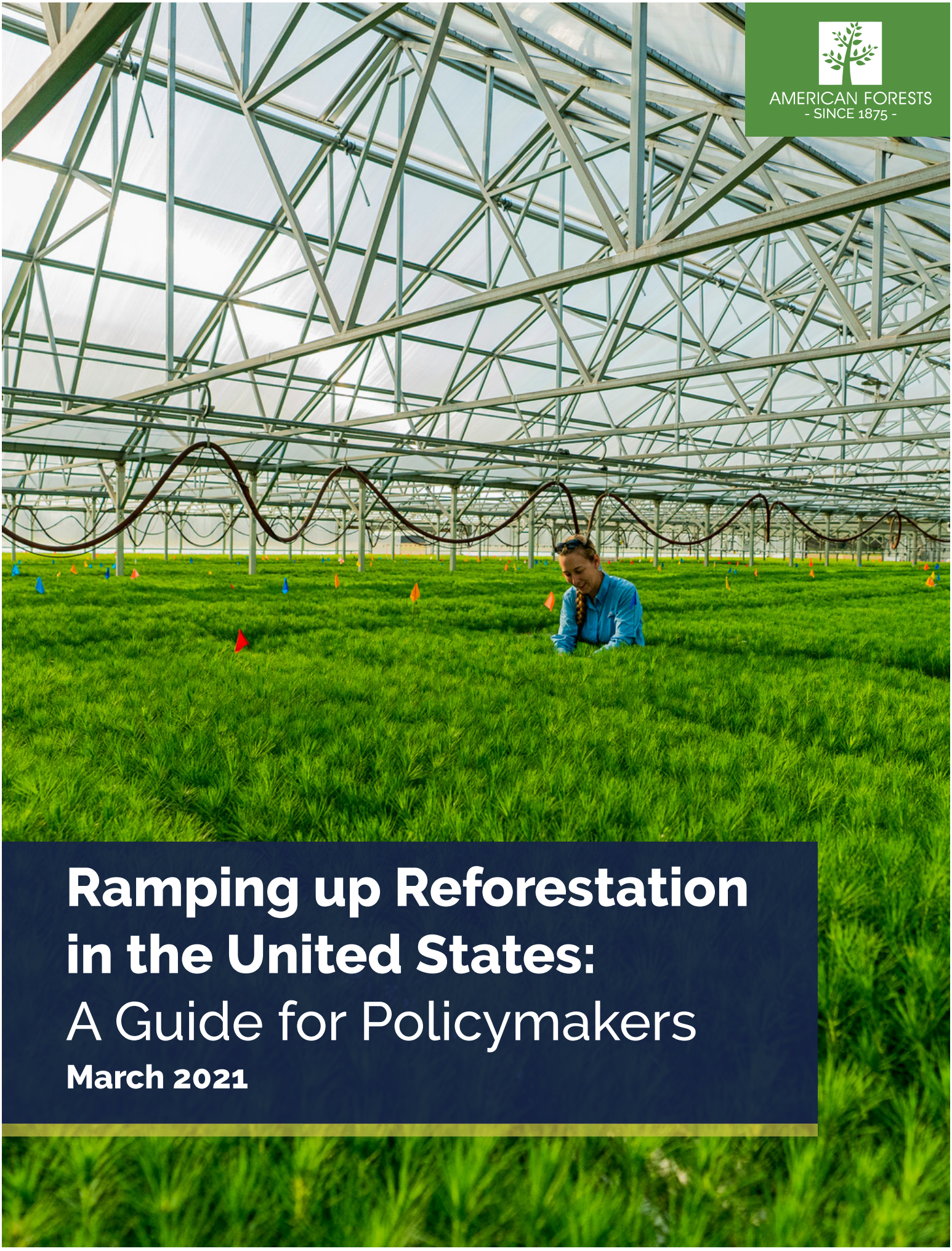


AMERICAN FORESTS
- SINCE 1875 -

Ramping up Reforestation in the United States:

A Guide for Policymakers

March 2021

Cover photo: CDC Photography / American Forests

Executive Summary

Ramping Up Reforestation in the United States: A Guide for Policymakers is designed to support the development of reforestation policies and programs. The guide highlights key findings on the state of America's tree nursery infrastructure and provides a range of strategies for encouraging and enabling nurseries to scale up seedling production. The guide builds on a nationwide reforestation assessment (Fargione et al., 2021) and follow-on assessments (*Ramping Up Reforestation in the United States: Regional Summaries* companion guide) of seven regions in the contiguous United States (Figure 1). Nursery professionals throughout the country informed our key findings and strategies through a set of structured interviews and a survey.

Across the contiguous U.S., there are over 133 million acres of reforestation opportunity on lands that have historically been forested (Cook-Patton et al., 2020). This massive reforestation opportunity equals around 68 billion trees. The majority of opportunities occur on pastureland, including those with poor soils in the Eastern U.S. Additionally, substantial reforestation opportunities in the Western U.S. are driven by large, severe wildfires.

Growing awareness of this potential has led governments and organizations to ramp up reforestation to meet ambitious climate and biodiversity goals. Yet, there are many questions about the ability of nurseries to meet the resulting increase in demand for tree seedlings. These include a lack of seed, workforce constraints, and insufficient nursery infrastructure.

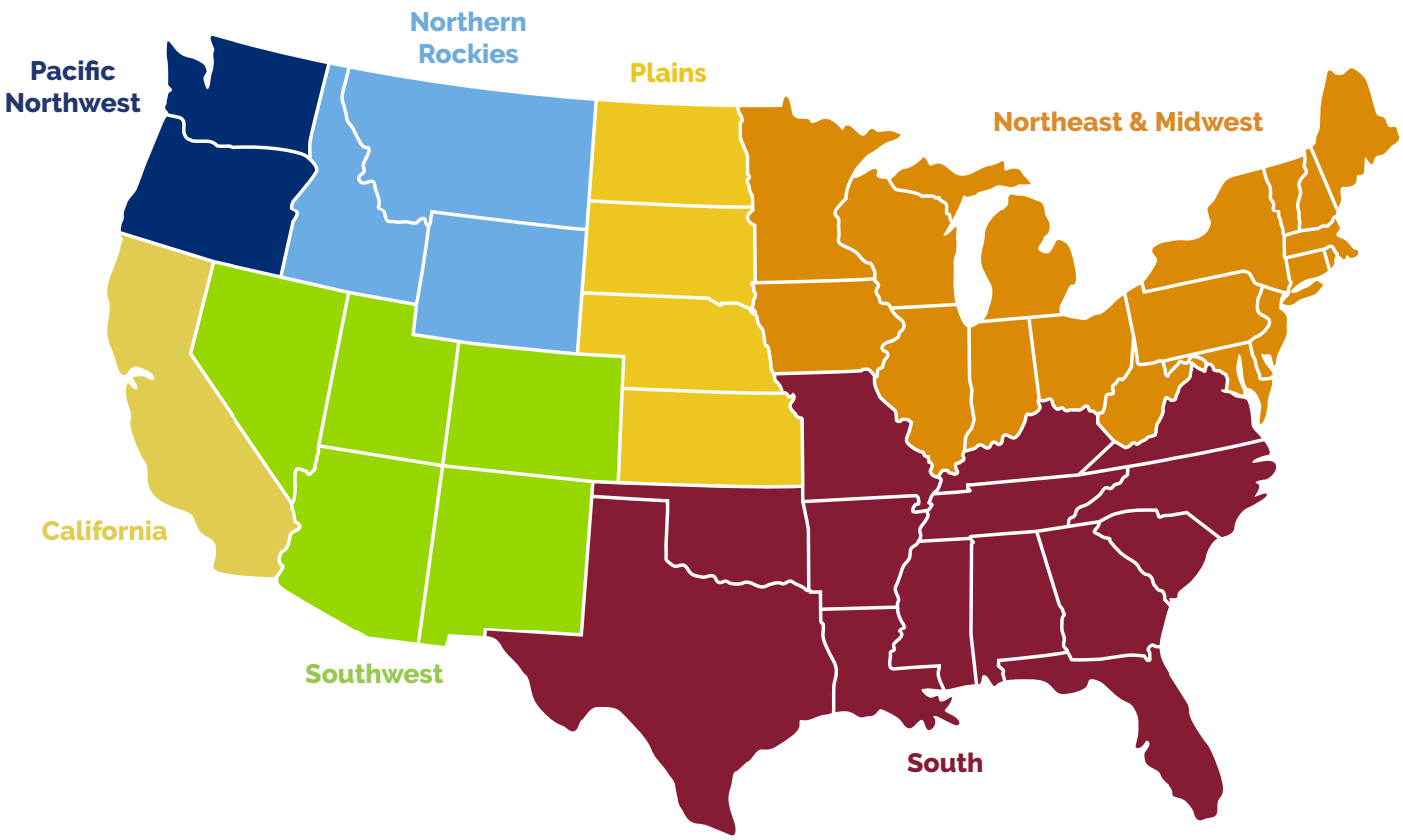
To meet half of the total reforestation opportunity by 2040 (i.e., 66 million acres) would require America's nurseries to produce an additional 1.8 billion seedlings each year. With new investments and creative solutions to many of the barriers that nurseries face, private and public nurseries have the potential to meet 80% of this need. However, because the ability of nurseries to expand capacity is unevenly distributed across the country, regions with more expansion potential — like the South and Pacific Northwest — may need to grow seedlings for other regions. The construction of new nurseries will also be needed to make up for gaps in seedling supply and to expand production to meet the entire 66-million-acre goal by 2040.

