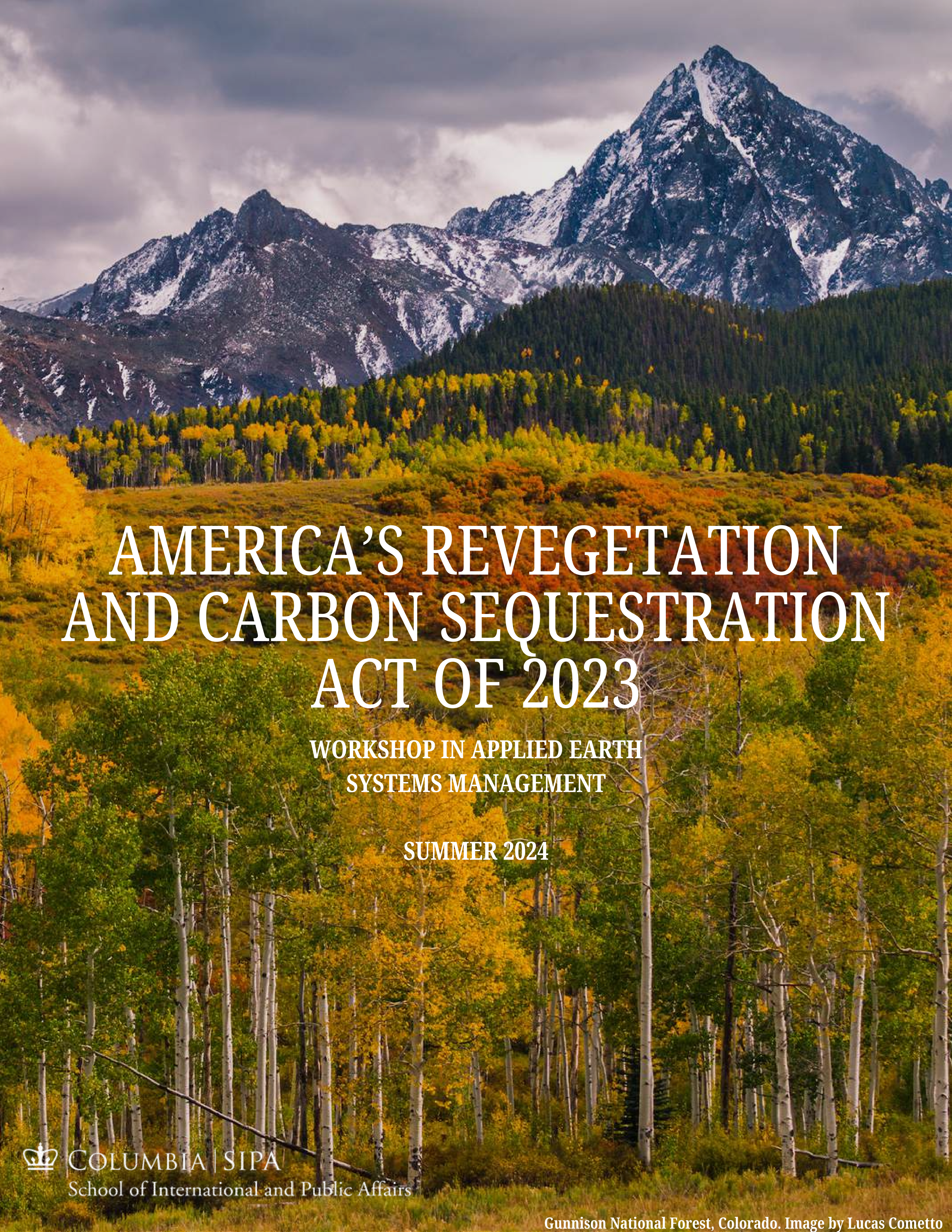

AMERICA'S REVEGETATION AND CARBON SEQUESTRATION ACT OF 2023

WORKSHOP IN APPLIED EARTH SYSTEMS MANAGEMENT

SUMMER 2024

COLUMBIA | SIPA
School of International and Public Affairs

Gunnison National Forest, Colorado. Image by Lucas Cometto

1 EXECUTIVE SUMMARY

The America's Revegetation and Carbon Sequestration Act of 2023 aims to address the critical environmental problem of deforestation and forest degradation in the United States. Forests cover 30% of U.S. land area and play a crucial role in mitigating climate change by sequestering carbon. After declines of U.S. forest area from the 1600s through the 1900s, improved forest management reversed this trend in the 20st century. By the 1960s, U.S. forests had become a net carbon sink again. However, U.S. forests and their role in carbon sequestration have recently become under threat again: invasive species, wildfires, and forest pests have led to increased forest degradation - a complex process which is further accelerated by climate change and a range of associated feedback loops. This negatively impacts both nature and people: Forest degradation does not only reduce carbon sequestration capacity, but also diminishes other environmental, economic, and social ecosystem services.

