/18/michigan-carbon-offsets-success-or-scam/>.

⁴⁴ DGB Group. (2024, July 9). Carbon credits set to transform Alaska's forest management. *DGB Group*. <https://www.green.earth/news/carbon-credits-set-to-transform-alaskas-forest-management>.

⁴⁵ Chay, F. & G. Badgeley. (2023, May 19). Additionality risks in Alaska's proposed forest offsets program. *Carbon Plan* <https://carbonplan.org/research/forest-offsets-alaska>.



covered by Land Life, and Colorado State Land Board will receive a modest lease payment of \$87,500 (\$87.50 per acre) in addition to not paying for planting costs.

Two key lessons from these state carbon projects are (1) the importance of partnering with an experienced project developer, and (2) the importance of designing a high-integrity project.

California and Hawaii both proceeded with being sole project proponents, and their project registration processes took years longer than those states that chose to work with experienced carbon project developers; in both cases, the states have not sold any credits to date despite beginning their carbon projects over a decade ago. Hawaii recently began to work with a carbon advisory firm ([TerraCarbon](#)) to support some aspects of their carbon project development. Developers can help shepherd state agencies through an otherwise complex and opaque process, help ensure that the state's investments in a carbon project are recouped, and that a project can find buyers.

At the same time, a developer partner cannot always ensure that carbon credits are sold if a project is deemed controversial or of uncertain quality. For example, Michigan DNR's most recent IFM projects have struggled to sell credits. It is therefore important to structure a project for high quality and integrity given increasing buyer sophistication and media scrutiny, and thereby to avoid issues with unsold credits and therefore financial risk and liability from a carbon project.

X. Risks, benefits, and other considerations for carbon projects on state lands

When done well, carbon crediting projects on state lands present few risks and many opportunities. However, it is important to keep several key risks in mind, as well as methods to mitigate risks that might negatively affect WA DNR's credibility, public perception, financial liability, and relationships with corporate and other partners.

Firstly, there are over-crediting and other project quality risks that might result in poor project ratings, reputational risk to WA DNR, and low credit sales. These can largely be mitigated through a good project design and accurate measurement of the project baseline (such as to properly account for the rate of natural regeneration on adjoining parcels). Additionally, WA DNR can work with a carbon credit rating agency to understand how the project would be rated and perceived by potential buyers relative to other projects available at similar price points.

Execution or implementation risk, in which a project struggles or fails to get registered and to issue credits (such as has occurred with California and Hawaii reforestation carbon projects on state lands), can also be mitigated. WA DNR can partner with a credible third-party developer to help guide WA DNR through the registration process, and to take on credit sales and other discrete project development responsibilities that WA DNR does not currently (as of June 2025) have clear legal authority to fulfill. In the case of a registry or methodology changing, experiencing multi-year registration delays, or even becoming insolvent, WA DNR can



proactively identify a backup registry and ARR methodology for which the project would be eligible, so as to be able to shift to the backup if the initial registry is a poor fit.

There are also risks that could be mitigated through the purchase of carbon credit insurance (see section V-f for more information.) Insurance can help mitigate against changes in policy and regulation, against changes in a registry's ARR methodology, unplanned or unintended forest degradation (such as from pests or disease), and even against total destruction and project reversal, such as in the case of another wildfire. Buffer pools, which are mandatory set-asides of issued carbon credits, can also help offset some of these losses. Buffer pools are typically 10-30% of each project's credits that are combined across all registered projects on a registry, to cover for any unexpected reductions in climate impact. Buyer contracts for carbon credits can also be structured in such a way as to limit WA DNR's financial liability in the case of project failure after credits are sold, such as through robust force majeure clauses.

Market risk is more difficult to mitigate, and remains a risk for all proponents of carbon crediting projects. For instance, large voluntary carbon buyers may lose interest in or are regulatorily forbidden from purchasing carbon credits. There may be an oversupply of carbon credits from lower-labor international projects that leads to a glut of available credits and depresses average prices for all ARR prices. WA DNR can remain up to date through carbon credit reports and other publicly available information to make informed decisions. Additionally, WA DNR can prioritize pre-purchases or other forms of advanced commitment from corporate buyers to reduce uncertainty and ensure that at least a portion of credits will be purchased. Finally, WA DNR can invest in marketing and other collateral to craft a compelling story about its projects, and ensure that they are differentiated and can garner competitive prices.

XI. Decision support tools

a. *Determining overall eligibility for carbon project development*

Carbon finance may help support further reforestation and afforestation efforts on WA DNR-managed lands. However, the act of tree planting alone does not necessarily constitute a reduction in atmospheric carbon or eligibility for carbon funding. Rather, eligibility for carbon financed tree-planting is contingent upon a given project's ability to fulfill ICVCM's Core Carbon Principles of additionality, leakage, durability, permanence, verifiability and in some cases, benefit sharing and co-benefits. Land managers must evaluate whether their project aligns with these criteria to determine if carbon finance is the appropriate funding mechanism for tree planting and other restoration efforts. The following decision tree tool (Figure 13) provides a series of questions that can assist WA DNR in making that determination. While each carbon registry has its own standards and methodologies, the decision tree in (Figure 13) incorporates considerations of core carbon principles common to all registries. One such theme is that of *additionality*. Key to this question is the likelihood of natural regeneration, which is why the first question addresses the timing of the deforestation event. Across all registries, it is assumed that if no regeneration has occurred within 10 years – even after harvest – there is an impediment to growth. The existence of such an impediment implies the possibility for additional carbon



sequestration through intervention. Importantly, carbon finance is not meant to subsidize 'business as usual' forestry where no such barriers to regeneration exist. The cause of regeneration failure – critical to durability assessments – also matters. Sites affected by herbivory, competing vegetation, or degradation rather than climate unsuitability, are more likely to support durable carbon storage in the form of restored forests. Other key principles drive the line of questioning throughout the decision tree. The decision tree provides managers with insight into whether a proposed tree planting effort has the potential to succeed as a carbon project or not. If a carbon project is not considered advisable, it says nothing about the ecological, economic or hydrological value that reforestation efforts may provide. Rather, failure means that reforestation cannot be justified on the basis of carbon removal alone. However, if it is determined that carbon finance may be applicable, the next section provides guidance on selecting the most appropriate methodology for the proposed ARR project.

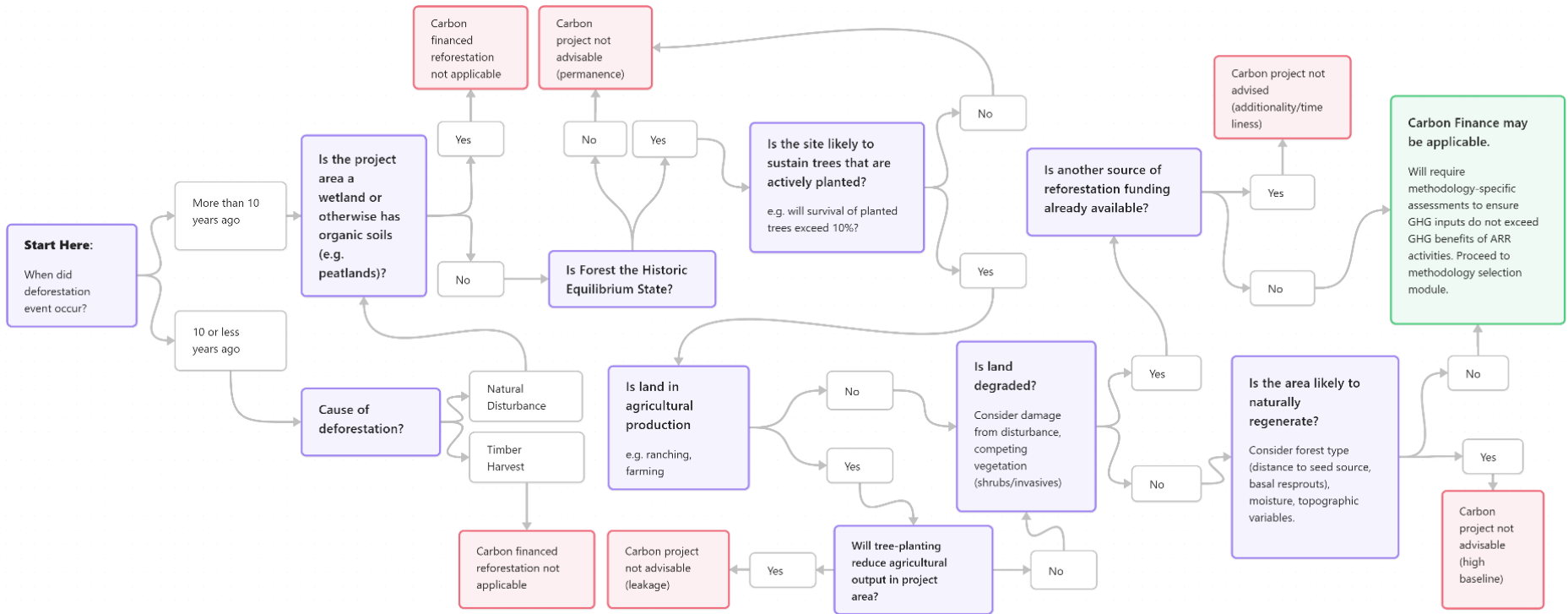


Figure 15: Decision tree to help determine ARR project eligibility for inclusion in voluntary carbon markets.



b. *Identifying relevant carbon credit methodologies given management constraints*

All leading registries considered here abide by ICVCM's Core Carbon Principles (see section IV-h). However, there are differences among registries in how those principles are interpreted. Consequently, the choice to abide by one methodology over another may result in significantly different obligations and management restrictions on Project Proponents. Our consideration of best-fitting carbon credit methodologies for WA DNR is informed by direct consultation with agency representatives about their land management priorities and limitations. WA DNR's stated desires were to preserve the ability to perform site preparation including the removal of burned material, harvest timber in accordance with carbon restrictions, and honor 99-year lease durations. When applied, these constraints suggest that either American Carbon Registry's *Afforestation & Reforestation of Degraded Land v 1.2*⁴⁶ (hereafter, referred to as ACR) or Gold Standard's *Afforestation – Reforestation GHG Emissions Reductions & Sequestration Methodology v 2.1*⁴⁷ (hereafter, referred to as Gold Standard) may be most suitable for WA DNR as of June 2025 (Figure).