In addition to infrastructure investments, nurseries require more well-trained and stable labor to manage seed collections and support growing operations. Nursery professionals from across the country cited labor shortages as the number one constraint to increasing nursery capacity. Policy makers can help address these challenges by adding jobs in key pinch points and encouraging workforce development through existing and developing programs like the new Civilian Conservation Corps.

Creative solutions exist to meet other challenges as well, including encouraging federal, state, tribal, and local land managers to partner with conservation organizations and others to bolster regional nursery infrastructure and investing in regional seed orchards to ensure ample availability of climate-adapted seed.

**This project was made possible with generous support from the Paul and June Rossetti Foundation and Sant Foundation.*

U.S. Reforestation Regions



Key Findings and Strategies

1. The contiguous U.S. has 133 million acres of reforestation potential.
2. America's existing private and public tree nurseries have the potential to double total seedling production with investments in infrastructure and other barriers.
3. Potential to expand seedling production to meet reforestation opportunities varies across regions.
4. Labor shortages are the number one barrier to increasing production at nurseries. Strategic investments in workforce development are needed to fix labor shortages across the reforestation pipeline.
5. Barriers to expanding seedling production include: labor shortages, lack of growing contracts, financing needs, land and water availability, and infrastructure.
6. There is a trend toward market consolidation into larger nurseries which may disadvantage smaller landowners and conservation plantings.
7. Public nurseries provide valuable research and technical support to America's overall nursery infrastructure and face unique barriers to expanding production.
8. The supply of diverse and climate-adapted seed is currently insufficient to meet reforestation opportunities. Nursery research is needed to address challenges, such as climate change, pests, and pathogens.

James Lozeau is part of the team working to restore whitebark pine at the Flathead Reservation in Montana.
Credit: Morgan Heim / American Forests.

Background

Reforestation is one of the greatest natural and working lands opportunities to reduce global greenhouse gas emissions (Griscom et al. 2017; Bastin et al. 2019). In the U.S., expanding reforestation practices, including tree planting, has the potential to sequester over 5% of total CO_2e annually emitted by the U.S. (Fargione et al. 2018). Additionally, restoring forest landscapes degraded by land use change or natural disturbances, like severe wildfire, creates numerous environmental co-benefits, such as clean water, reduced flooding, improved soil health, expanded wildlife habitat, and enhanced forest resilience.

Reforesting landscapes also advances socio-economic benefits. For instance, every $1 million invested in rural reforestation in North America supports as many as 40 jobs across the reforestation pipeline from seed collection and storage, to tree seedling production in nurseries, to site preparation for planting, to post-planting maintenance and monitoring (Garrett-Peltier et al., 2009; Green Analytics, 2019). Growing the reforestation pipeline was a highly effective tool for economic recovery in the New Deal era with the original Civilian Conservation Corps and is poised to yet again factor significantly in the current need for worldwide economic recovery.

These ecological and economic benefits have generated enthusiasm and momentum for large-scale, global reforestation activities, including The Bonn Challenge and the United Nations Decade of Ecosystem Restoration. Most recently, the World Economic Forum launched the Trillion Trees Initiative (1t.org), a campaign aimed at conserving, growing, and restoring 1 trillion trees globally by 2030. American Forests and the World Economic Forum launched the 1t.org U.S. Chapter in 2020 to catalyze U.S. action toward the global goal. To date, dozens of companies, governments, and non-governmental organizations (NGOs) have pledged to plant and conserve over 1 billion trees throughout the U.S, and some of these pledges have included nursery production and investment.

There is tremendous potential for reforestation across the U.S. A recent estimate suggests there are over 133 million acres of land suitable for reforestation and tree planting in the U.S. (Cook-Patton et al., 2020). These reforestation opportunities exist in every state and across private, public, and tribal lands, both in urban and rural settings. Yet, reforesting even half of this opportunity over the next 20 years would require more than doubling the scale of the nation's tree nursery sector (Fargione et al., 2021).

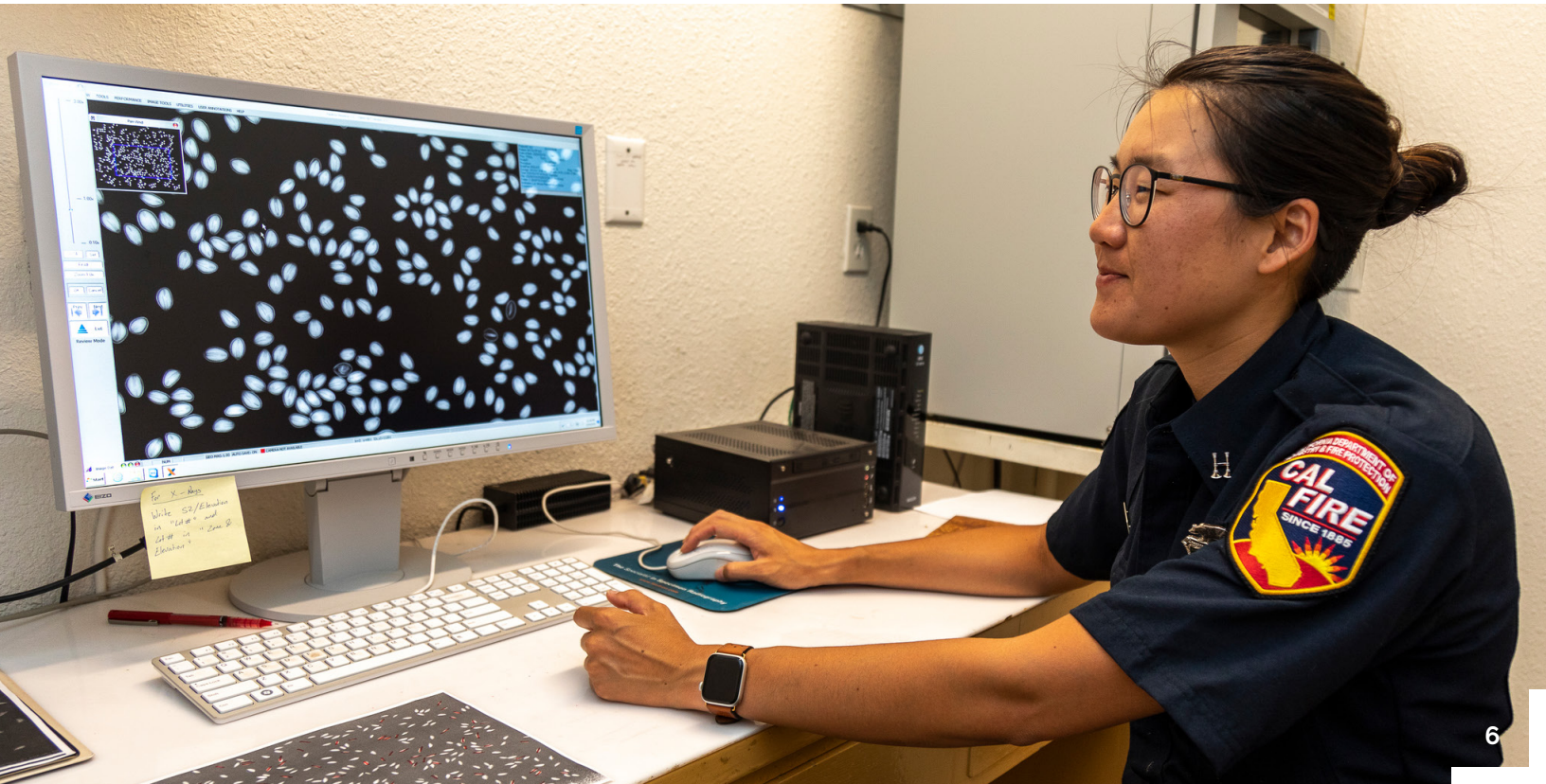
America's tree nurseries produce an estimated 1.3 billion seedlings annually, enough to plant around 2.5 million acres each year (Haase et al. 2020) (Table 1). The nursery system includes a collection of large and small private nurseries that serve small, local reforestation projects to large-scale reforestation of timberlands. There are also a handful of federal nurseries and several state nurseries that serve restoration-based and post-harvest reforestation needs for the USDA Forest Service and other agencies, state lands, and private landowners. However, the number of public nurseries has declined over time due to a varied set of challenges, including budget cuts to federal and state forestry programs and fluctuations in the timber industry. The number of states with nurseries has declined by 19% since 2005, mostly due to an inability to cover their costs with seedling sales (National Association of State Foresters, 2016). In the last several decades, 14 USDA Forest Service nurseries have closed, with only six remaining (Dumroese et al. 2005).