Two areas of this proposed legislation are explored in this report: Revegetation and Carbon Sequestration Through Forest Management and Innovation. The proposed National Revegetation Effort aims to assess and revegetate at least 25% of identified lands over a 10-year period. This report addresses vulnerability assessment, the identification of priority areas for revegetation, and landscape-scale simulation modeling. This effort will improve forest health and growth, soil health, heterogeneity, and biodiversity through prescribed fires, thinning and planting. It prioritizes areas such as burned zones and regions with high carbon sequestration potential. In order to enhance carbon sequestration, management plans that address the recovery of stand-replacing disturbances are supposed to help recover forests from increasingly frequent and severe wildfires. Improved forest management approaches such as thinning and management of invasive grasses should help to reduce the negative impact of these fires. To finance these efforts, enrolling National Forests' into carbon markets is one potential pathway. Other approaches include promoting innovation in forest products, such as creating markets and commercialization plans for biochar. The Act will also advance the use of mass timber for long-term carbon storage in wood products, promote educational programs, and further research on sustainable forest conservation.

In conclusion, the America's Revegetation and Carbon Sequestration Act of 2023 presents a comprehensive approach to forest conservation and management in the United States. The proposed solutions address the multifaceted challenges facing U.S. forests, including the spread of invasive species, increasing wildfire intensity, and the social, cultural, and economic impacts of forest degradation. The Act's implementation could significantly contribute to both mitigating and adapting to climate change and improving the vital ecosystem services provided by U.S. forests.

Acknowledgments

Workshop Manager:

Vrinda Goenka

Deputy Manager:

Rebecca Barel

Team Members:

Amanda Biscoe

Benjamin Greenstein

Brooke Harrison

Daniel Cassara

Fei (Yifei) He

John Watters

Nadine Palmowski

Nicholas Britton

Tianyi Wang

Faculty Advisor:

Dr. Matthew Palmer

Aspen grove in the Rocky Mountains | Image by Colorado.com

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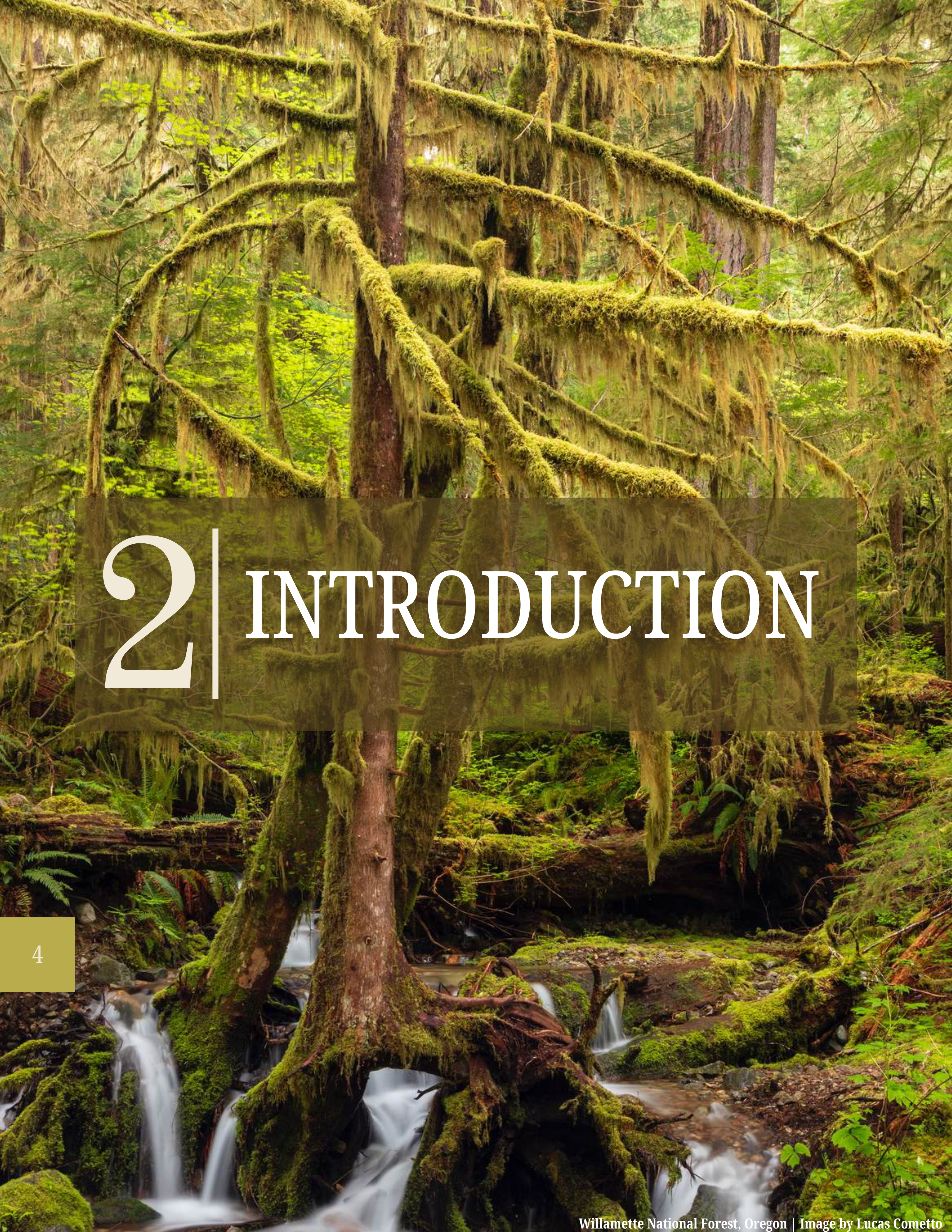
2 | INTRODUCTION