Both ACR's and Gold Standard's requirements fit well with WA DNR's stated management objectives. ACR and Gold Standard both offer comparatively short crediting periods (40 and 30-50 years, respectively), the ability to renew, and no subsequent uncredited monitoring periods. This duration aligns with WA DNR's 99-year lease constraint and contrasts sharply with other registries' longer requirements (e.g., Climate Action Reserve's⁴⁸ 100-year monitoring period). Both methodologies also allow for harvesting timber – with some constraints – setting it apart from Ecosystem Restoration Standard's⁴⁹ and Open Forest Protocol's⁵⁰ no-harvest requirement. Last, both methodologies allow WA DNR to perform site prep and intermediate treatments including controlled burns and the removal of biomass – often an essential component of post-fire site preparation. WA DNR's need to remove burned material prevents Verra's *VM0047 Afforestation, Reforestation, and Revegetation v1.1* from being considered, as this methodology mandates that all burned material must remain onsite.⁵¹

⁴⁶ ACR. (2017). Methodology for the quantification, monitoring, reporting and verification of greenhouse gas emissions reductions and removals from afforestation & reforestation of degraded land (Version 1.2). *Winrock International*. <https://acrcarbon.org/wp-content/uploads/2023/03/ACR-Afforestation-Reforestation-of-Degraded-Land-v1.2-1.pdf>.

⁴⁷ Gold Standard Foundation. (2024). Afforestation – Reforestation GHG Emissions Reduction & Sequestration Methodology (Version 2.1). *Gold Standard for the Global Goals*. <https://globalgoals.goldstandard.org/403-luf-ar-methodology-ghgs-emission-reduction-and-sequestration-methodology/>.

⁴⁸ Climate Action Reserve. (2023). U.S. Forest Protocol v 5.1). https://www.climateactionreserve.org/wp-content/uploads/2023/07/Final_Forest_Protocol_V5.1_7.14.2023.pdf.

⁴⁹ Ecosystem Restoration Standard. (2024). M001: Methodology for Terrestrial Forest Restoration (Version 1.1). <https://docs.ers.org/m001-methodology-for-terrestrial-forest-restoration-v1.1.pdf>

⁵⁰ Open Forest Protocol. (2024). Afforestation / Reforestation / Revegetation (ARR) Carbon Whitepaper (Version 1.1). <https://docsend.com/view/75zb4teggzvmyva>.

⁵¹ Verra. (2023). VM0047 Afforestation, Reforestation, and Revegetation, v1.0. *Verra*. <https://verra.org/methodologies/vm0047-afforestation-reforestation-and-revegetation-v1-0/>.



Other registries may still present compelling carbon development options for WA DNR. Isometric Registry's *Reforestation v 1*⁵² (hereafter referred to as Isometric) may be one such alternative. Isometric requires a 40-year minimum monitoring period following a variable length crediting period - a duration that could be supported by current lease-length restrictions. Isometric also allows selective harvest, intermediate treatments, and the removal of burned material as part of site preparation. Isometric did not initially make the shortlist due to its requirement to plant more than 5 species from 2 genera. However, its species diversity requirement may not be so arduous as its methodology also states that "... some regions ... naturally support a limited number of species" and that Project Proponents "... may deviate from the minimum required species in these regions." If WA DNR can make the case for reduced species diversity to registry representatives, it would be just as viable as ACR and Gold Standard. Isometric may indeed be a preferable option for WA DNR considering that they are presently the only registry of these final three options that supports dynamic baseline evaluation – a quality increasingly important to discerning credit buyers. Further, Isometric puts the financial burden of verification and validation on the carbon credit buyers rather than the Project Proponent.

⁵² Isometric Registry. (2024). *Reforestation Protocol v.1.0.3*. <https://registry.isometric.com/protocol/reforestation>

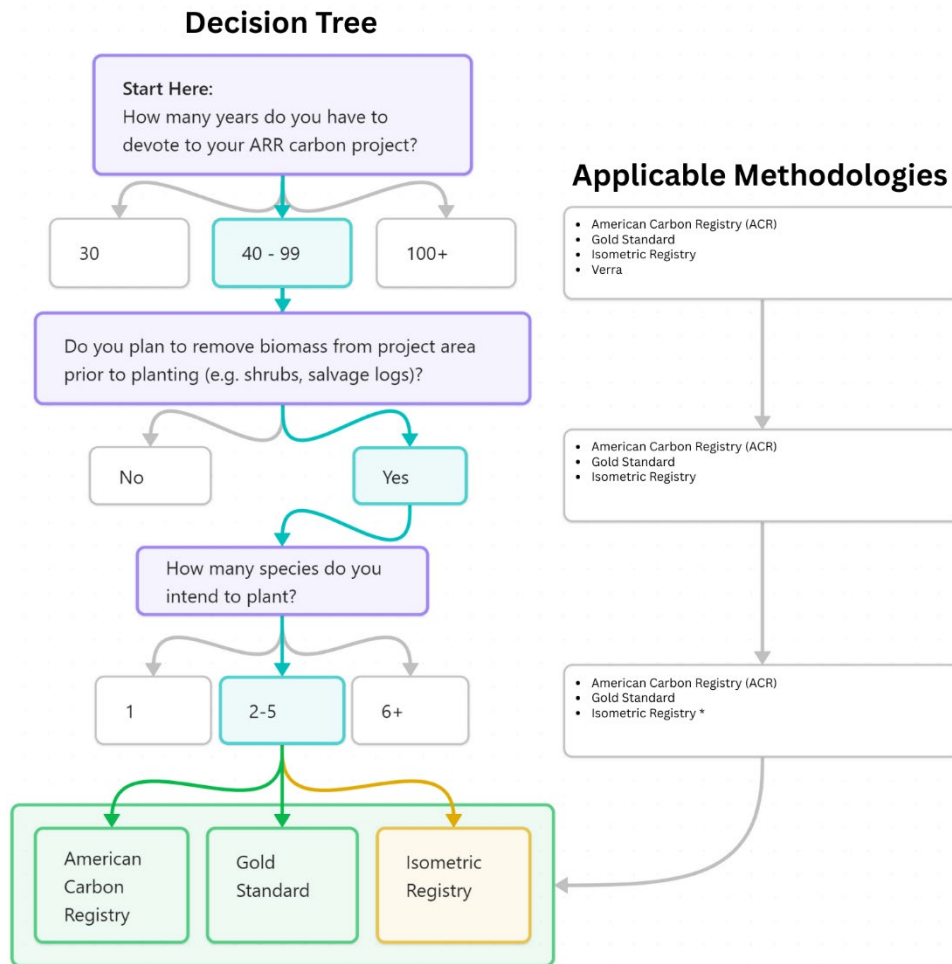


Figure 16: Afforestation, reforestation, and revegetation methodology selection recommendation. While reforestation scenarios may vary, turquoise boxes represent the most likely responses from WA DNR based on direct consultation with WA DNR staff. Isometric Methodology abbreviations are as follows: American Carbon Registry’s ‘American Carbon Registry – Afforestation & Reforestation of Degraded Land (v1.2)’; Gold Standard’s ‘Gold Standard – Afforestation – Reforestation GHG Emissions Reductions & Sequestration Methodology (v2.1)’; Isometric Registry’s ‘Reforestation (v1.0)’; Verra’s ‘VM0047 Afforestation, Reforestation, and Revegetation (v1.1)’.

Finally, WA DNR must take special care in considering the impact of Washington State Forest Practices Rules on the additionality of post-fire carbon projects. Chapter 222-34 WAC states that reforestation is required following any harvest that removes 50% or more of the timber volume from a stand within any 5-year period.⁵³ Post-fire salvage harvest would likely trigger this mandatory reforestation clause, causing any tree-planting effort to fail the regulatory surplus test put in place by all leading carbon registries. This is to say that any tree planting would not represent additional carbon being sequestered as such tree planting is already required by law.

⁵³ Washington State Department of Natural Resources. (2024). Title 222-34 WAC: Reforestation. In Title 222 WAC: Forest Practices Rules. https://www.dnr.wa.gov/publications/bc_rules_title222_wac.pdf.



All the registries considered relevant for WA DNR have the capacity to process and consider such an appeal through the submission of a deviation request. In a deviation request, WA DNR or a project development partner may explain the extenuating circumstances as to why reforestation measures present additional carbon sequestered beyond business as usual. Key to establishing the additionality of post-fire salvaged sites would likely be evidence that the salvage harvest in question is not profitable in its own right. Although deviation requests are common and often honored, approval of deviation requests is not guaranteed and as such it will be critical for WA DNR to explain these circumstances to a carbon project developer and provide assistance in crafting the deviation request. If WA DNR is interested in carbon-financed reforestation through a carbon registry it is critical that they acquire approval of the request before proceeding with activities that would trigger a mandatory reforestation per the requirement of Washington State Forest Practices Rules Chapter 222-34.

c. *Geospatial analysis identifying WA-DNR lands that meet regulatory criteria*

Our analysis identified ~16,600 acres of Reforestation Need and ~20,600 acres of Afforestation Opportunity across Washington State Trust Lands (Figure 15). The overwhelming majority of these acres (98%) were in Eastern Washington, defined as east of the Cascade Mountains crest. Seed Transfer Zones 600, 611, and 613 were among the top five seed zones for both greatest Afforestation Opportunity (AO) and greatest Reforestation Need (RN) and had the greatest overall tree-planting opportunity (Table 1: Reforestation and Afforestation Opportunity in Eastern and Western WA DNR managed lands). A more detailed breakdown of AO and RN by Seed Zone and region is included in supplementary documents (*AORN_SeedZones.xlsx*) alongside a similar breakdown of AO and RN by Regional Inventory Unit parcel (*AORN_RIUs.xlsx*). For more information on the analysis, see Appendix A.

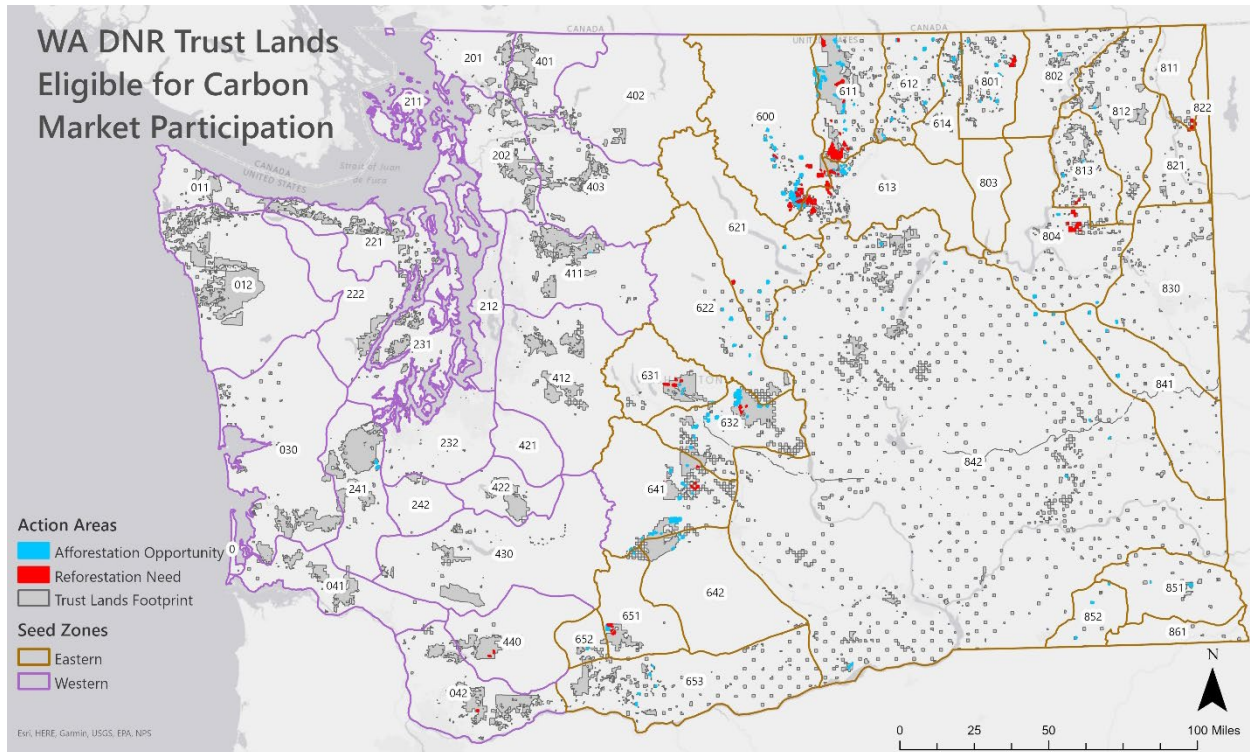


Figure 17: Map of Afforestation Opportunity and Reforestation Need identified on WA DNR managed lands eligible for Carbon Market participation. Polygon width enhanced for visibility.