At this stage, the overwhelming majority of the nation's tree nurseries are privately owned and focus on tree species for reforestation after commercial harvests with private landowners in the South, Pacific Northwest, and parts of the Northeast and Midwest. While large, private nurseries produce the majority of commercial tree species, smaller native plant nurseries are important for producing a diversity of native species for restoration-based plantings.

While large, private nurseries are generally able to support demand for tree seedlings, their infrastructure capacity can be tested by unexpected increases in demand due to severe wildfires, pest outbreaks, and other disturbances, as seen on the West Coast after the large 2020 fire season.

The reforestation opportunities in the U.S. are massive, but any additional reforestation will require strategic investments in seed procurement, tree nursery production, and other components of the reforestation pipeline across both private and public sectors (Fargione et al. 2021).

Jessica Huang, seed bank manager at the L.A. Moran Reforestation Center, reviews an image of the x-ray test performed on the seeds to determine moisture content, purity and overall seed viability. Credit: Luciane Coletti / American Forests.



Key Findings and Recommended Strategies

1. The contiguous U.S. has 133 million acres of reforestation potential.

Climate change is fueling unprecedented threats to our forests, including rising temperatures, increased and prolonged drought, extreme weather events, intensified pest and pathogen activity, and larger and more severe wildfires. These stressors upend the ability of forests to grow back on their own after disturbances due to degraded soil, lack of water, and reduced survivability of saplings (Van Mantgem et al., 2009; Westerling, 2016; Stevens-Rumann, 2018; Pile, 2019; Millar, 2016; Little, 2010; Barbero et al., 2015).

The USDA Forest Service has historically relied more heavily on natural regeneration to restore forests after a disturbance like wildfire. Now, however, natural regeneration in national forests only meets 40% of the need due to these above stressors. Foresters must plant the remaining 60% to ensure adequate reforestation (USDA Forest Service, 2017).

Large and severe wildfires along with prolonged drought (Parks and Abatzoglou, 2020) have created vast areas with few remaining trees that are mature enough to produce seed. As a result, these areas have insufficient seed and fail to regenerate (Cansler, 2014; Miller, 2015; Stevens-Rumann, 2018; Steel, 2018; North et al., 2019; Korb, 2019). Without reforestation, severely burned areas transition to other vegetation types. For example, dry-forests throughout the west are converting to grass and shrub systems that threaten many natural benefits that communities rely on, such as provision of drinking water and carbon sequestration (Davis, 2019; Stevens-Rumann, 2019).

Beyond these drivers, which are anticipated to continue increasing the need for reforestation, there are already over 133 million acres of reforestation opportunity across the U.S. (Cook-Patton, et al., 2020) (Table 1). Reforestation should be designed to meet landowner goals and can include a variety of strategies like silvopasture, tree planting, and natural regeneration.

Wildfire is the main driver of reforestation potential in the West, and large amounts of pasture that were formerly forest drives opportunities in the east. Reforestation opportunities are limited to areas that historically supported forests to avoid conflicts with other habitats like grasslands.

Table 1. Regional reforestation opportunity and seedling needs

Study Region	Total Reforestation Opportunity (million acres)
South	63.2
Northeast & Midwest	38.8
Southwest	11.7
Northern Rockies	9.4
California	3.9
Pacific Northwest	3.2
Plains	2.6
Total (Lower 48)	133

Opportunities exist across both public and private ownerships. On federal land, the USDA Forest Service has as much as 7.4 million acres of reforestation potential, and the Bureau of Land Management has around 3.8 million acres. State parks, forests, and other lands have a total of 2.5 million acres of reforestation potential. Family woodland owners, farmers and producers, and other private landowners have the largest cumulative potential at 114 million acres.

Table 2. Regional reforestation opportunity by landowner (million acres)

Study Region	Federal	State	Private	Other	Total
South	0.2	0.5	61.9	0.7	63.2
Northeast & Midwest	0.1	0.7	37.4	0.6	38.8
Southwest	5.8	0.7	3.7	1.5	11.7
Northern Rockies	3.5	0.4	4.1	1.3	9.4
California	1.0	0.1	2.7	0.2	3.9
Pacific Northwest	0.5	0.1	2.5	0.2	3.2
Plains	0.2	0.0	2.3	0.1	2.6
Grand Total	11.3	2.5	114.6	4.5	133

While California and the Pacific Northwest have relatively fewer reforestation opportunities, the total opportunity is still massive (nearly the size of the State of Maryland) and critically important to protecting water supplies and storing carbon. It is important to note that the reforestation opportunity analysis (Cook-Patton et al. 2020) included large fires only up to 2015.

Seedlings from an American Forests 2018 planting in the Lower Rio Grande Valley in Texas. Credit: Givewith.

2. America's existing private and public tree nurseries have the potential to double total seedling production with investments in infrastructure and other barriers.

America's tree nurseries currently produce an estimated 1.3 billion seedlings annually, enough to plant around 2.5 million acres each year (Haase et al. 2020).

Within existing greenhouses, seedbeds, and other infrastructure, nurseries have the potential to increase seedling production by 34% nationwide (Fargione et al., 2021). Combining this nationwide data with detailed, regional survey data, tree nurseries operating at maximum production would produce an additional 438 million seedlings per year.[1] This ability to scale-up production within the constraints of current infrastructure, however, is dependent on addressing market demand, labor shortages, seed availability, and other barriers discussed in this guide.

The potential to expand seedling production varies greatly based on ownership. Federal nurseries have the greatest potential to increase production at 151% over existing output, while state and private nurseries have the potential to increase production by 74 and 21%, respectively. Private nurseries have the least room to expand production without investing in new infrastructure, yet are currently responsible for producing 80% of all seedlings nationally (Fargione et al., 2021).

Therefore, new infrastructure, especially for private nurseries, will be needed to expand seedling production. With the necessary investment, 76% of tree nurseries are willing to add new greenhouses, seedbeds, and other infrastructure (Fargione et al., 2021) and could produce an additional 1 billion bareroot and container seedlings per year.

All told, America's nurseries have the potential to expand nursery production by 1.4 billion seedlings and produce a total of 2.7 billion seedlings annually, when combined with existing output (Table 3). These estimates are based on survey responses from existing nurseries and do not reflect the potential for opening new nurseries that could further expand seedling production.