Willamette National Forest, Oregon | Image by Lucas Cometto

With more than 750 million acres of forests spanning the United States, wooded lands cover 30% of the nation's total land mass. The United States has the fourth-largest national forest area in the world (Tidwell, 2016). One crucial function of these forests is mitigating climate change via carbon sequestration, which is the removal and storage of carbon from the atmosphere. In 2021, U.S. forests removed an estimated 0.8 gigatons (Gt) of carbon dioxide from the atmosphere (Hoover & Riddle, 2023). This represents ~13% of U.S. gross carbon emissions in that year (EPA, 2024). Today, U.S. forests contain a total carbon stock of ~60 Gt, stored in both living and dead biomass and thereby sequestered from being released into the atmosphere and further fueling climate change. With appropriate forest management, this amount could even be increased in the future. Beyond this critical role in carbon sequestration, forests provide a variety of other benefits to both nature and people, with their ecosystem services encompassing environmental, economic, social, and cultural benefits.

After centuries of deforestation from the 1600s to the 1900s, the U.S. started to better manage and sustain its forests in the mid-1900s (Perry et al., 2022). However, in recent decades, human actions and climate change have started to pose new threats to these ecosystems. Increasing wildfires, storms, and droughts, as well as proliferating impacts from invasive pests and pathogens, are leading to forest degradation, i.e. the loss of the ability to provide important ecosystem services to nature and people (Gichuki et al., 2019). One important consequence of this degradation is that forests are sequestering less additional carbon than they used to, a 14% decline in annual sequestration rate between 1990 and 2021 (Figure 1).

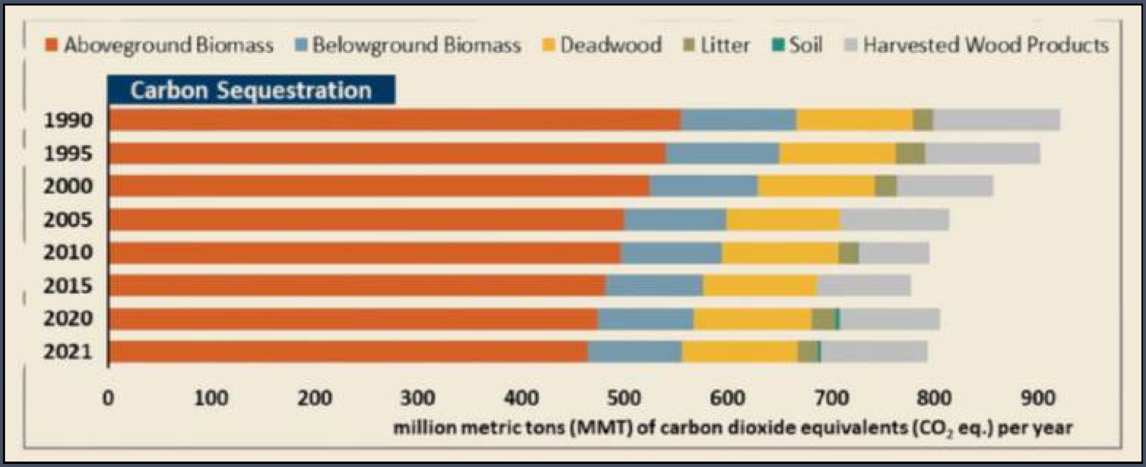


Figure 1: U.S. Forest Net Carbon Sequestration per Year, 1990-2021. Different pools of carbon stocks in forests or produced from forests in the case of harvested wood products (Reproduced from Hoover & Smith, 2021)