Pre-existing leases or encumbrances (hereafter referred to as ‘Agreements’) may present WA DNR with barriers to carbon project implementation. We recommend WA DNR conduct a thorough review of any such Agreements on prospective project sites before initiating carbon project development. The Agreement types that overlapped the most with prospective AO and RN areas were 60: *Special Use Permits* (~23,000 acres) followed by 11: *Permit Ranges* (~17,800 acres), 10: *Grazing Leases* (~12,000 acres), and 78: *Water Rights* (~8,400 acres).

Rank	Region	Seed Zone	Afforestation Opportunity Acres
1	East	600	5,452
2	East	632	2,849
3	East	611	2,423
4	East	641	2,065
5	East	613	1,197

Rank	Region	Seed Zone	Reforestation Need Acres
1	East	611	5,618
2	East	600	3,629
3	East	613	1,690
4	East	804	1,614
5	East	631	852

Table 1: Reforestation and Afforestation Opportunity in Eastern and Western WA DNR managed lands.

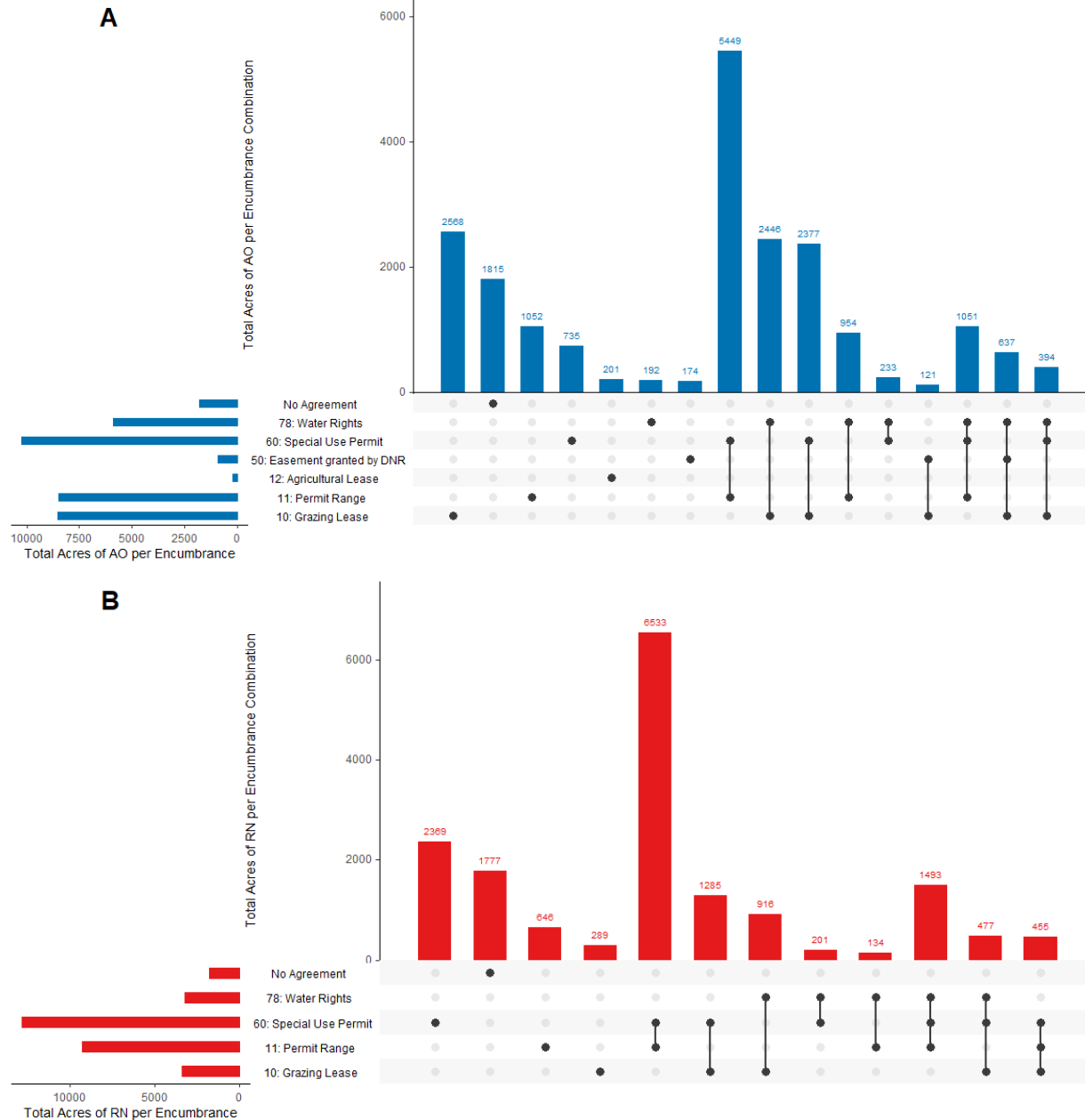


Figure 18: (A) Afforestation Opportunity by Lease and Encumbrance Type on WA DNR Managed Lands. (B) Reforestation Need by Lease and Encumbrance Type on WA DNR Managed Lands. In these UpSet plots^{54 55} horizontal bars show total size of each Agreement type in acres. The matrix of dots and connecting lines in the center represent unique combinations of Agreement types where each row corresponds to a single Agreement type and each column represents a unique intersection of one or more Agreement types. The vertical bar chart on the top quantifies the area in acres of each Agreement combination (i.e., the number of acres encompassed by that specific

⁵⁴ Conway, J. R., Lex, A., & Gehlenborg, N. (2017). UpSetR: An R package for the visualization of intersecting sets and their properties. *Bioinformatics*, 33(18), 2938–2940. <https://doi.org/10.1093/bioinformatics/btx364>

⁵⁵ Lex, A., Gehlenborg, N., Strobel, H., Vuillemot, R., & Pfister, H. (2014). UpSet: Visualization of Intersecting Sets *IEEE Transactions on Visualization and Computer Graphics (InfoVis)*, 20(12), 1983-1992. <https://doi.org/10.1109/TVCG.2014.2346248>



combination of overlapping Agreements on WA DNR managed lands). All Agreement combinations with fewer than 100 acres were removed from graphic to enhance legibility.

Agreements on Trust Lands often overlap with other Agreements. The most common overlapping Agreement types in both RN and AO areas were 11: *Permit Range* and 60: *Special Use Permits* (Figure 16). ARR project activities that cause the agricultural output of areas with Grazing, Range, or Dry Land Agricultural Agreements to decrease agricultural productivity may require additional agricultural commodity leakage deduction from carbon credits. The specifics of any such deductions will depend on WA DNR’s chosen carbon methodology.

Afforestation Opportunity and Reforestation Need per BPS

Echoing Chapter 4, we used LANDFIRE Biophysical Setting (BPS) to identify potentially suitable forest types in identified AO and RN patches on WA DNR managed lands.⁵⁶ BPS data are estimates of what vegetation communities – including forest types – occurred historically on the landscape prior to Euro-American settlement. These estimates are essential for identifying what forest types could be supported on currently non-forested areas (i.e., AO patches). Use of BPS data also aligns with the original Reforestation Hub methodology for identifying reforestation opportunity.⁵⁷ The most common BPS class across both AO and RN patches was ‘Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest.’ Per [LANDFIRE’s description](#), these systems tend to be dominated by Douglas-Fir, Ponderosa Pine, and Grand Fir (Figure 17).

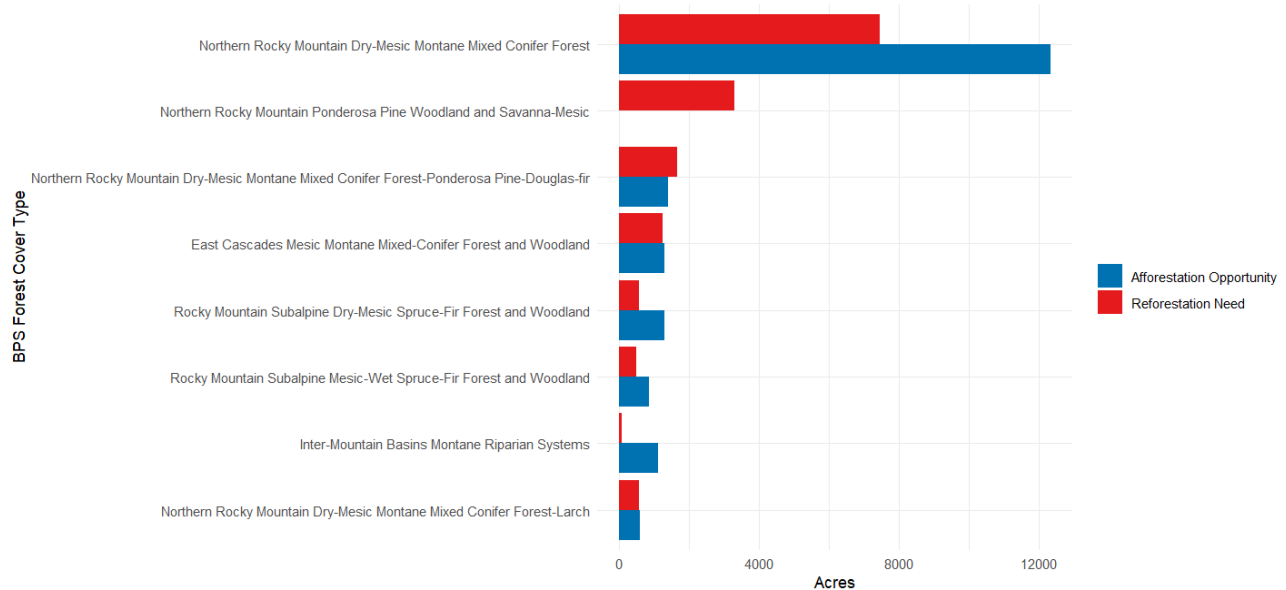


Figure19: Afforestation Opportunity and Reforestation Need by Forest Type. All BPS classes representing fewer than 500 acres were removed from graph for legibility.