Table 3. Current and potential annual nursery production

	South	Northeast & Midwest	Southwest	Northern Rockies	California	Pacific Northwest	Plains	Total
Current Production (FY19, million seedlings)	1,090	46	0.8	13	12.9	135	3.6	**1,302**
Unused Capacity (million seedlings)	358	28	1.1	24	0.2	24	3.2	**438**
Current Capacity (current prod. + unused, million seedlings)	1,448	74	1.8	38	13.1	159	6.8	**1,740**
Current Bareroot Production (% of total)	79%	74%	17%	14%	0%	56%	73%	**75%**
Current Container Production (% of total)	21%	26%	83%	86%	100%	44%	27%	**25%**
Potential Bareroot Expansion (million seedlings)	383	22	0.3	15	-	24	2.0	**446**
Potential Container Expansion (million seedlings)	439	16	2.8	21	7.3	63	1.0	**550**
Expansion Potential among Existing Nurseries (million seedlings)	822	38	3.0	37	7.3	87	2.9	**996**
Total Expansion Potential (unused capacity + expanded production, million seedlings)	1,179	65.3	4.1	61.0	7.5	110.6	6.1	**1,434**
Regional Share of Total Expansion Potential	82.2%	4.6%	0.3%	4.3%	0.5%	7.7%	0.4%	**100%**
Total Potential Production (current + unused + expanded production, million seedlings)	2,269	111.5	4.9	74.4	20.4	245.9	9.8	**2,736**

Nationally, to meet the full potential of expanding production capacity at existing nurseries could require an investment of approximately $1 - $6 billion.[2] This involves additional container growing operations (greenhouse space), the purchase of additional land for bareroot seedbeds, as well as associated infrastructure for storage, processing, administration, etc. Nurseries growing container seedlings tended to report a greater potential to expand nursery infrastructure than those producing bareroot seedlings. Our analysis does not consider the costs of constructing new nurseries but focuses on expanding existing operations. Standing up brand new nursery operations will likely be more expensive given the need to factor in the cost of land, utility hook ups, additional permitting and site work, and other factors.

Nursery expansion requires firm commitments from customers, ideally multi-year contracts before they take on debt to finance expansion. It also takes time. Assuming that farmland with well-drained soils is immediately available to expand bareroot production — a highly optimistic assumption — it takes at least two years to prepare the soil and establish an irrigation system to get to the point of sowing seeds and one to two more years to grow seedlings ready for harvest. To expand a container nursery would take one or two years to establish the necessary infrastructure before sowing and one year to grow the seedlings. Container operations in climates that do not require greenhouses, like parts of the South, could start up more quickly. Another option would be to repurpose existing but underutilized non-tree nurseries and greenhouses from other segments of the agricultural sector to shift to tree seedling production.

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1. Estimates for current nursery production are reported in Haase et al. (2020). We estimated unused nursery capacity and potential to expand beyond current capacity based on survey responses from each region, extrapolated to the total production figures in Haase et al. (2020). Expansion figures were estimated separately for container and bareroot production in each region (e.g. total number of container seedlings produced in region x, multiplied by the average of survey respondents' stated ability to expand container production in that region).

2. Expansion costs were estimated based on an interview question 'How much would it cost (in dollars) to expand by the amount you indicated in the previous two questions (including greenhouses, land, water, etc.)'. To extrapolate to total industry figures, we analyzed cost responses on a per seedling basis — quoted expansion cost divided by the number of new seedlings produced — and treated costs for bareroot and container nurseries separately.

Recommended strategy: Support nursery production expansion through USDA loan and conservation programs.

The US Department of Agriculture (USDA) can strategically link USDA Rural Development Business and Industry Loan Guarantees or Farm Services Agency loan programs to expand capacity at existing nurseries (e.g., adding new greenhouses) or start up brand new nurseries, including land purchases. These loan programs can be targeted to regional reforestation initiatives and USDA Farm Bill incentive programs (e.g., USDA NRCS Regional Conservation Partnership Program) to provide nurseries with long-term market demand signals that enable them to take on debt to scale up capacity.

Recommended strategy: Create a grant program or funding category within existing federal grant programs to advance technology transfer and research into efficiencies that can be gained in the reforestation pipeline.

There is no current source of funding to help state, local, tribal, and NGOs advance reforestation. A new federal grant program should be established to provide matching grants to local governments, tribes, and states — as well as NGOs such as a land trusts — to advance reforestation. In addition to funding reforestation, this program should fund establishment, expansion, and refurbishing of state, tribal, local, and NGO tree nurseries.

Recommended strategy: Include trees and tree nurseries in infrastructure policy.

With most of the nation's infrastructure nearing or presently exceeding its projected lifespan, the next 20 years could see significantly increased infrastructure investment, including natural infrastructure projects like targeted tree planting. This timeframe aligns with an anticipated reforestation market boom linked to global reforestation goals and the burgeoning carbon removal market (UNPRI, 2020).

A national infrastructure package should include a focus on tree planting to enhance ecosystem services (e.g., improving water quality via constructed wetlands and reforested riparian areas) alongside investments in traditional gray infrastructure projects (e.g., wastewater treatment plants). In the next 20 years, we are likely to see infrastructure investments in carbon removal technologies, like Direct Air Capture machines, yet forests right now capture carbon dioxide from the air in a much more cost-effective manner and, thus, warrant consideration for infrastructure investment in carbon removal.

A young seedling growing on the Perez Ranch in La Joya, Texas. Credit: James Foguth / American Forests.

3. Potential to expand seedling production to meet reforestation opportunities varies across regions.

It would take an additional 1.8 billion seedlings produced annually to reforest 66 million acres or half the total reforestation opportunity in the U.S. by 2040. America's existing nurseries could theoretically meet nearly 80% of this need, as there is potential to add 1.4 billion seedlings per year with investments at existing nurseries. Yet, this ability to expand production is not evenly distributed across the country.

With well-established commercial nursery infrastructure, the South and Pacific Northwest regions make up 90% of the national expansion potential. On the other hand, the Southwest, California, and Plains regions have limited ability to expand seedling production without establishing new nurseries (Table 2).

This regional variation is not always well aligned with where reforestation opportunities exist. For example, the Northeast and Midwest, Southwest, and California regions are not able to add enough capacity to meet a 2040 goal of reforesting half of their total opportunity. The regions would require over 600 million more seedlings than they could potentially produce.

Given this regional mismatch in opportunity and ability to expand capacity, meeting the 2040 goal may require a combination of the South and Pacific Northwest regions to use their excess capacity for growing seedling for other regions, as well as construction of new nurseries in regions where huge reforestation opportunities exist (See recommended strategies in Finding 2).

Table 4. Estimated potential for production expansion

Study Region	Total Reforestation Opportunity (million acres)	2040 Restoration Goal (half of total opportunity, million acres)	Seedlings Needed Annually to Meet 2040 Goal (million seedlings)	Expansion Potential (annual production, million seedlings)	Net Potential to Meet 2040 Goal (million seedlings)
South	63.2	31.6	990	1,179	189
Northeast & Midwest	38.8	19.4	555	65	(490)
Southwest	11.7	5.9	93	4.1	(89)
Northern Rockies	9.4	4.7	74	61	(13)
California	3.9	2.0	31	7.5	(23)
Pacific Northwest	3.2	1.6	26	111	85
Plains	2.6	1.3	21	6.1	(14)
Total (Lower 48)	133	66	1,789	1,428	(361)

Source: Cook-Patton et al., 2020; Haase et al., 2020.

Recommended strategy: Better connect assessments of regional reforestation opportunities to assessments of seedling production across regions, and to strategies to scale up production. Also see recommended strategies under Finding 5 to provide better information to land managers and nurseries and invest in state/regional reforestation centers.

Recommended strategy: Strategies recommended in Finding 2 also apply to Finding 3.

Florentino Caldera, with the U.S. Fish and Wildlife Service, examines seedlings growing on the Perez Ranch in La Joya, Texas. Credit: James Foguth / American Forests.

4. Labor shortages are the number one barrier to increasing production at nurseries. Strategic investments in workforce development are needed to fix labor shortages across the reforestation pipeline.

Workforce limitations are a significant factor across America's nursery infrastructure. Expanding seedling production will also require growing the labor pool in other parts of the reforestation pipeline (e.g., for seed collection, in designing new reforestation projects, and for planting and post-planting maintenance). Thus, significant opportunities exist to grow jobs, especially in rural areas where nurseries are most often located. In general, there are more jobs at bareroot nurseries than container nurseries, but across both types most nurseries have a small year-round core staff that expands substantially with seasonal workers during busy seasons. Across the reforestation pipeline, significant workforce expansion is needed in seed collection, nursery production, site preparation, tree planting, and post-planting activities.

Nationally, survey participants cited labor as the largest barrier to expanded seedling production with some regional variability. Within our survey, labor is a constraint to expanded production for private nurseries in the Pacific Northwest and state nurseries in the South, but private nurseries in the South rarely cite this.