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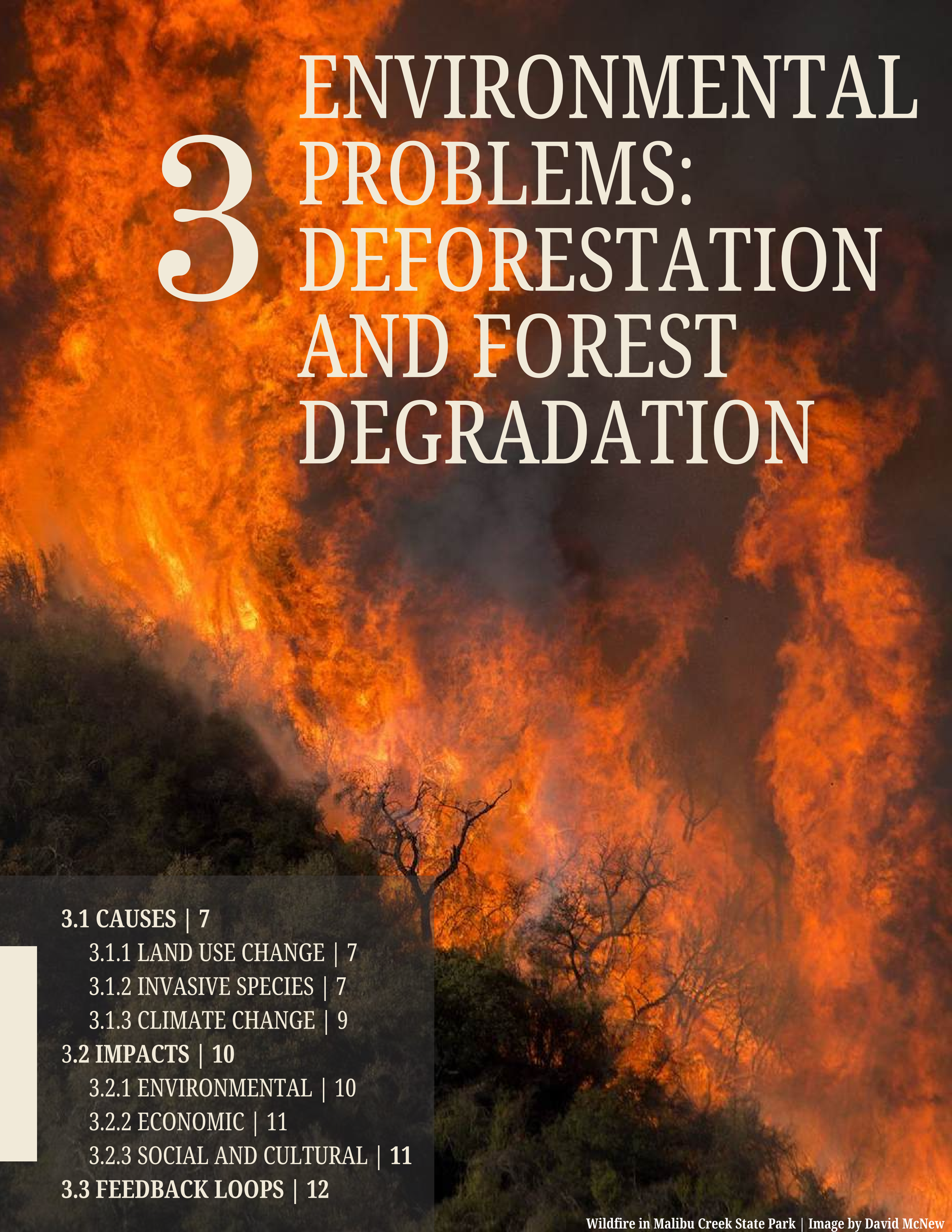