⁵⁶ LANDFIRE. (2016). Biophysical Settings (BPS), Version 1.4.0. U.S. Department of the Interior, Geological Survey, and U.S. Department of Agriculture. <https://landfire.gov/vegetation/bps>.

⁵⁷ Cook-Patton, S. C., Gopalakrishna, T., Daigneault, A., Leavitt, S. M., Platt, J., Scull, S. M., Amarjargal, O., Ellis, P. W., Griscom, B. W., McGuire, J. L., Yeo, S. M., & Fargione, J. E. (2020). Lower cost and more feasible options to restore forest cover in the contiguous United States for climate mitigation. *One Earth*, 3(6), 739–752. <https://doi.org/10.1016/j.oneear.2020.11.013>.



While BPS data were essential for characterizing the potential vegetation communities of AO patches, RN patches could be considered in terms of National Forest Type (NFT) data⁵⁸. Concurrent with the BPS results for RN, Douglas-Fir and Ponderosa Pine – which dominate the Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest type – are the most common NFT classes across RN on WA DNR Managed Lands (Figure 18).

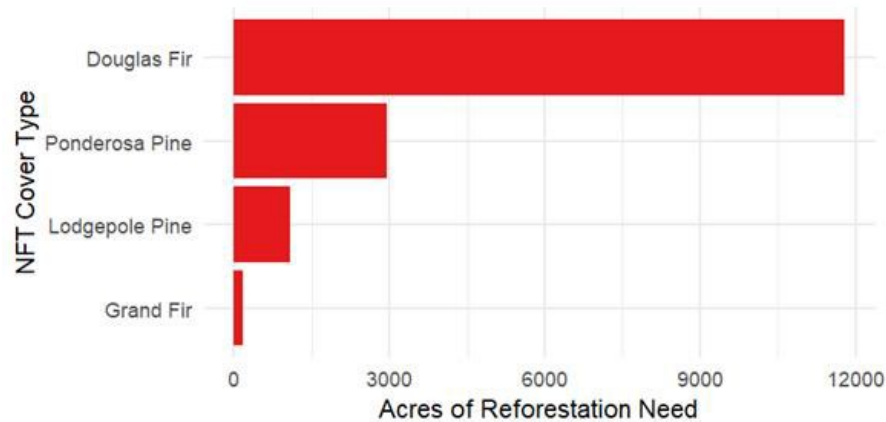


Figure 20: Reforestation Need on WA DNR managed lands by National Forest Type class.

XII. Findings from preliminary carbon feasibility assessments of two fire scars

To test potential financial feasibility of reforestation carbon projects on state lands, WA DNR selected two fire scars in eastern WA that, in combination, are broadly representative of the types of state lands that might be selected for carbon projects.

We tested financial feasibility for these two sites across four different ARR methodologies: Verra VM0047 v1.1, ACR ARR v1.2, CAR US Forest Protocol v5.1, and Isometric Reforestation v1.0. In terms of financial feasibility, we assumed costs of \$411/acre for site preparation and planting, a buffer pool reservation of 20%, and a discount rate of 5%.

All four methodologies yielded relatively similar results in terms of carbon storage and financial feasibility at each project site. Isometric feasibility estimates showed slightly lower carbon storage per acre due to the inclusion of life cycle emissions resulting from reforestation project activities, but as Isometric carbon credits often sell for higher prices, this lower credit issuance rate is unlikely to result in lower overall revenues than with the other three methodologies tested. Gold Standard’s ARR methodology was not tested for feasibility here, but is not expected to yield significantly different results.

a. Carlton Complex Fire

⁵⁸ US Forest Service Geospatial Technology and Applications Center. 2025. https://data.fs.usda.gov/geodata/rastergateway/forest_type/.



The Carlton Complex fire—one of the largest contiguous fires in Washington State history—burned 256,100 acres in Okanogan County in north central Washington in 2014, including approximately 48,750 acres of WA DNR-managed lands. Since 2014, the fire scar has seen limited natural regeneration and has not yet been replanted. This landscape has relatively low precipitation (300-500 mm annually) and low productivity in terms of timber growth. Initial estimates based on a WA DNR planting prescription of 200 trees per acre (TPA) of 100% ponderosa pine show approximately 20-40 tons CO₂e of cumulative potential carbon storage per acre over the first 40 years.

Preliminary financial feasibility estimates show that this site would not be a good fit for carbon project development, in that carbon revenues alone likely would not be sufficient to cover all reforestation costs. The carbon sequestration and revenues that could be generated from this project, even at prices of \$100/ton or more, are not sufficient to cover the expected planting and other project development costs of over \$400/acre. Carbon prices of \$130/ton or higher can make this project viable, but are unlikely to be palatable to carbon buyers in the near term and would require a firm 10-year or longer credit pre-purchase by a company to reduce the risk of no credit sales.

If sites like the Carlton Complex are considered high priority for WA DNR to replant, this might be achieved through partial subsidization of reforestation costs in addition to carbon credit revenues, or by leveraging alternative, non-carbon ecosystem services markets (see section XIII). If a carbon crediting project is to be developed at these lower-productivity sites, a project developer may be more interested in engaging through a fee-for-service model rather than a share of carbon revenues.

The low viability of this site is primarily due to low site productivity, low planting density, and planting with only ponderosa pine, which sequesters carbon more slowly than other native conifer species like Douglas fir.

b. Jolly Mountain Fire

The Jolly Mountain fire in central eastern WA burned for three months across 36,800 acres in 2017 on Okanogan-Wenatchee National Forest, as well as on land managed by WA DNR and The Nature Conservancy. The landscape has higher average precipitation than the area of the Carlton Complex Fire, and has higher productivity. Initial estimates based on a WA DNR planting prescription of 250 TPA with a mix of 50% ponderosa pine, 25% western larch, and 25% Douglas fir show sequestration of 50-80 potential tons CO₂e per acre over 40 years, depending on the methodology used and their buffer pool reserve requirements.

Preliminary financial feasibility estimates show that this fire scar could potentially support a carbon project, particularly at prices above \$40/ton.

The higher financial viability of this site for carbon projects is driven by moderate site productivity, slightly higher planting density, and planting faster carbon-sequestering species in addition to ponderosa pine.



XIII. Ecosystem services markets beyond carbon

The voluntary carbon market is only one example of “payments for ecosystem services” (PES) markets that could be used to support ecosystem health and restoration activities. In all PES markets, landowners, land managers, and other asset owners are incentivized either to reduce polluting activities, or compensated for offsetting others’ polluting activities through specific ecosystem restoration activities. Examples of ecosystem services markets beyond carbon include those related to habitat conservation and biodiversity (such as wetland mitigation banking and biodiversity credits), and those related to watershed health (such as soil conservation payments, water quality trading, and volumetric water rights payments, buybacks, and trading).

The voluntary carbon market is perhaps the most expansive and widely applicable PES market because there are many established and recognized pathways to reduce or sequester greenhouse gas emissions. However, as illustrated by the example of the Carlton Complex fire, some WA DNR lands may not be a good fit for carbon projects, in the sense that carbon credit revenue likely would not cover expected site preparation and planting costs. For these less productive or more marginal lands, watershed payments programs may be more suitable, especially if payors downstream of the land parcel own assets where water is critical for operations (such as a data center or power plant).

XIV. Case studies of forest carbon projects on state lands

A. Michigan

- a. *Lead state agency:* Michigan Department of Natural Resources
- b. *Project name:* Big Wild Forest Carbon Project
- c. *Developer partner:* Anew Climate
- d. *VVB:* SCS Global Services
- e. *Project structure:* Land leased to 3rd party developer for carbon project
- f. *Project type:* IFM
- g. *Project area:* 101,272 acres
- h. *Methodology used:* American Carbon Registry Improved Forest Management (IFM) on Non-Federal U.S. Forestlands
- i. *Registry project code:* [ACR 614](#)
- j. *Crediting period length:* 2020-2040
- k. *Revenue generated:* \$12M
- l. *Project summary:* The Bluesource - Michigan DNR Big Wild Forest Carbon Project is located on 101,272 acres of northern hardwood, mixed hardwood, and mixed conifer forests in Michigan’s Pigeon River Country State Forest, in the Northern Lower Peninsula of Michigan. The property encompasses acreage in Otsego, Cheboygan, Presque Isle and Montmorency counties. Most of northern Michigan, including Pigeon River Country, was logged aggressively between 1860 and 1910, and was explored for other resource extraction, including oil and



gas. After large parts of Pigeon River Country were reverted to state ownership, the project area was managed for multiple uses, including timber production, habitat, water quality, and recreation. The project action will allow the forest to progress naturally with less intensive commercial harvesting than would otherwise be expected on the state forestlands.

- m. *Learnings*: This was among the first registered carbon projects on state lands in the U.S., and Michigan DNR optimized for ease of setup rather than project quality or integrity. Critics have claimed that was very little additionality from this project, meaning that the amount of harvesting that would have taken place would have been similar in a non-carbon crediting scenario.^{59,60} Critics have also raised environmental justice concerns, in that the main buyer (a natural gas utility based in Detroit, MI called DTE Energy) will continue emitting pollutants and will pay Michigan DNR for offsets without compensating the local communities that are most harmed.⁶¹ Michigan DNR has gone on to develop additional carbon projects, and has had difficulty selling more recent projects after the first sale to DTE Energy.
- n. *Links*: [Project context](#); [Project Design Document \(PDD\) and other registry project documents](#).

B. Oregon

- a. *Lead state agency*: Oregon Department of State Lands
- b. *Project name and location*: Elliott State Research Forest
- c. *Developer partner*: Anew Climate
- d. *Project structure*: Land leased to 3rd party developer for carbon project
- e. *Project type*: IFM
- f. *Project area*: ~83,000 acres
- g. *Methodology used*: ACR Improved Forest Management (IFM) on Non-Federal U.S. Forestlands
- h. *Registry project code*: [ACR1143](#)
- i. *Crediting period length*: 40 years
- j. *Revenue generated*: TBD (project not yet issuing credits, potentially up to \$9M)⁶²
- k. *Project duration*: 80 years
- l. *Project summary*: The Oregon Department of State Lands manages the Elliott State Research Forest (ESRF), established in 2024, and envisions turning it into a world-class research forest. The OSU research plan and associated HCP

⁵⁹ Samilton, T. (2024, February 18). Critics say DTE Energy's "Natural Gas Balance" program is more marketing than emissions reducing. *Michigan Public Radio-NPR*. <https://www.michiganpublic.org/environment-climate-change/2024-02-18/critics-say-dte-energys-natural-gas-balance-program-is-more-marketing-than-emissions-reducing>.