Table 5. Barriers to Expanding Seedling Production Capacity at Existing Nurseries.

Barrier	# Responses
Workforce	53
Market	43
Land	31
Financing	31
Infrastructure	27
Lack of Desire to Expand	26
Seed Availability	20
Water	11
Regulations	10
Logistics	8

Volunteers plant seedlings in the Lower Rio Grande Valley at the 2018 Rio Reforestation event. Credit: Givewith.

Nurseries draw from the same seasonal labor pool as the agricultural sector. This labor pool also provides vital positions in field forestry, namely tree planting and fuel reduction work. Since the 1980s, H2B visa guest workers have been an integral part of the forest sector, especially in the reforestation and nursery sectors of California, the South, and the Pacific Northwest (McDaniel and Casanova, 2003). Several survey respondents noted that the migrant workforce is key to meeting production targets and that expanding tree seedling production will require consistent access to a low-wage workforce for labor-intensive activities. Survey participants repeatedly cited immigration policy as their single largest concern.

In addition to workforce shortages, we also uncovered multiple instances where nursery managers will soon retire, taking decades of knowledge with them. Filling these critical positions with people who have the necessary expertise and skills can be challenging.

Recommended strategy: Add agency capacity to address key pinch points within seedling production at public nurseries.

In addition to needing more funding for reforestation projects, agencies need new additional staff capacity to support the increase in projects. Specifically, the USDA and Department of Interior agencies, like the USDA Forest Service and U.S. Fish and Wildlife Service, would benefit from enhanced reforestation staffing focused in four areas:

- Increasing capacity for reforestation oversight and partnership coordination at the agency headquarters level;
- Establishing a Reforestation Coordinator position for each agency field region, building on the success of these positions in regions where they already exist. The coordinators could also be shared positions with state, local, or non-governmental partners; and
- Increasing field staff capacity for reforestation planning and contracting. In addition, agencies should develop a mobile "action team" across all needed disciplines to help mobilize, particularly impacted areas after each wildfire season.
- Lifting hiring prohibitions at public nurseries to facilitate expansion of full-time staff and the seasonal workforce, as appropriate.

Recommended strategy: Address tribal workforce challenges.

Lands held in trust by the Bureau of Indian Affairs and lands held in fee by tribes and tribal members have significant reforestation potential. Yet, tribal forestry programs are understaffed with need for a 65% increase in positions. The *Third Report on Indian Forests and Forest Management* (2013) identified workforce challenges that could be aided by federal support for the Intertribal Timber Council Workforce Development Strategy.

Recommended strategy: Include nursery production in the new Civilian Climate Corps.

The forest restoration sector has the opportunity to train and employ workers displaced by the COVID-19 pandemic, as well as those marginally employed prior to the pandemic. The January 27, 2021 Executive Order on Tackling the Climate Crisis at Home and Abroad (EO 14008, sec. 215) directs the Secretary of Agriculture, in conjunction with the Secretary of Interior, to submit a strategy for the creation of a Civilian Climate Corps Initiative. Many of the state nurseries in operation today, or previously closed, were originally Civilian Climate Corps work camps with Civilian Climate Corps workers constructing the nurseries, managing the tree production process, and planting the trees. In fact, the original Civilian Climate Corps was referred to as the "Tree Army" because they planted 3 billion trees during the Great Depression. Rebooting the Civilian Climate Corps can be an integral component of a modern-day national tree planting push aligned with the great draw down of greenhouse gas emissions now needed.

In addition to EO 14008, recent national legislative activity has centered on re-establishing the Civilian Conservation Corps to help create capacity and economic opportunity, with special provisions targeted to engage people from socially disadvantaged communities. In the longer term, people who participate in such a program could receive the necessary training to fill vacant nursery positions.

Recommended strategy: Create opportunities for Job Corps to provide training and employment onramps in the forestry and reforestation sectors.

Recent legislative proposals at the federal level would assist non-federal entities in developing or expanding programs that help persons from underserved and high-need populations, such as veterans, opportunity youth, and persons returning from incarceration or drug treatment, to enter careers in natural resources. These programs include training in apprenticeships in various forestry activities, such as tree seed collection, forest health management activities, nursery production, and reforestation.

Kuldeep Singh, nursery manager at the L.A. Moran Reforestation Center, inspects the conifer seedlings in the shade house. Credit: Luciane Coletti / American Forests.

Recommended strategy: Train horticulture students for work in the forest nursery sector.

Nurseries often have difficulty finding people with plant propagation training. A scholarship program could help bring qualified people into the sector. Based on interviews, investing in forestry and horticulture programs — especially at technical schools — will help nurseries. Some schools report success placing students working at university nurseries in management positions within regional public and private nurseries. Developing stronger connections with educational programs at regional community colleges and universities could funnel a career pipeline of skilled labor.

Recommended strategy: Mitigate loss of institutional knowledge when turnover occurs.

Maintaining and expanding institutional nursery expertise was a key recommendation voiced by federal employees in our survey. In addition, very few contracting officers know how to administer cone collection contracts (e.g., there are only four in California), and when these individuals leave, they are difficult to replace. Funding and training are foundational issues and could be incorporated into existing recommendations to deal with turnover problems in the USDA Forest Service and other federal agencies (e.g., "promote in place" policies). Private nurseries are also facing pending loss of institutional knowledge with the nationwide wave of retirements.

5. Barriers to expanding seedling production include: labor shortages, lack of growing contracts, financing needs, land and water availability, and infrastructure.

Large private nurseries tend to grow on contract, while smaller private nurseries and state nurseries more often grow some, or all, of their seedlings on "spec," deciding on the species and number of trees that they will grow each year by speculating what buyers will want one or two years later when seedlings are ready to sell. This business model is risky as climate and economic conditions can leave nurseries with too little or too many trees. This risk also drives nurseries to grow tree species that they are more likely to sell which can limit availability of the broader array of tree species needed for ecological restoration or climate adaptation goals.

Federal nurseries grow seedlings based on orders placed by national forest districts for a specific number of particular tree species. Federal nurseries are prohibited from selling directly to the public and their production is constrained by limits on hiring new permanent and seasonal workers. For all nursery types, strong demand signals, in the form of large multi-year growing contracts, paired with appealing financing options, will be needed to facilitate expansion projects.

Barriers to expansion vary somewhat by region (see *Ramping Up Reforestation in the United States: Regional Summaries* companion guide). For private nurseries in the South, uncertain market demand (i.e., contracts of sufficient size and duration) is the largest barrier to expanded production. Access to land is the second constraint cited by private nurseries followed closely by infrastructure constraints (e.g., need to replace aging equipment, financing to upgrade to modern equipment, ongoing maintenance, etc.). Furthermore, in the South, access to financing was a more significant issue for state nurseries than for private nurseries, while such a breakdown was not found in other regions.

Recommended strategy: Reinvigorate and create new Farm Bill programs that promote conservation plantings that translate to seedling orders for nurseries.

Conservation-oriented reforestation on private lands in several regions closely tracks federal funding programs. State nurseries are critical sources of seedlings for these programs, which often focus on multiple native species and vegetation types. Declines in conservation funding through the Farm Bill parallel declines in state nursery sales and overall financial viability. Much of the Farm Bill funded reforestation is truly additive, and the water, wildlife, and carbon removal benefits could be significant. For instance, in the South there are over 2 million acres of marginal cropland or challenging pasture that could be reforested using programs like the Conservation Reserve Program (Cook-Patton et al., 2020). Doing so with a 50:50 mix of southern hardwoods and pine would sequester over 85 million metric tons CO2e over the next 25 years.

Additionally, the Farm Service Agencies' Emergency Forest Restoration Program helps small non-industrial landowners facing severe tree mortality from insects, drought, and wildfire. Eligible activities include site preparation, seedlings, and planting labor. As wildfire and other threats increase, funding for this program should also expand.

The USDA could also establish a Carbon Bank, utilizing Commodity Credit Corporation authorities and funding, to purchase carbon dioxide emissions reductions from farm and forest landowners (Bonnie et al. 2020). This would further incentivize ecologically appropriate tree planting on working lands and provide a strong market signal to nurseries to scale up production of nursery stock. This Carbon Bank could also serve as a buffer pool necessary to de-risk private investment in the U.S. carbon removal reforestation market.