3 ENVIRONMENTAL PROBLEMS: DEFORESTATION AND FOREST DEGRADATION

Wildfire in Malibu Creek State Park | Image by David McNew

3.1 CAUSES

3.1.1 Land Use Change

Deforestation describes the conversion of forest land to non-forest uses such as agriculture or urban areas (Gichuki et al., 2019). Extensive deforestation in the U.S. was a phenomenon that occurred primarily in prior centuries: On U.S. lands, this trend was mainly observed between the 1600s and the early 1900s. The U.S. Department of Agriculture estimates that forest area declined ~30% during this time, mostly in the eastern U.S. where the land was used for settlements and related farming activities (Perry et al., 2022). This means that CO2 emissions were released, e.g. by burning the wood from the deforested area, and the overall carbon stored in the forest - the carbon stock - has been reduced. The rate of carbon stock reduction accelerated until the early 20th century (Miner et al., 2014). By then, an increasing need to sustain forest resources for a growing population called for improved forest management. An expansion of agriculture within the Great Plains furthermore led to abandonment of marginal agricultural lands and the natural recovery of forests in the eastern U.S.. These forces stabilized and then increased the amount of forest area. Ultimately, U.S. forests became a net carbon sink, sequestering more carbon than they release every year (Figure 2, Miner et al., 2014).

3.1.2 Invasive Species

The U.S. is the country with the highest number of recorded invasive alien species, species that have spread beyond their natural geographic range in the past centuries (Turbelin et al., 2017). The reasons for the spread of these species are complex and interrelated, however, there are a few main drivers (Crowl et al., 2008). On a global level, spreading mainly occurs via intentional or unintentional human transport of species across continents, such as via shipping. On a regional

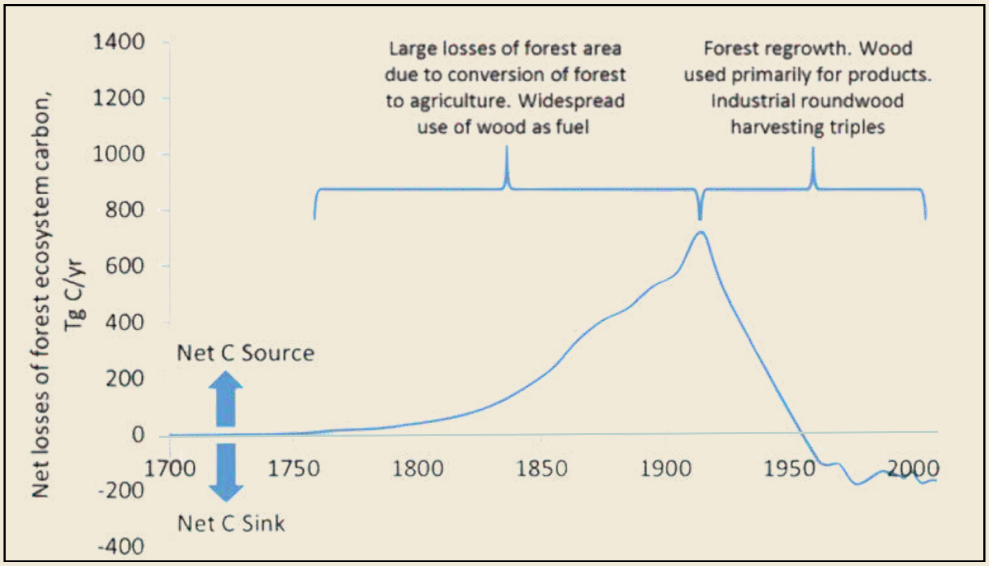


Figure 2: U.S. forest ecosystem carbon storage, developing from a net carbon source to a net carbon sink from 1700 to early 2000s (Miner et al., 2014)

level, species spread across areas with conditions that are suitable for them, sometimes accelerated by human-induced change of ecosystems such as fragmentation or degradation of habitat. Climate change can contribute to both: rising temperatures enable invasive species to spread to previously unsuitable regions, and increasing climate change-induced disturbances degrade ecosystems, opening up opportunities for invasion. (Bowmann et al., 2017)

In light of these developments, invasive grasses have created a significant threat to forests in the western U.S.. These grasses include, for instance, Cheatgrass, Ventenata, and Medusahead, all of which have expanded their populations rapidly over the past century (Bansal et al., 2014). The threat lies in their ability to survive in arid conditions and subsist on the nutrients left following a forest fire. They are also highly competitive, taking up soil resources and space from native species, thereby reducing the abundance of native species (Bradley et al., 2018).

As a specific example, Cheatgrass (Bromus tectorum) poses a significant challenge to forest management. THe species is capable of growing quickly, having a faster rate of growth than many of the competing, native grasses within the western U.S. Rapid growth allows cheatgrass to take advantage of high nitrogen availability following wildfire, leading to expansion across the region (Molvar et al., 2024). Once established, cheatgrass seedlings quickly grow shallow lateral roots, allowing them to outcompete native species for water and nutrients. As a result, cheatgrass seeds have been found to suppress 73% and 67% of the native bluebunch wheatgrass and bottlebrush squirreltail in study areas (Molvar et al., 2024). This way, cheatgrass leads to forest degradation and poses a great

Left: Bromus tectorum
Image by S. Dewey, Invasive Species Council of British Columbia

Right: Cheatgrass field in Washington State
Image by Hannah Letinich, The Nature Conservancy

threat to biodiversity within the western U.S. (Nagy et al., 2020).