⁶⁰ Cass, C. (2022, October 18). Michigan carbon offsets: Success or scam? *Great Lakes Echo*. <https://greatlakesecho.org/2022/10/18/michigan-carbon-offsets-success-or-scaml/>.

⁶¹ Thompson, C. (2021, October 13). Is this Michigan forest the key to reducing the state's carbon? *Phys.org*. <https://phys.org/news/2021-10-michigan-forest-key-state-carbon.html>.

⁶² Baumhardt, Alex. 2024. "Oregon inks agreement with developers to enter entire state forest into carbon market." *Oregon Capital Chronicle*. <https://oregoncapitalchronicle.com/2024/10/31/elliott-state-forest-anew-carbon-credits/>



voluntarily set aside tens of thousands of acres of timber as forest reserves for the 80-year HCP term.

- m. *Learnings*: The project has been listed on ACR but has not yet completed validation, and is still in the process of inventory and baseline measurement as of June 2025.
- n. *Links*: [Registry project listing](#); [Registry project documentation](#).
- o. Contact: Brett Brownscombe, Brett.Brownscombe@dsl.oregon.gov

C. Colorado

- a. *Lead state agency*: Colorado State Land Board (CSLB)
- b. *Developer partner*: Land Life Company USA PBC (Land Life)
- c. *Project structure*: Land leased to 3rd party developer (Land Life) for carbon project after approval by the Commissioners of the Colorado State Land Board; will be implemented by Land Life & Colorado State Forest Service (CSFS). Land Life will do the planting work and other implementation for the first 3 years, after which the CSFS takes over everyday land management. The lease term is 40 years, after which the land reverts back to Colorado. Land Life pays a per-acre fee to the Colorado State Land Board (essentially the lease payment) rather than sharing proceeds from carbon credit sales.
- d. Expectation that land will remain forested for 100 years, but no lease obligation after year 40 unless SLB renews forest carbon project on registry
- e. *Project type*: post-fire reforestation (ARR)
- f. *Project area*: ~1,000 acres across 5 properties
- g. *Methodology used*: Verra VM0047
- h. *Crediting period length*: 2025-2065
- i. *Revenue generated by the state agency*: \$87,500
- j. *Project duration*: 100 years
- k. *Learnings*: Based on the contract terms, the state of Colorado will be able to fully cover its planting costs (because they will be covered by Land Life) and to receive a nominal amount back toward the state budget. It was also able to develop a reforestation carbon project while maintaining existing grazing and other leases.
- l. *Project summary*: In 2025, The Colorado State Board of Land Commissioners (State Land Board) approved an ecosystem services forest carbon lease with Land Life Company USA PBC (Land Life), marking the first forest carbon production lease on state trust property in Colorado. The project will restore up to 1,000 acres of land severely damaged by wildfires across Grand, Huerfano, and Larimer counties. The State Land Board initially identified nearly a dozen parcels for Land Life to evaluate through remote sensing and then field visits, analyzing attributes including project size, burn severity, salvage, and the status of natural regeneration. After the evaluation process, Land Life identified five properties significantly impacted by the Spring Creek (2018), Silver Creek (2017), High Park (2012), and Cameron Peak (2020) wildfires as best suited for reforestation and inclusion in the carbon project.



The State Land Board and Land Life view this first lease agreement as an exciting pilot program that could serve as a model for reforestation on other state trust properties in the future.

- m. Links: [CO SLB Press Release](#), [Land Life Press Release](#).
- n. Contact: Emily Barbo, Colorado State Land Board, 720-854-3330, emily.barbo@state.co.us; Clara Rowe, Land Life, 603-986-7434, c.rowe@landlifecompany.com

D. Hawaii

- a. *Project name*: Ola Hou – Restoring Hawaii’s Native Forests
- b. *Lead state agency*: State of Hawai’i Department of Land and Natural Resources Division of Forestry and Wildlife
- c. *Developer partner*: none (fully developed by State of Hawai’i Department of Land and Natural Resources)
- d. *VVB*: Aster Global Environmental Solutions Inc.
- e. *Project structure*: This project aims to afforest degraded pasturelands
- f. *Project type*: REDD
- g. *Project area*: 1,562 acres
- h. *Methodology used*: Verra VM0047 – Climate, Community, and Biodiversity (CCB) label
- i. *Registry project code*: [VCS 2321](#)
- j. *Crediting period length*: 40 years (2015-2035 is the first crediting period)
- k. *Revenue generated*: N/A (no credits have been issued as of June 2025; first verification will be in 2026)
- l. *Project duration*: 2015-2055
- m. *Learnings*: This project has taken at least five years to get registered and validated, in part because the project activities were undertaken before a baseline was established (which then makes it much more difficult to establish a baseline of climate impact). It is an aggregated project that can (theoretically) include any land in Hawaii, and is meant to serve as a demonstration project. The Department of Land and Natural Resources is working to identify additional potential parcels to add to the initial project area, and is waiting for regulatory clarity on the ability to sell carbon credits to corporate buyers located outside Hawaii.
- n. *Project summary*: In February 2015, the State of Hawai’i Department of Land and Natural Resources (DLNR) initiated the Ola Hou – Restoring Hawai’i’s Native Forests project. Project activities were implemented by the project proponent in Nakula Natural Area Reserve (NAR) and Kahikinui Forest Reserve (FR) in Leeward Haleakalā in the county and island of Maui (State of Hawai’i), and include construction, expanding and maintaining fence line, controlling and removing feral livestock and non-native ungulates, planting native trees and plants, and monitoring and removing invasive species. Additional planting activity was performed in partnership with the Leeward



Haleakalā Watershed Restoration Partnership (LHWRP) organization. The Nakula NAR and Kahikinui FR have been subjected to grazing by cattle, feral goats and hogs for over 100 years. Over this time, subject to this grazing pressure, the forest gave way to non-native savannah grassland composed almost entirely of invasive grass species. Due to a large population of feral ungulates and the steep terrain in this region, vegetation loss leading to erosion of topsoil has led to further degradation and loss of carbon stocks from the project sites. By planting and facilitating the natural regeneration via removal of feral ungulates, native woody species such as koa (*Acacia koa*), 'ōhi'a (*Metrosideros polymorpha*), olopua (*Nestegis sandwicensis*), mamane (*Sophora chrysophylla*), and pukiawe (*Styphelia tameiameia*) are being restored, creating essential habitat for rare native flora and fauna, and carbon is being sequestered. These project instances are expected to remove an average of 287 t CO₂ annually from the atmosphere over the project lifetime. Restoration of koa and 'ōhi'a forests in Hawai'i will provide positive climate change adaptation benefits, including increasing available water, reducing soil erosion, and providing higher elevation, quality wildlife habitat. This project is to be registered under the Verified Carbon Standard (VCS) as a grouped ARR project and is being developed in compliance with Verified Carbon Standard, version 4.5 and VCS AFOLU Requirements using VM0047 Methodology v1.0. This project is also being registered under the Climate, Community, and Biodiversity Standard version 3.1.

- o. *Links:* [Project listing on Verra registry](#)
- p. *Contact:* Jennifer Grimm, 1+ 808 587-0166, jennifer.w.grimm@hawaii.gov

E. California

- a. *Lead state agency:* CA Department of Parks and Recreation
- b. *Developer partner:* none (fully developed by CA Department of Parks and Recreation)
- c. *Project name:* The Cuyacama Rancho State Park (CRSP) Reforestation Project
- d. *Project structure:* Project developed on state forest lands solely by CA Department of Parks and Recreation, supported by corporate philanthropic funding.
- e. *Project type:* post-fire reforestation
- f. *Project area:* 5,664 acres
- g. *Methodology used:* Climate Action Reserve Forest Project Protocol, v. 3.2
- h. *Registry project code:* [CAR 505](#)
- i. *Crediting period length:* 40 years
- j. *Revenue generated:* None
- k. *Project duration:* 2007-2011
- l. *Known buyers or corporate funders:* Disney, Odwalla, Poseidon Water, ConocoPhillips
- m. *Learnings:* The project was registered with CAR in 2009, but has never issued credits despite extensive project documentation and project verification completed in 2011. The majority of the project budget was used for site prep (44%) and follow-on



- treatments (32%), with the remainder of the budget going towards outreach (15%) and post-planting monitoring (9%). Planting first began in 2008, and given the extensive land area, Cal Parks continued planting parts of the project through 2020.
- n. *Project summary:* The Cuyamaca Rancho State Park (CRSP) Reforestation Project is a project to create long-term climate benefits and restore a conifer forest which was destroyed by a significant natural disturbance. CRSP is 40 miles (64 km) east of San Diego within the Peninsular Range of mountains. The project consists of 2530 acres (1023 ha) in the 24,768 acre (10,023 ha) park, in dispersed patches designed to restore the mixed conifer forests of the park over time. In October and November of 2003, the Cedar Fire burned over 279,900 acres (113,000 ha) in Southern California including almost the entire CRSP. Conifer mortality in the park was high (>95%) due to extremely high temperatures which resulted in low seed cone survival. Post-fire vegetation has been dominated by herbs, shrubs and re-sprouting oak species. The goals of the project are to restore the biodiversity and ecosystem functioning of the park and protect it from threats of damaging wildfire, disease, and invasive exotics.
 - o. Links: [CAR 2011 project summary](#); [list of registry project documents](#).

XV. Conclusion

Carbon markets are the most developed markets for payments for ecosystem services globally, and can be a powerful tool for funding reforestation and other forest-based projects on state lands. At the same time, carbon markets have faced repeated setbacks and criticism from the scientific community, which has tempered demand for carbon credits. Reforestation-based carbon credits are considered among the highest-quality kinds of carbon credits, and as of June 2025, American Forests anticipates that demand for these credits will continue to be sufficient to warrant development of carbon projects on WA DNR-managed lands.

Carbon markets present an opportunity for WA DNR to reforest areas that have been burned or otherwise heavily degraded and unable to naturally regenerate as forest. They may be especially helpful for areas in Eastern Washington that are less productive than high timber productivity areas in coastal Washington, but productive enough to sustain multiple species (aside from only ponderosa pine) and therefore to result in sufficient carbon sequestration for successful carbon projects.

Learning from other state-developed carbon crediting projects, we recommend that WA DNR consider partnering with a carbon project developer with experience developing and selling carbon credits from reforestation projects, and with strong relationships to corporate buyers of carbon credits. This will help reduce the risk that WA DNR invests time and resources into developing carbon projects that are ultimately unable to sell credits and thereby recoup WA DNR's reforestation and other costs.