Recommended strategy: Develop state and/or regional "Reforestation Centers"

Given the number of barriers to ramping up reforestation throughout the pipeline, a coordinated approach will be necessary. Partners in New Mexico are currently proposing that the state invest in a new Reforestation Center, including establishment of a state nursery and seedbank infrastructure, programs that enhance the reforestation pipeline (e.g., seed collection and monitoring of tree plantings), and a long-term strategy for meeting the state's reforestation needs. The key to success will be integrating partners engaged in reforestation, including the state forestry agency and universities. California's state forestry agency, Cal Fire, is implementing a similar strategy through the L.A. Moran Reforestation Center. Similar centers should be established in states and regions with significant reforestation potential and need.

The USDA Forest Service manages the Reforestation, Nurseries, and Genetic Resources or "RNGR" program to facilitate technology transfer and advance the nursery field. This network can be the key resource for partners as they develop Reforestation Centers and programs.

Seedlings growing in the Lower Rio Grande Valley. Credit: Givewith.

Recommended strategy: Provide better information to land managers and nurseries to better manage risks and grow seedling production capacity.

If nurseries ramp up seedling production for reforestation, they will need access to information to help them manage their business risks. Nurseries need clear demand signals from land managers. Geospatial tools can be used to facilitate development of reforestation plans that will better coordinate long-range seedling needs between land managers and nursery managers. Such plans can incorporate existing reforestation opportunities plus likely near-term future needs based on wildfire, drought, timber harvest, and other factors. Combining this data with forest types, elevation bands, climate vulnerabilities, seed zones, and other information will help nurseries better plan for future demands. A number of recent examples show promise:

- The online data visualization tool, Reforestation Hub, could provide the foundation for reforestation plans by making reforestation goals and seedling demand forecasts possible. The Reforestation Hub displays The Nature Conservancy's reforestation opportunity analysis at the county level to support planning and prioritization of reforestation actions across the country. Importantly, this data source segments opportunities by reforestation type (e.g., post-commercial harvest, urban tree canopy expansion, post-fire restoration, conservation plantings).
- New Mexico's State Forest Action Plan is establishing a collaborative program to identify and prioritize reforestation needs and nursery capacity around the state.
- California's Forest Management Taskforce Action Plan is developing a state-wide reforestation strategy to address pipeline barriers.
- The U.S. Fish and Wildlife Service is working with conservation organizations, universities, and the State of Texas to implement a regional plan to reforest the native ecosystem of the Lower Rio Grande Valley.

Recommended strategy: Unlock carbon finance for reforestation.

Private market finance of reforestation is the next frontier in nature-based carbon reductions offering the most cost-effective and significant near-term carbon removal strategy.[3] The Intergovernmental Panel on Climate Change (IPCC) has deemed carbon removal strategies as essential to avert catastrophic climate change (de Coninck et al., 2018). In fact, this strategy could generate $800 billion in annual carbon removal market revenues by 2050 (UNPRI, 2020). As companies push to create net-zero carbon emissions and other goals, they will increasingly look for carbon removal projects like reforestation to help them meet their commitments. With carbon finance, corporate investments in reforestation can scale demand for reforestation projects quickly. Yet, current voluntary and regulatory markets are not stimulating investment in reforestation at the scale needed. Therefore, innovations will be required.

As the majority of reforestation opportunities in the U.S. occur on private land, these markets will play a significant role in infusing new funds for reforestation projects that add additional forests to the landscape. Likewise, on public lands facing reforestation challenges, these markets can support projects that help restore forest in degraded landscapes. Public lands may also play a critical role in de-risking carbon removal markets to unlock private finance. The potential establishment of reforestation buffer pools on public lands, effectively acting as insurance for other carbon projects, could further drive private sector investment by reducing the risk of project failures due to wildfire and other threats.

Recommended strategy: Advance markets for forest products.

The main drivers of tree seedling production in the U.S. are reforestation after timber harvests and wildfire. By extension, forest product markets are an essential driver of our nation's reforestation workforce and infrastructure. While forests provide numerous values, markets for wood product are vital for sustainable forest management and can help stabilize seedling orders, leading to the steady demand needed to shore up the foundation of nursery capacity upon which additional seedling output can be built. There are several steps to support forest product markets, including investments in product research and commercialization, and encouraging the use of wood in government (local, state, and federal) buildings.[4] Lastly, it is worth noting that while wood product markets are an important component of overall demand for reforestation, demand for other forest values also plays a critical role in spurring reforestation, as evidenced by the large area of land reforested via the Farm Bill conservation programs.

Recommended strategy: Increase flexibility around planting dates and nursery storage.

Greater flexibility can help land managers plan more reforestation projects by helping them to better manage the inherent uncertainties when planting trees. For example, the high elevations of the Sierra Nevada Mountains have a narrow planting window squeezed between snow cover and high summer heat. If dry weather begins early, it may force managers to skip planting to the next planting season.

Fall planting can provide flexibility by building in an extra planting season at the start. Fall plantings can be technically challenging to execute successfully, but these plantings, when successful, can give seedlings a head start before the spring and summer growing seasons begin. However, Federal land managers report that the federal fiscal year and annual budgeting process make fall planting challenging.

Additionally, land managers need flexibility in managing when trees are delivered from the nursery and when they are planted to accommodate weather, labor constraints, etc. After being "lifted" from the nursery, seedlings need to be cold stored (shorter term; 1-6 weeks) or freezer stored (longer term; 2-5 months) to discourage mold growth and minimize respiration and depletion of carbohydrate reserves prior to planting. However, most land managers do not have coolers to adequately store seedlings before planting. To reduce costs, the creation of Cooler Cooperatives may provide some flexibility for both long- (stationary coolers) and short-term (refrigerated trucks) seedling storage. One example is the Private Forest Landowner Network in eastern Oregon that maintains a stationary cooler for private landowners in northeast Oregon and southeast Washington.

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3. Carbon removal strategies are those that actively remove carbon dioxide from the atmosphere vs. those strategies that avoid its transfer to the atmosphere.

4. The 2020 policy platform of the Forest Climate Working group provides detailed options for supporting wood product markets. https://forestclimateworkinggroup.org/

Example of cones and seeds from Sierra and Coast Redwoods, from the Seed Bank exposition at the L.A. Moran Reforestation Center. Credit: Luciane Coletti / American Forests.

Recommended strategy: Expand contract growing, limit waste, and increase seedling contract volume.

Due to market uncertainties, storage or transportation issues, and other factors, not all seedlings grown in nurseries are planted.

To help reduce the number of unused nursery seedlings, tools can be developed to link land managers to nurseries when there is an excess of seedlings. For example, a central website or an automated notification system can be established to notify land managers when excess seedlings of suitable provenances are available.

Additionally, landowner seedling cooperatives could be created to coordinate and batch seed collections, seedling orders, and seedling distribution on a contract basis to reduce the need for nurseries to speculate on the type and amount of stock needed each year and, thus, reduce waste. The Private Forest Landowner Network in eastern Oregon groups private landowners together to complete batch contract orders in a way that offers landowners better prices for their seedlings and limits the volatility of the speculation market for both the landowners and the nurseries from which they purchase seedlings.

6. There is a trend toward market consolidation into larger nurseries which may disadvantage smaller landowners and conservation plantings.

Several people in the forest nursery sector that were interviewed indicated that many small nurseries in their region would likely shut down over the coming years as current owners retire. Survey results also suggest that larger nurseries can expand more readily than smaller nurseries, meaning that increased demand will primarily benefit large nurseries able to secure large contracts, achieve economies of scale, and operate with a greater economic cushion than most small operations. Fewer smaller nurseries may create issues for certain landowners, such as smaller non-industrial forest owners who periodically obtain relatively small seedling orders (i.e., the speculative market). These landowners will have a harder time finding seedlings because larger private nurseries tend to grow on contract for large landowners. Additionally, much of the diverse native plant production in the country occurs at smaller private native plant nurseries.

Recommended strategy: Encourage expansion of non-industrial landowner seedling cooperatives to facilitate bundling of seedling orders in contracts with nurseries.

Recommended strategy: Maintain and grow markets for native plant material, including the full diversity of native trees, which are often grown at smaller native plant nurseries.

The buff-bellied hummingbird nests in the dense thorn forest habitat in the Lower Rio Grande Valley. Credit: Norman Bateman / Adobe Stock.