Outside of cheatgrasses' competitive advantage and impact on the grass community, its litter creates a highly flammable fuel source, which leads to an increase in wildfires within invaded areas: A study from 2000 to 2015 showed that forest areas where cheatgrass achieved a land coverage of 15% or more, were twice as likely to burn multiple times than areas without cheatgrass (Bradley et al., 2018). This heightened fire frequency comes from phenological differences between cheatgrass and native species: Growing in early spring, cheatgrass absorbs large amounts of water, making the surrounding area much drier as the growing season progresses. Once it dies, the plant litter becomes tinder-dry, and thereby a fuel for wildfires (Bradley et al., 2018).

3.1.3 Climate Change

Climate change is another driver of contemporary forest degradation. From many related issues that ultimately drive forest degradation, wildfires are the most visible. Rising temperatures have led to growing forest wildfire areas as well as longer annual fire seasons in the western US. With an increase of 10.4 million acres from 1984 to 2015, the forest wildfire area is now almost twice as large as would be expected without climate change (Abatzoglou & Williams, 2016). At the same time, we observe a dramatic increase in annual fire season lengths: In the 30 years between 1973-82 compared with 2003-2012, the wildfire season has become longer by 3 days each year, cumulatively expanding the fire season by about 90 days (Westerling, 2016).

Apart from wildfires, there are a number of other climate change-related drivers of forest degradation: the number of droughts in the U.S. has started to rise alongside global warming. Droughts not only make forests more susceptible to catching fire, but also stress trees, reduce their growth - and thereby carbon sequestration - and make them more susceptible to damage from pests (Sohn et al., 2016). Increasing extreme weather events such as hurricanes, other wind storms, heavy rainfall events, and ice storms also contribute to forest degradation through fragmentation of continuous forest, loss of trees, and increases in soil erosion (Kogut, 2023).

Goat Marsh Lake area southwest of Mount St. Helens, Washington | Image by Lucas Cometto

3.2 IMPACTS

Forests provide a range of ecosystem services, the direct and indirect contributions of ecosystems to human well-being (Pearce, 2023). Degraded forests can lose their ability to provide these services with negative environmental, economic, social and cultural consequences for both nature and people.

3.2.1 Environmental

Forest degradation comes with environmental consequences on a global level, by increasing the amount of carbon in the atmosphere and thereby accelerating climate change. The reason for this is that deforestation directly impacts the ability of terrestrial ecosystems to sequester carbon. Not only is the carbon stored in the forests' biomass released when trees are killed and their wood burns or decomposes, but the future potential of carbon sequestration is diminished (IPCC, 2019). One important nuance of this impact is that forest carbon stocks vary by region and type of forest: live aboveground tree carbon stocks in the U.S. range from 5.2 tons of carbon per acre in the Great Plains to 52.6 tons of carbon per acre in the Pacific Northwest (Hoover & Smith 2021). This difference, by a factor of 10, makes it far more impactful if a forest is destroyed in the Pacific Northwest in contrast with the Great Plains.

Secondly, forest degradation has negative impacts on biodiversity. Forests provide habitats and essential resources for many species. Disrupting the ecological processes in forests can lead to a decline in biodiversity (Gardner et al., 2007). One example for western U.S. forests is the effect of decreasing whitebark pine (Pinus albicaulis) populations on endangered grizzly bears (Ursus arctos horribilis).The nuts of the whitebark pine represent an essential source of food for grizzly bears, accumulating their energy reserves before hibernation (van Manen et al., 2013). The whitebark pine populations are declining since the introduction of a pathogen called pine blister rust. This disease is caused by an introduced fungus (Cronartium ribicola) that was first detected in the U.S. in the early 1900s (Kinloch & Comstock, 1981).

Finally, forest loss and degradation also cause forests to become more susceptible to future degradation and natural disasters (Busch, 2017). Degraded forests are less resistant to storms, become worse at regulating water supply and microclimate under the canopy, and have decreased capacity to filter water and air. These reduced ecosystem services further suffer from a range of positive feedback loops encompassing forest degradation, climate change, wildfires, tree growth decline, and susceptibility to invasive species, further detailed in section 2.3.