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Chapter 5 – Appendix A:

Identifying Eligible Areas for Afforestation, Reforestation, Revegetation (ARR) Carbon Project Development on Washington Department of Natural Resources Managed Lands

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Abstract

Background: In this Chapter we identified areas within Washington State Department of Natural Resources (WA DNR) managed lands that meet regulatory criteria for inclusion in carbon markets, specifically for afforestation and reforestation (ARR) carbon projects. This work builds on the results of Chapter 1 and Chapter 4 in which Reforestation Need (RN) and Afforestation Opportunities (AO) were identified across the whole of Washington State. Here, we refined those statewide results by applying additional spatial filters to identify potentially eligible and operational areas (≥ 25 -acre patches) for ARR carbon project development on WA DNR managed lands.

Results: The results of our analysis indicate that there are over 37,000 acres across WA DNR managed lands where ARR carbon project development may be suitable based on the requirements of leading ARR carbon crediting methodologies. We also provide analyses of AO and RN potential by seed zone, forest cover type, and pre-existing encumbrances and leases. Of these potentially eligible acres $\sim 16,600$ may be suitable for reforestation specifically. These sites represent the highest priority areas for ARR carbon projects as post-fire reforestation addresses risk of conversion to non-forest land cover and involves minimal risk in displacing agricultural production relative to afforestation projects.

Conclusion: While each area will require ground truthing prior to any tree-planting activities, these results highlight the scale of the opportunity and specific locations where WA DNR may focus its subsequent feasibility assessments. The potential area eligible for carbon projects may also increase over time with subsequent wildfires and expirations of Agreements that may inhibit carbon project development. Carbon project development in these areas may complement and enhance long-term forest management objectives by providing additional finance to re-establish forest cover.

Keywords: reforestation, afforestation, ARR, Pacific Northwest, wildfire, forest management, carbon, Washington



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Contents

Abstract	1
Acknowledgements	2
Table of Contents	3
Introduction	4
Methods	4
Identification of Reforestation Need and Afforestation Opportunity on WA DNR managed lands	4
Carbon-Informed Spatial Filtering	4
Identification of Operable Units via Patch Analysis	5
Results	6
ARR Opportunity across WA DNR Managed Lands	6
ARR Opportunity on existing leases & encumbrances	6
ARR Opportunity per Biophysical Settings Data	7
Conclusion	10
Literature Cited	11

List of Tables and Figures

Table 1	7
Figure 1	6
Figure 2	8
Figure 3	9
Figure 4	9



Introduction

In this Chapter we identified areas within Washington State Department of Natural Resources (WA DNR) managed lands that meet regulatory criteria for inclusion in carbon markets, particularly for potential afforestation and reforestation carbon projects. This work builds on the results of Chapter 1 and Chapter 4 in which Reforestation Need (RN) and Afforestation Opportunities (AO) were identified across the whole of Washington State. Here, we refined those statewide results by applying additional spatial filters – excluding non-WA DNR managed lands as well as areas overlapping with wetlands, irrigated agricultural lands, and non-forest Biophysical Settings classes – to identify areas eligible for Afforestation, Reforestation, and Revegetation (ARR) carbon project development on WA DNR managed lands.

To further support implementation planning, we conducted a patch analysis to delineate operable units based on spatial contiguity and minimum area thresholds. We also provide forest type data from National Forest Type (NFT) and Biophysical Settings (BPS) datasets to assist WA DNR in prioritizing seed types. The results of this analysis provide Washington Department of Natural Resources (WA DNR) with an initial framework for identifying and prioritizing the development of ARR carbon projects on WA DNR managed lands.

Methods

Identification of Reforestation Need and Afforestation Opportunity on WA DNR managed lands

We began by combining data from Chapters 1 and 4 representing RN and AO for Washington State. Though the results of the previous Chapters are purposefully not spatially explicit, the underlying data can still be used to identify potential tree-planting opportunities. Of the three different RN scenarios modeled in Chapter 1 based on seed dispersal distance, we selected the 60m distance to represent RN for this analysis. 60m is the median distance beyond which regeneration is unsuccessful in Western forests and thus provides a threshold where intervention may be required to promote forested conditions (Stevens-Rumann and Morgan, 2019). Combined with AO identified in Chapter 4, these layers provided spatially explicit representations of areas where forest loss or degradation due to timber harvest, severe fire, or agricultural conversion may have occurred across the state. We then clipped these data to the extent of WA DNR managed lands, limiting our analysis to lands currently under the jurisdiction of WA DNR where tree-planting activities may be warranted.

Carbon-Informed Spatial Filtering

Next, we applied a series of spatial filters to the identified AO and RN on WA DNR managed lands to align with carbon regulatory requirements and agency priorities. First, we removed all areas classified as “Wetlands” in the ‘LCL_RS_RPT’ attribute of WA DNR’s *Large Data Overlay* (LDO, accessed 1/25/2024) dataset. Removing these areas is consistent with most leading carbon methodologies’ requirement to avoid ARR projects on wetlands or organic soils (i.e., peatlands) so as not to manipulate the water table, release additional, potent greenhouse gases



like methane as a result of reforestation, or degrade carbon-rich ecosystems (American Carbon Registry, 2017; Gold Standard Foundation, 2024; Verra, 2023).

We then excluded areas with irrigated agricultural lands as identified by WA DNR managed land parcels with the “Agreement 12” value in WA DNR’s *NatureE – Encumbrance Polygons* dataset (accessed March 2025). WA DNR indicated that these irrigated areas should remain in agricultural production and were therefore not candidates for Afforestation. Secondly, converting these areas to forest cover could introduce risks of market leakage for agricultural commodities associated with decreased onsite production – thereby potentially undercutting carbon benefits (Isometric, 2024). By excluding these areas, displaced agricultural production – i.e., leakage – risks are minimized.

Next, we removed all pixels with non-forested vegetation types based on the ‘VEG CLASS’ attribute in LANDFIRE’s Biophysical Settings dataset (LANDFIRE, 2016). Specifically, we excluded all pixels in any of the following classes: ‘Barren’, ‘Grassland’, ‘Water’, ‘Perennial Snow/Ice’, ‘Shrubland’, and ‘Sparse Vegetation’. Only pixels in the ‘Conifer’, ‘Hardwood’, ‘Hardwood-Conifer’, and ‘Riparian’ classes were considered for the remainder of the suitability analysis. This step ensured that selected areas reflected plausible biophysical potential for long-term forest establishment.

Identification of Operable Units via Patch Analysis

Last, we performed a patch analysis to identify areas large enough to justify reforestation or afforestation activities. Based on consultation with WA DNR, a minimum area threshold of 25 acres within a 0.5 km² window was established to identify ‘viable’ tree-planting units and ensure neighboring but non-contiguous areas of AO and RN could be included within an operationally feasible single implementation unit.

To identify potential implementation units for ARR carbon projects, we applied a moving window analysis to the filtered (30m pixel) AO and RN raster layers. Using a 720m x 720m (~128 acre) window, we calculated the total area of qualifying pixels (i.e., the area within the window comprising RN or AO pixels with a reforestation need or afforestation opportunity) using focal statistics at a 30m increment. We retained only those pixels at the center of each window where the total area was either equivalent to or exceeded 25 acres. This approach identified pixels as the centers of ‘hot spots’ (i.e., individual pixels surrounded by \geq 25 acres of RN or AO), but these individual pixels do not include all pixels that contributed to the 25-acre minimum threshold. To capture contributing pixels, we buffered each hot spot by 12 pixels – half the length of the window – in all directions, thereby identifying the full extent of each operable unit. The result is a spatial layer representing implementation-ready units – areas that met all ecological, regulatory, and operational thresholds – while excluding small, fragmented patches unlikely to support viable projects.

To support implementation planning, we summarized the total area of RN and AO by Biophysical Settings (BPS) class – or by National Forest Type (NFT) class where applicable for AO to align with Chapter 1 – seed zone, and lease type. This stratification was intended to



provide WA DNR with actionable insights regarding where tree planting needs are concentrated on WA DNR managed lands, a consideration of tree-planting feasibility with respect to existing leases, and what types of seedlings may be required, and from which seed transfer zones those seedlings may be sourced.

Results

ARR Opportunity across WA DNR Managed Lands

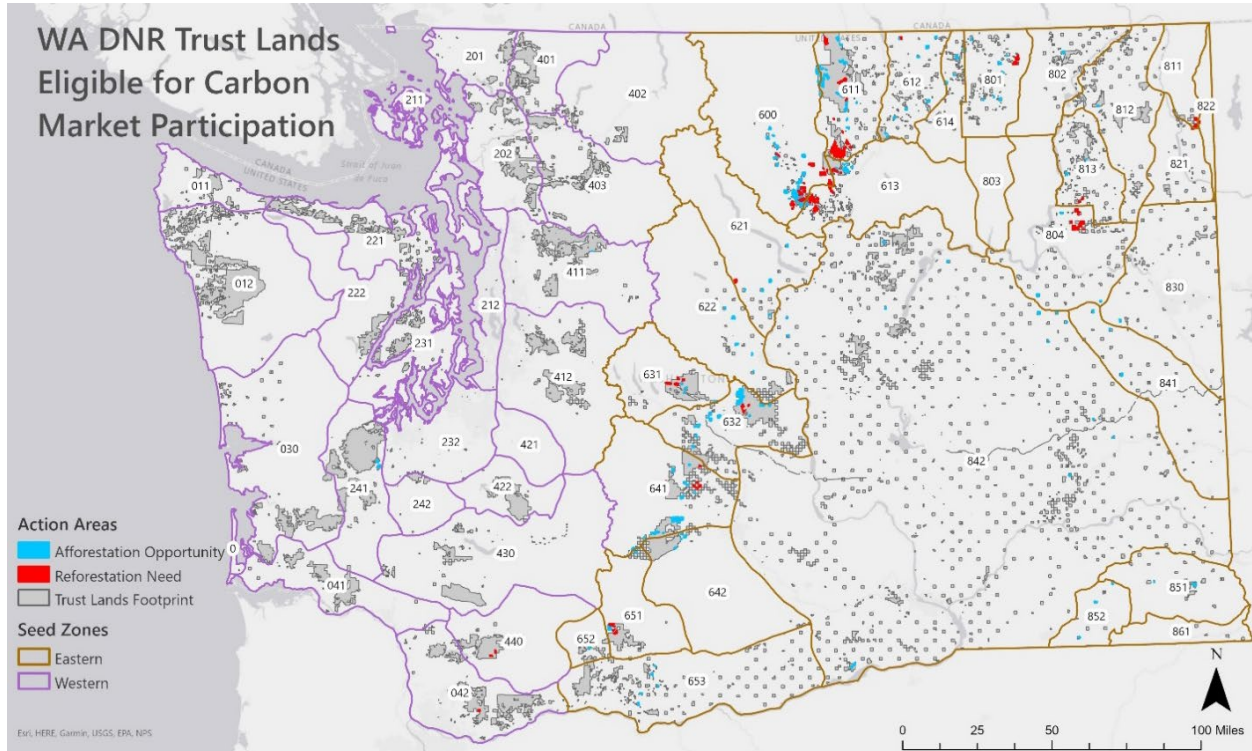


Figure 1. Map of Afforestation Opportunity and Reforestation Need identified on WA DNR managed lands eligible for Carbon Market participation. Area enhanced for visibility.