7. Public nurseries provide valuable research and technical support to America's overall nursery infrastructure and face unique barriers to expanding production.

State and federal nurseries are critical to meeting our reforestation opportunities as they manage over 10% of the total reforestation opportunity in the U.S. and operate seedbanks for a much wider diversity of species, seed zones, and elevations than the private sector. Additionally, they implement research functions and public education programs that are critical to advancing the nursery industry as a whole and for supporting national priorities to respond to climate adaptation needs and carbon removal opportunities.

Despite their essential role, public nursery infrastructure has greatly diminished over time due to changes in demand and challenging business models (Dumroese et al. 2005; NASF, 2016), all while the reforestation needs on public lands are growing. The USDA Forest Service has over 7 million acres of reforestation potential across its national forests. To meet this need through tree planting would require 700 million more seedlings than America's nurseries could provide by maximizing existing capacity and adding new capacity with additional investments.

Federal nurseries have unique challenges that limit their ability to scale up production to meet this opportunity. For example, they rely on appropriations and are forced to undertake extensive time-consuming analyses to justify increased staff or infrastructure funding, thereby limiting their ability to meet increased demands for seedlings. Planned public nursery expansions often take multiple funding cycles to attain the requested funding, and then they must complete permitting to get to the construction stage. The process can take many years.

State nurseries face similar challenges. Several nurseries have closed in recent decades (NASF 2016). Additionally, those nurseries that are still in operation have dramatically cut production. The greatest factors limiting expanded production at state nurseries are labor shortages, declining demand especially from conservation plantings linked to Farm Bill landowner incentives that are no longer available, state nursery business models that often produce a significant volume for the speculative market (i.e., more financial risk for the nursery), state budget limitations, and regulations that limit state nursery production. State nurseries are often considered low priority and expendable in state budgets (Haase and Davis, 2017). State nurseries with idled capacity principally need budgets that would support additional labor and construction of additional greenhouses for container seedling production or field cultivation for bareroot seedling production. State and Federal hiring freezes can also be a barrier to nursery expansion, or even to operate at existing available capacity.

Recommended strategy: Encourage federal and state agencies and other partners to cooperate in delivering regional nursery infrastructure needs.

In recent years, bi-lateral funding and work arrangements between states and national forests have increased significantly, whereby state forestry and natural resource staff lead a number of activities that were traditionally reserved for federal employees. Federal agencies should actively engage states and other organizations to develop new partnerships that address seed collection, sharing seed between state and federal inventories, contributing to environmental decision making, and administering site preparation, planting, and maintenance work.

For example, the USDA Forest Service and states can use cooperative programs, such as Good Neighbor Authority and Shared Stewardship, to leverage planning, funding, and staff capacity to jointly meet landscape reforestation needs. The Southwest has 12 million acres of reforestation opportunity, but there are currently no federal nurseries in the region. Therefore, national forests in the region source seedlings from as far away as Oregon, increasing the costs and reducing the availability for Pacific Northwest plantings. One option would be for national forests to meet some of their seedling needs from state and private nurseries in their region. This demand could stimulate a more robust regional infrastructure that produces local species of need, better accounts for local effects of climate change like drought, supports local research, and stimulates regional economies.

Recommended strategy: Ensure public land managers include reforestation needs among their land management priorities.

Other federal and state agencies should more robustly include climate-adapted reforestation in their long-term management plans like the USDA Forest Service's required national forest management plan revisions under the National Forest Management Act. This long-term planning should include reforestation as a key goal and delineate needed local actions (i.e., volumes of seedlings and cone collections likely needed over time). Doing so will help federal agencies prepare to more quickly reforest after disturbances like severe wildfire.

Recommended strategy: Expand the USDA Forest Service's Reforestation Trust Fund to address the existing backlog and growing complexities in post-wildfire restoration.

The Reforestation Trust Fund (RTF) provides funding to reforest America's national forests. The Fund is capitalized by tariffs on a variety of imported wood products. When the fund was created in 1980, it was capped at $30 million. Forty years later, this funding is no longer sufficient to meet the growing list of reforestation needs driven by climate change. Recent legislative bills, like the REPLANT Act of 2020, would increase the funding allocated to the RTF and allow the USDA Forest Service to meet its reforestation opportunities while growing its reforestation pipeline, including nursery infrastructure, seed collection, and seedling production.

Recommended strategy: Establish dedicated reforestation funding for Department of Interior Agencies.

The National Park Service, Bureau of Land Management, U.S. Fish and Wildlife Service, and Bureau of Indian Affairs have more than 7 million acres of reforestation opportunity, yet Department of Interior (DOI) agencies do not have a dedicated funding source for reforestation, comparable to the USDA Forest Service's Reforestation Trust Fund. As a result, annual DOI reforestation accomplishments are currently less than half those of USDA Forest Service. DOI agencies need increased focus on their reforestation pipeline along with reliable funding to scale up reforestation appropriately.

Recommended strategy: Expand overall production while maintaining a balance between private and public nurseries.

Public policy needs to be mindful of potential tension between public nurseries and the private nursery sector. In some places, there is market overlap (e.g., provision of seedlings to small private landowners), but there is also some market segmentation. Public nurseries mainly produce for public lands, and vice versa for private nurseries. State and federal nurseries also tend to operate seedbanks for a much wider diversity of species, seed zones, and elevations than the private sector and often fulfill a research function.

In some regions, much of the idled capacity is in public nurseries. Increasing production should be mindful of avoiding undue competition with private nurseries. In regions with reduced public nursery capacity, there could be an opportunity for federal-state partnerships to bolster nursery capacity in a way that emphasizes climate resilience focused on the diversity of species, seed zones, elevations, and genetics. This is justified, in part, because the private sector is unlikely to do this on their own. In fact, several participants in our study raised concerns that the private sector does not always produce and market the right trees for the right places given their need to supply a wider market.

State nurseries often play an important role in providing seedlings for family landowners in addition to state lands. State nurseries generally focus on a greater diversity of tree species and seed genotypes. They also sell seedlings on a small scale compared with large, private nurseries. Additionally, state nurseries often serve as a key source of diverse stock for conservation plantings. This makes soil and water conservation districts one of their key customers. These customers often serve private landowners in designing conservation plantings (e.g., forest diversification plantings).

(From left to right) Jon Dale (American Forests), Rene Ruiz (U.S. Fish and Wildlife Service) and Erica Leiserowitz and William Rechin (Student Conservation Association) picking seeds on the Santa Ana National Wildlife Refuge in Alamo, Texas. Credit: James Foguth / American Forests.

8. The supply of diverse and climate-adapted seed is currently insufficient to meet reforestation opportunities.

Tree planting and reforestation starts with seeds. Tree seeds used in nursery production are obtained from specialized seed orchards or from the wild. Our national survey found that roughly 20% of seedlings in the U.S. are produced from wild collected seeds, often for trees planted in lower volumes (e.g., species used in conservation or restoration plantings) and for hardwoods, since most hardwood seeds do not store well. In regions with a large forest industry presence, most seeds are from seed orchards, including those managed by tree improvement cooperatives (TICs) focused on genetic selection for increased wood production in a few commercial species. Larger nurseries tend to rely more on seed orchards than do smaller nurseries.

Public agencies run most of the seed banking infrastructure in the country, and there are gaps in available seeds within nursery inventories. Gaps in seed inventories need to be addressed to have adequate seed supplies for all permutations of species, seed zone, and elevation bands. For instance, supplies of low-elevation seed sources in California are running low as demand skyrockets. At the national level, the total conifer seed inventory at any given nursery will last less than four years, and hardwood seeds would only last one year. Adopting alternative seed sourcing strategies — especially those designed to account for climate projections — will likely exacerbate existing gaps in seed inventories by adding further complexity to nursery decision making regarding which tree species and seed origins to produce. Maintaining a broader diversity of seed sources is vital for forestry to be able to respond to climate change stressors.

A significant concern for ramping up reforestation is that there are not enough seed collectors and seed extractories to clean and process seeds for storage. To ensure that poorly performing seeds do not take up valuable space in the reforestation pipeline, labs are needed to test seed viability. Seed inventories vary regionally and depend on how well species can be stored, access to storage facilities, adequacy of funding to support storage and infrastructure, and assurance that demand for a particular species persists. Limited seed inventory constrains the ability of nurseries to respond to increased demand with seed stock of the appropriate species, genetics, and quality.