3.2.2 Economic

Deforestation and forest degradation have profound economic impacts. Timber harvesting is the main source of income resulting from forests in the U.S.. Due to the regenerative capability of forests, timber harvest can be practiced sustainably if the harvest and tree mortality levels do not exceed the rate of regrowth (Perry et al., 2022). Thanks to careful forest management over recent decades, U.S. harvest volumes are now relatively small and surpassed by replanting or the natural recruitment of trees - leading to a positive annual rate of carbon sequestration. However, with rising tree mortality due to natural disasters such as wildfires or pest outbreaks, forest productivity is compromised, increasing the risk of tipping into a net loss of forest (Perry et al., 2022).

Apart from decreasing revenues from the timber industry, damage-repair costs are another important economic consequence of forest degradation. With increasing frequency and severity of wildfires, especially in western U.S. forests, annual fire expenditures have been increasing exponentially over the past decades, from 25 million USD/year in the 1980s to around 400 million USD/year in the 2010s - an increase by around 8 times (Figure 3).

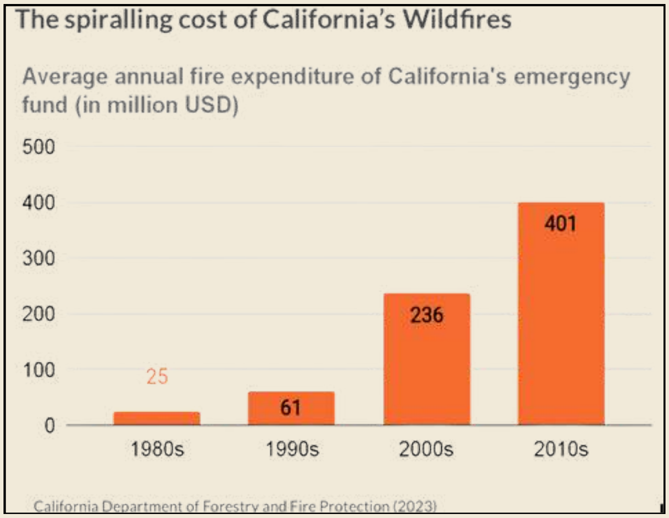


Figure 3: Average annual fire expenditure of California's fire suppression emergency fund at the Department of Forestry and Fire Protection. The fund's expenditures encompass all fire-related costs for wildfires that cannot be extinguished in a first attempt by local firefighting efforts (California Department of Forestry and Fire Protection, 2023).

3.2.3 Social and Cultural

The cultural, spiritual, and recreational value of forests as well respresent an important part of their ecosystem services. Local and indigenous communities rely on forests for resources such as livelihood, food, and spiritual value (Molnar et al., 2004). In addition, people who enjoy outdoor activities in forests are losing opportunities to recreate in these ecosystems. In 2023, it was estimated that there are more than 60 million outdoor hiking participants in the U.S. (Statista Research Department, 2024), who could be negatively impacted by forest decline. This reduced recreational use would thus negatively impact the 560 billion USD outdoor recreation economy, which accounted for 2.2 % of U.S. GDP in 2022 (U.S. Bureau of Economic Analysis, 2023)

Fire burns inside a redwood in California's Big Basin Redwoods State Park after 2020 wildfire

Image by Marcio Jose Sanchez

3.3 FEEDBACK LOOPS

Climate change threatens forests, but forest degradation itself is also fueling climate change, creating a positive feedback loop. As described by Harris et al. (2020), with rising global temperatures, forests become drier, milder winters lead to reduced snowpack, and the length of fire seasons increases. These factors dry out vegetation, thereby making it more susceptible to ignition by human activity or lightning. As a result, wildfires both release carbon emissions directly and reduce the ability of forests to sequester carbon, both of which contribute to increasing concentrations of greenhouse gases and further accelerate climate change.