Our analysis identified ~16,600 acres of Reforestation Need and ~20,600 acres of Afforestation Opportunity across WA DNR managed lands (Figure 1). The overwhelming majority of these acres (98%) were in Eastern Washington, defined as east of the Cascade Mountains crest. Seed Transfer Zones 600, 611, and 613 were among the top five seed zones for both greatest AO and greatest RN and had the greatest overall tree-planting opportunity (Table 1). A more detailed breakdown of AO and RN by Seed Zone and region is included in [supplementary documents](#) ([AORN_SeedZones.xlsx](#)) alongside a similar breakdown of AO and RN by Regional Inventory Unit parcel ([AORN_RIUs.xlsx](#)).

ARR Opportunity on existing leases & encumbrances

Pre-existing leases or encumbrances (hereafter referred to as 'Agreements') may present WA DNR with barriers to carbon project implementation. We recommend WA DNR conduct a



thorough review of any such Agreements on prospective project sites before initiating carbon project development. The Agreement types that overlapped the most with prospective AO and RN areas were 60: *Special Use Permits* (~23,000 acres) followed by 11: *Permit Ranges* (~17,800 acres), 10: *Grazing Leases* (~12,000 acres), and 78: *Water Rights* (~8,400 acres).

Agreements on WA DNR managed lands often overlap with other Agreements. The most common overlapping Agreement types in both RN and AO areas were 11: *Permit Range* and 60: *Special Use Permits* (Figure 2). ARR project activities that cause the agricultural output of areas with Grazing, Range, or Dry Land Agricultural Agreements to decrease agricultural productivity may require additional agricultural commodity leakage deduction from carbon credits. The specifics of any such deductions will depend on WA DNR’s chosen carbon methodology.

Rank	Region	Seed Zone	Afforestation Opportunity Acres	Rank	Region	Seed Zone	Reforestation Need Acres
1	East	600	5,452	1	East	611	5,618
2	East	632	2,849	2	East	600	3,629
3	East	611	2,423	3	East	613	1,690
4	East	641	2,065	4	East	804	1,614
5	East	613	1,197	5	East	631	852

Table 6. Reforestation and Afforestation Opportunity in Eastern and Western WA DNR managed lands.

ARR Opportunity per Biophysical Settings Data

Echoing Chapter 4, we used LANDFIRE Biophysical Setting (BPS) to identify potentially suitable forest types in identified AO and RN patches on WA DNR managed lands (LANDFIRE, 2016). BPS data are estimates of what vegetation communities – including forest types – occurred historically on the landscape prior to Euro-American settlement. These estimates are essential for identifying what forest types could be supported on currently non-forested areas (i.e., AO patches). Use of BPS data also aligns with the original Reforestation Hub methodology for identifying reforestation opportunity (Cook-Patton et al., 2020). The most common BPS class across both AO and RN patches was ‘Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest.’ Per LANDFIRE’s description, these systems tend to be dominated by Douglas-Fir, Ponderosa Pine, and Grand Fir (Fig. 3).

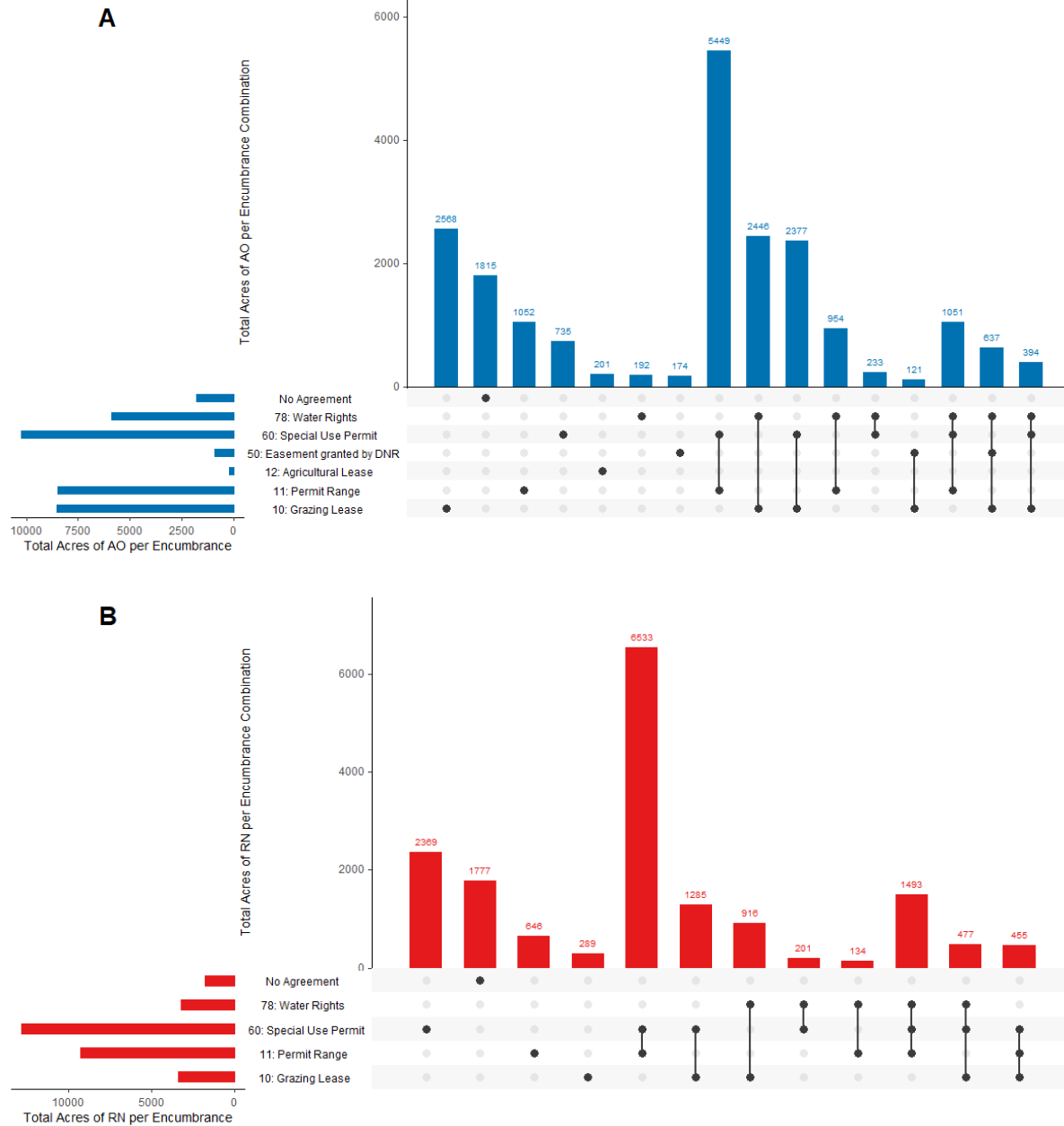


Figure 2. (A) Afforestation Opportunity by Lease and Encumbrance Type on WA DNR Managed Lands. (B) Reforestation Need by Lease and Encumbrance Type on WA DNR Managed Lands. In these UpSet plots (Conway et al., 2017; Lex et al., 2014) horizontal bars show total size of each Agreement type in acres. The matrix of dots and connecting lines in the center represent unique combinations of Agreement types where each row corresponds to a single Agreement type and each column represents a unique intersection of one or more Agreement types. The vertical bar chart on the top quantifies the area in acres of each Agreement combination (i.e., the number of acres encompassed by that specific combination of overlapping Agreements on WA DNR managed lands). All Agreement combinations with fewer than 100 acres were removed from graphic to enhance legibility.

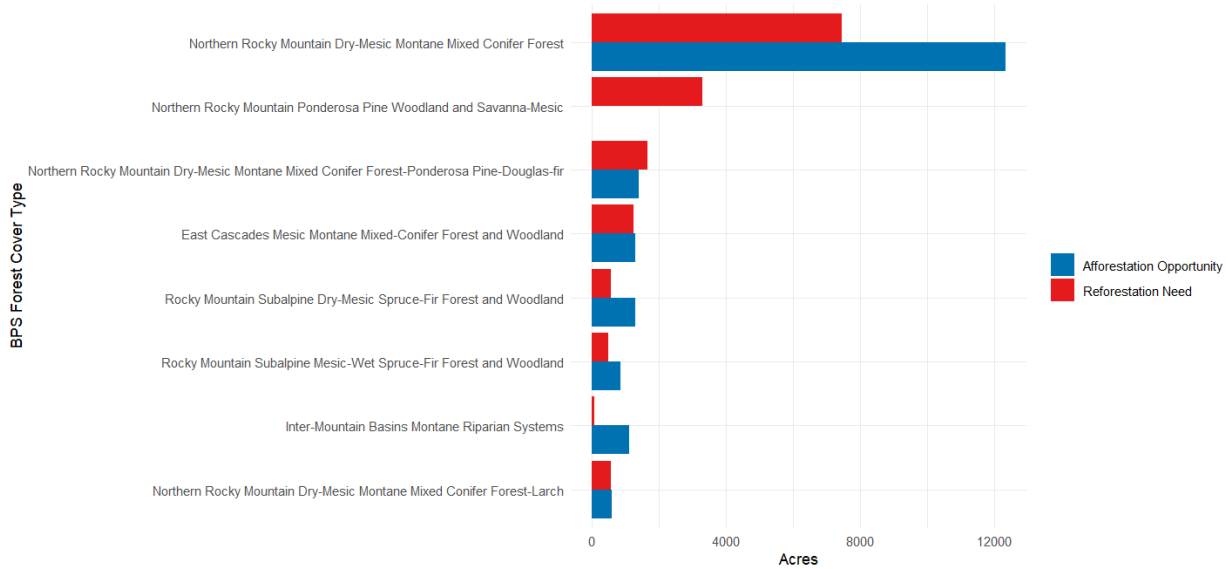


Figure 3. Afforestation Opportunity and Reforestation Need by Forest Type. All BPS classes representing fewer than 500 acres were removed from graph for legibility.

While BPS data were essential for characterizing the potential vegetation communities of AO patches, RN patches could be considered in terms of National Forest Type (NFT) data from the US Forest Service Geospatial Technology and Applications Center (https://data.fs.usda.gov/geodata/rastergateway/forest_type/; accessed October 2024). Concurrent with the BPS results for RN, Douglas-Fir and Ponderosa Pine – which dominate the Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest type – are the most common NFT classes across RN on WA DNR managed lands (Figure 4).