Kuldeep Singh, nursery manager at the L.A. Moran Reforestation Center, inspects the conifer seedlings in the shade house. Credit: Luciane Coletti / American Forests.

Recommended strategy: Invest in seed orchards and create redundancy in the seed orchard system.

Threats from wildfire, pests and pathogens, and other sources are stressing America's seed orchards. For example, at least one of the three main USDA Forest Service seed orchards in California was significantly damaged in the 2020 wildfires. To avoid the loss of existing seed sources and key genetics, new and more diverse seed orchards are needed to create greater redundancy across the country and to support the increased use of climate-adapted seed.

Orchards make seed collection much more efficient and should be established at wide scales to meet the challenges of adapting to climate change and combating forest diseases, as opposed to solely reproducing the best genetics for timber production. Investments should also be made in mapping and protecting known seed trees and collection areas from fire and pests. Low-elevation seed sources, as well as threatened and underrepresented species, should be first priorities for these efforts.

Recommended strategy: State seedbanks should be bolstered or developed and sharing between federal and state inventories encouraged.

Every state should have a seedbank to allow projects for all target species at all appropriate elevations. Seed banks must have adequate seed storage facilities with a backup power supply in the event that primary power sources for refrigeration are disrupted. The California Department of Forestry and Fire Protection (Cal Fire) seedbank and the Oregon Department of Forestry's seedbank and seed orchards are good models. These state seedbanks supply seed primarily to non-federal clients, facilitating projects that might not otherwise happen due to lack of seed. Seed shortages can lead to use of maladapted seed. Collections are also at least somewhat coordinated with USDA Forest Service geneticists to achieve better coverage via combined funding.

Seeds collected by public agencies should be made available to all ownerships to increase the supply and diversity of seed available. For example, seed collected by the USDA Forest Service is typically only available to the districts that collect the seed. If the seeds are not used, they can be wasted and miss an opportunity to enhance state and private banks.

Recommended strategy: Better link the climate-adapted seedling needs of land managers with the seed availability, production capacity, and seed collection needs of nurseries.

State and private partners in California are pioneering an approach for California's seedbanks to better link climate-adapted seedling needs of land managers with seed availability, production capacity, and seed collection needs of nurseries. This system can be complicated to manage so land managers should increasingly be trained in the use of tools — like the Seedlot Selection Tool and the Climate Zone Seed Tracker.

Recommended strategy: Increase capacity within the USDA Forest Service Genetics Program.

USDA Forest Service geneticists are leaders in reforestation and forest-climate adaptation efforts. However, there are far too few of them, and budget cuts have reduced capacity at the worst possible time. Genetics staffing in USDA Forest Service Region 5 (California) has shrunk by more than half, for example, and funding for seed provenance studies has been eliminated. One individual serves the entire Southwest, Southern Rockies, and Northern Rockies regions. Much more could be accomplished with a greater number of geneticists available to serve not only the USDA Forest Service, but also other land management agencies and landowners. Creative partnerships with states, academia, and multiple federal agencies are needed to address this need.

Increasing outreach and assistance capacity to non-USDA Forest Service land managers is an important opportunity. More geneticists would mean more — and more successful — planting projects, more comprehensive seed collection efforts, and better tools and knowledge sharing. *The Genetic Options for Adaptation to Climate Change* report is a roadmap to climate adaptation at scale, but more geneticists are needed to fully realize the opportunities laid out (St. Claire and Howe, 2009). Such staff would also be key to engaging TICs in climate adaptation efforts, establishing more seed orchards, and expand nurseries' ability to propagate rare, threatened, and disease-resistant species (Potter et al., 2019). These needs will only increase over time.

More forest geneticists could allow for the establishment of expanded science-based guidance and implementation for states, tribes, and local governments on seed transfer rules that may prove to be essential for climate adaptive purposes.

Recommended strategy: Federal tree geneticists and climate adaptation scientists should receive funding to establish seed zones and corresponding seed inventories, in regions where this information is insufficient or does not exist. This information is needed for planting genetically appropriate, locally adapted trees.

Seed zones are costly to develop and adhere to but are extremely important for determining the appropriate source to use for a given reforestation site. At seedbanks and nurseries, stored seeds are organized by species, occasionally by genotypes, and seed zone (i.e., latitude and longitude, elevation, etc.). The South has five seed zones for commercial tree species and robust access to seed for these species. In the Northeast, seed zones were only recently developed and will need to be adopted by managers and nurseries alike (Pike et al., 2020). The West has multiple seed zones given the diversity in topography and climate. Seed banks and seed inventories in the West have gaps in seed for several species at several elevation bands and seed zones. For instance, the significant loss of disease-resistant sugar pine parent trees during the recent Sierra Nevada mass tree mortality event has produced scarcity in sugar pine seed sources. Seedbanks and inventories at nurseries should be expanded to fill gaps in seed supplies.

Recommended strategy: Increase funding and capacity for cone collections with federal and state agencies.

Training for tree climbers to collect seed and contracting opportunities for seed collection are both needed to ramp up seed collection. Inadequate cone collections can lead to a reduction in reforestation project size, cause expensive delays, or force managers to use inappropriate seed sources. Seed collectors ideally select seed in a way that maintains genetic diversity. Such best practices can be reinforced through training.

Recommended strategy: Establish new seed collection networks.

Possibilities for new seed collection networks include: private lands in the American Tree Farm system, extension foresters, TICs, and citizen scientists armed with apps. The Bureau of Land Management "Seeds of Success" program could be expanded to include tree-seed collections. This blueprint could also be adapted to include elements of the "Genetics Strike Team" concept, where teams would use the Seedlot Selection Tool to identify climate-adaptive seed collection areas, assess seed trees and landowners, and coordinate collection opportunities and funding.

Having a distributed network of seed collectors is desirable because it keeps costs down and provides better coverage. If one entity holds too many contracts, then there is a chance they spread themselves too thin and miss collection opportunities. It also makes sense to have a private/non-federal workforce because federal staff tend to be too busy during the fire season, which overlaps with cone collection season. Including cone collection among tasks in stewardship agreements and contracts is one opportunity if agreement holders and contractors have the proper training and oversight.

Recommended strategy: Engage TICs and non-USDA Forest Service seedbanks in climate adaptation and collections of seeds for underrepresented trees.

Non-USDA Forest Service seedbanks and TICs can help to address the urgent need for increasing collections of underrepresented seeds within regions. TICs have successfully established seed orchards and tree breeding programs. This expertise and social infrastructure should be adapted to encourage seed collection and development with a climate-adaptation mindset. Places with established TICs have much more robust seedbanks and more regular collections, though this applies primarily to commercial timber species. Such collections should be expanded to include species, genetics, and seed origins (e.g., underrepresented species, elevation bands, and seed zones).

In parts of the West, low-elevation trees may be adapted to warmer, drier climates, but seed crops are becoming smaller, less frequent, and affected by insects and poor germination rates. Large, severe wildfires are also decimating low-elevation stands at disproportionate rates.

In the Northeast and Midwest and South regions, underrepresented species — and/or species of conservation concern — should have their seeds banked and made available to landowners for conservation plantings. Growing demand for longleaf and shortleaf pine in the South are examples of how the private sector can adapt to service new seedling markets when they occur.

9. Nursery research is needed to address challenges, such as climate change, pests, and pathogens.

New, non-native forest insects invade the U.S. at the rate of around 2.5 pests per year (Lovett et al., 2016). This continual invasion of pests has significant implications for nurseries. For example, Sudden Oak Death was primarily spread by nurseries in California, and the resulting regulations have constrained markets geographically and made operations more expensive.

The recent proliferation of the Emerald Ash Borer in Northeastern forests — and the promise of identifying, breeding, and planting resistant ash stands — also illustrate the opportunity to increase research capacity and improve nursery systems for forest adaptation efforts (Leahy, 2020). Research funding is also needed to encourage new nursery practices aimed at climate adaptation.

Recommended strategy: Fund basic research into addressing climate change adaptation, as well as forest pests and pathogens, through nursery production. Ensure that such research involves both the public and private sectors.

Kuldeep Singh, nursery manager at the L.A. Reforestation Center, shows the seeds processed in the precision forest seeder, a machine set to start operating in 2021. Credit: Luciane Coletti / American Forests.

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