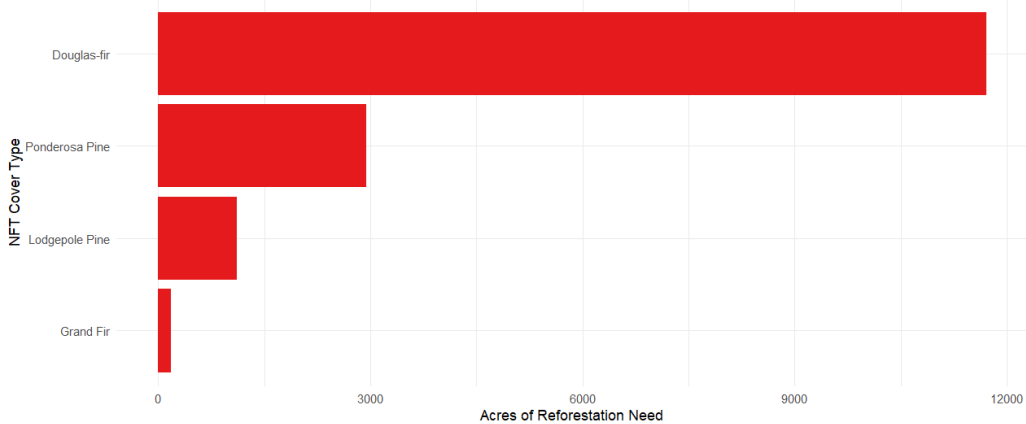


Figure 4. Reforestation Need on WA DNR managed lands by National Forest Type class. All BPS classes representing fewer than 100 acres and 'non-forest' land cover class area excluded from graph for legibility.



Conclusion

Over 37,000 acres across WA DNR managed lands were identified in this analysis as being potentially eligible for ARR carbon projects. These areas represent both a current opportunity for re-establishing forest cover and an eligibility based on the requirements of leading ARR carbon crediting methodologies discussed elsewhere in this report. While each area will require ground truthing prior to any tree-planting activities, these results highlight the scale of the opportunity and specific locations where WA DNR may focus its subsequent feasibility assessments. The potential area eligible for carbon projects may also increase over time with subsequent wildfires and expirations of Agreements that may inhibit carbon project development.

Approximately 16,600 acres of RN were identified on WA DNR managed lands. These sites represent the highest priority areas for ARR carbon projects. Post-fire reforestation addresses risk of conversion to non-forest land cover and involves minimal risk in displacing agricultural production (i.e., leakage) relative to afforestation projects. Most of these sites are in Eastern Washington and dominated by dry conifer forest types. As such, they are unlikely to conflict with existing timber production and harvesting goals. Rather, carbon project development in these areas may complement and enhance long-term forest management objectives by providing additional finance to re-establish forest cover.



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Overarching Conclusion

Washington State faces an escalating need for reforestation and a substantial potential for afforestation across its landscape. This comprehensive assessment identified nearly one million acres of reforestation need generated in the last decade and the potential future need is likely to dramatically increase through mid-century in fire-prone Eastern Washington. Beyond reforesting impacted areas, our analysis identifies over 736,350 acres of persistent non-forested land with potentially viable afforestation opportunities, primarily on private lands. Addressing these multifaceted challenges and achieving the ambitious goal of reforesting and afforesting one million acres by 2040 demands a unified, proactive, and adaptive management approach that recognizes the interconnectedness of the entire forest restoration ecosystem.

Key Recommendations and Next Steps

Our findings underscore several recommendations that can greatly enhance Washington's reforestation efforts. First, developing a holistic, adaptive and strategic reforestation plan is strongly recommended. This plan should account for different drivers of reforestation need across the state. Focusing on fire-resilient forest management and post-fire reforestation strategies for Eastern Washington while continuing to support timber harvest demand and reforestation in Western Washington is crucial to meeting the one million acres of reforestation goal. There is also significant potential for afforestation on grasslands, shrublands, pasturelands, and marginal croplands. These opportunity areas will require additional consideration of suitability, ecological benefit, competing conservation values, and existing land uses, but could theoretically contribute to additional seed need beyond the current and projected reforestation need. The Washington reforestation plan should also emphasize climate adaptation strategies, including investments in wildfire mitigation like fuel reduction and prescribed burning and promotion of genetically appropriate, climate-adapted seed. It is crucial that the overall strategy considers potential shifts in species distribution and the need for assisted migration, ensuring the "right tree in the right location" for future forest resilience. To inform and ensure best practices this adaptive reforestation approach should tailor strategies to specific site requirements and projected environmental conditions, as well as allowing learnings to inform and adjust approaches. An all-lands approach, encompassing federal, state, Tribal, and private ownerships, is strongly recommended. This should prioritize building trusted partnerships to maximize impact and efficiency. A comprehensive seed strategy should be developed that primarily focuses on collecting adaptive and diverse seed from areas with strong genetics to increase resiliency to drought and heat events. This strategy should also include collecting from areas at risk of extirpation to preserve a seed bank of native species that might otherwise be lost and explore cultivating seed orchards to supplement wild collections.

Strengthening the reforestation supply chain through strategic investments and policy reforms is strongly recommended. This involves transitioning from short-term to long-term (e.g., 3-5 year)



contracts for nurseries and service providers, providing the necessary financial security and consistent demand for infrastructure investment, workforce development, and operational stability. Implementing fair pricing models that reflect the true cost and value of reforestation work, with a focus on best value over lowest bid, will better support reforestation efforts with higher quality end results. Optimizing nursery and seed capacity requires collaboration with private nurseries and seed banks to ensure an adequate supply of diverse, climate-informed seed-sourcing to align nursery capacity with projected reforestation and afforestation needs. Continued research into the reforestation demand-need misalignment will inform these adjustments. Significant investment in workforce development and support is also needed, encompassing training in management, leadership, and safety best practices. Addressing the administrative burdens faced by independent contractors by supporting them through Small Business Development Centers will directly boost the success of reforestation companies. Concurrently, reforming the H-2B visa program for longer-term commitments will ensure a stable and skilled labor force for both planting and site preparation, and de-risk business expansion.

Enhancing data, monitoring, and information accessibility will drive more effective decision-making. This includes implementing a comprehensive system for tracking harvest data, post-fire regeneration, and afforestation survivorship across all land ownerships to provide more accurate estimates of reforestation needs and success. Regular monitoring of planting success will allow for adaptive management, providing timely insights into the utility of specific plans. The establishment of a readily accessible, centralized information hub (e.g., a web platform) for all stakeholders is a need that has been expressed across the spectrum of professionals involved in reforestation. This hub should combine multi-decadal and cross-sectional knowledge that connects landowners with resources, surplus seedlings, and service providers. In addition, it could provide educational materials for small woodland owners and serve as a platform for communication among nurseries, reforestation service providers, and other organizations. Leveraging existing initiatives, such as American Forests' developing landowner resource hub, Sustainable Northwest's forthcoming Post-Fire Reforestation Guidebook for Non-Industrial Private Forestlands in Eastern Washington, and the [Reforestation, Nurseries, and Genetics Resources Directory and Marketplace](#) initiative, can accelerate this development. This could also include features to connect contractors with project opportunities.

Fostering robust collaboration and strategic partnerships is the only way forward to overcome the challenges in reforestation. This entails actively strengthening partnerships among federal agencies, Tribal governments, private landowners, non-profits, research institutions, and community stakeholders. Recognizing that a unified, integrated approach is essential for long-term success requires addressing and bridging perceived divides. The Pacific Northwest Reforestation Network (PNRN), currently in development, represents a pivotal opportunity to bring unprecedented value to regional reforestation efforts. By fostering a formal, collaborative structure, the PNRN can strategically streamline coordination, dismantle bottlenecks, optimize



the seed supply, and bolster workforce development. Moreover, its pooled technical expertise will be instrumental in defining the core attributes of effective funding mechanisms, with member organizations leveraging their advocacy capabilities to translate these insights into concrete policy changes and proactive solutions.

Finally, prioritizing and securing dedicated funding and leveraging carbon market opportunities can work toward obtaining the necessary financial support. This means advocating for and securing dedicated, long-term funding mechanisms to support all facets of reforestation efforts that includes cone collection, site preparation, planting, maintenance, wildfire risk reduction, climate adaptation strategies, workforce development, and the establishment and maintenance of infrastructure like a centralized information hub. Special attention should be given to simplifying funding access for small woodland owners through simple reforestation funds with fixed cost-share rates.

Furthermore, Washington DNR can pursue Afforestation and Reforestation (ARR) carbon project development on suitable managed lands (over 37,000 acres identified). This could involve exploring lease or easement agreements with third-party carbon project developers, particularly for moderate- to higher-productivity lands where carbon revenue returns are more likely to cover all project costs and ideally generate revenues for the state. Strategic carbon methodology selection focused on ex-post methodologies from reputable registries like ACR, Gold Standard, and Isometric, that align with WA DNR's management constraints (e.g., 99-year maximum commitment, and ability to remove fuels during site preparation) and which are approved by leading buyer coalitions is strongly recommended. A competitive RFP process to select qualified, high-integrity carbon project developers based on proven experience in U.S. reforestation carbon projects, a strong track record of selling premium carbon credits, and strong relationships with corporate buyers and buyer coalitions is advised. WA DNR should define its roles and focus on initial site identification, project design, upfront financing of planting and site prep, implementation of field activities, and monitoring after planting, with deviation requests to registries concerning mandatory reforestation clauses in WAC Title 222-34, project registration, verification, and carbon credit sales support from carbon project developers.

Remaining Gaps and Future Research

While this assessment provides a strong foundation, several critical gaps and areas for future research remain to be addressed. There is a need to further refine the socioeconomic indicators of climate vulnerability to prioritize outreach and investment for afforestation, particularly on private lands where incentives and carbon financing can drive change and align ecological integrity with equitable climate outcomes in high-vulnerability counties like Yakima. Furthermore, the estimate of potential afforestation is only a first step in identifying suitable afforestation projects. Additional study is needed to further constrain theoretically suitable lands by incorporating variables such as probability of survivorship, carbon sequestration potential,



habitat value, and landowner commitment. Future iterations of afforestation analysis could also incorporate urban expansion projections and dynamic prioritization based on patch size, riparian proximity, or biodiversity corridors. A deeper economic analysis of reforestation strategies, including long-term returns on investment from carbon markets and ecosystem services, would significantly strengthen resource allocation and support efforts to secure alternative funding or investments. While wildfire projections are included, a more nuanced understanding of how other large-scale disturbances (e.g., insect outbreaks, disease, and windthrow events) might impact future reforestation needs is warranted. Further analysis is needed to understand why demand does not align with need, which will better inform recommendations and approaches to increase demand for necessary reforestation efforts. Seed orchards, collection, and storage warrants further analysis to better understand seed needs and capacity. Finally, comparing Washington's reforestation projections and strategies with similar efforts in Oregon and other neighboring states offers valuable insights and opportunities for regional synergy, supporting broader reforestation strategies and policy support.

Washington State is better positioned to achieve its ambitious reforestation goals through the implementation of these recommendations and the proactive resolution of identified research and capacity gaps, thereby supporting the development of more resilient, biodiverse, and productive forests that contribute to the region's economic, social, and ecological well-being.