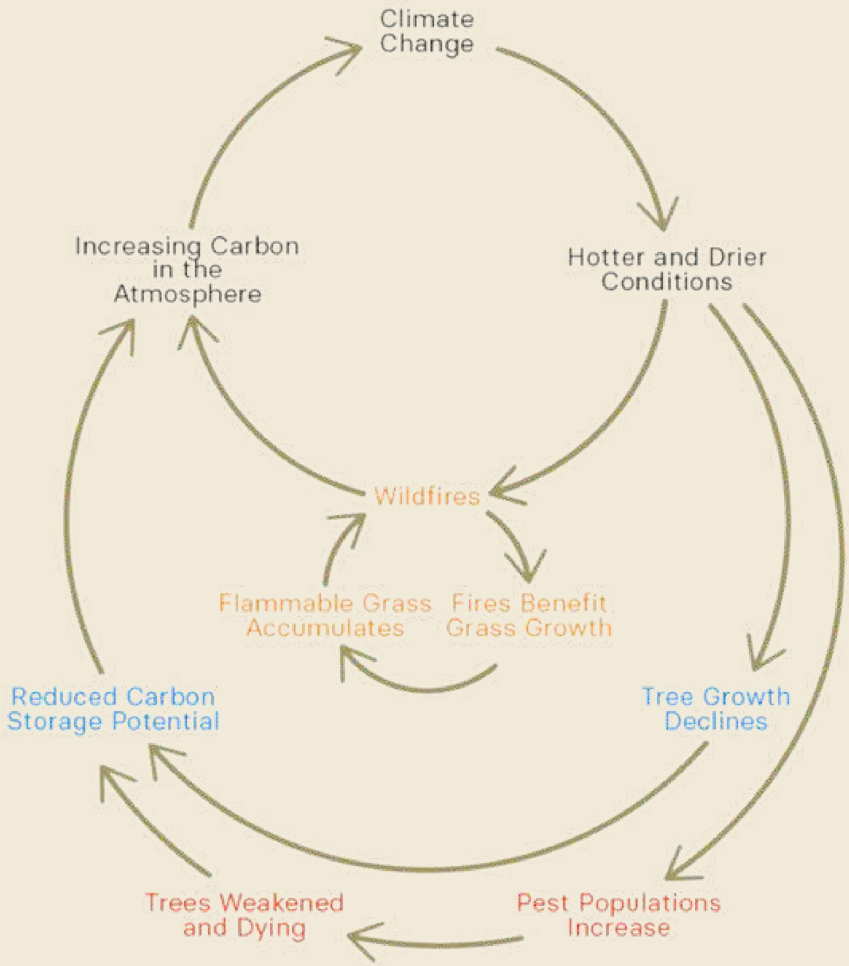


Figure 4: Positive feedback loops are accelerating forest degradation.

As shown in Figure 4, this feedback loop is further intensified by adjacent positive feedbacks: The burned area after wildfires benefits the spread of invasive grasses such as cheatgrass. These flammable grasses accumulate, dry out soils and easily catch fire, thus reinforcing the feedback loop. Hotter and drier conditions can furthermore lead to a decline in tree growth and increasing pest populations, which can both weaken and kill trees. Both increased fire from invasive grasses and declining tree growth ultimately lead to reduced carbon storage potential of forests, further increasing atmospheric carbon levels.

SUMMARY OF THE ACT

4

The America's Revegetation and Carbon Sequestration Act of 2023 is a bipartisan bill introduced in September 2023 during the 118th U.S. Congress. Its primary goals are to improve revegetation and carbon sequestration activities in the United States, addressing climate change, conservation, and economic development. The Act outlines a comprehensive approach to these issues through various initiatives and programs.

Quinalt Rainforest in Olympic National Park, Washington | Image by: Lucas Cometto

4 SUMMARY OF THE ACT

Title I - Revegetation

Title I establishes a comprehensive National Revegetation Effort. This initiative requires federal agencies to assess lands for revegetation needs within one year and develop a 10-year strategy to revegetate at least 25% of identified lands. Priority is given to areas such as burned zones, flood-prone regions, and locations with high carbon sequestration potential. The Act also allows for voluntary participation from non-federal landowners.

Title I also establishes a Job Corps program for tree planting training and maintenance. It introduces a grant program for tree planting projects aimed at reducing residential energy consumption, with a focus on equitable distribution of funds across the country.

The legislation addresses revegetation on specific types of land, including a pilot program for introducing native vegetation to eligible mined land. It also allows for international cooperation, enabling the U.S. Forest Service to provide technical assistance for tree planting activities in other countries and to partner with international NGOs for global carbon sequestration through revegetation.

Gunnison National Forest, Colorado | Image by Tad Bowman

Title II - Carbon Sequestration Through Forest Management and Innovation

Title II focuses on improving forest management activities to increase carbon sequestration. It outlines a methodology for carbon credit management for the National Forest System to generate funds to finance some forest management activities. It requires annual reports to Congress on the program's status.

Title II also mandates the creation of model land and resource management plan amendments for recovery after stand-replacing disturbances, with plans to be revised for each National Forest System unit within 10 years. This aims to enhance the resilience and adaptability of forests and rangelands.

Forest product innovation is addressed through a pilot program for using biochar as a cattle feed additive and the development of a national commercialization plan for its distribution. The legislation also outlines an action plan to control invasive grasses, promoting resilience, biodiversity, and carbon sequestration in forests, rangelands, and grasslands.

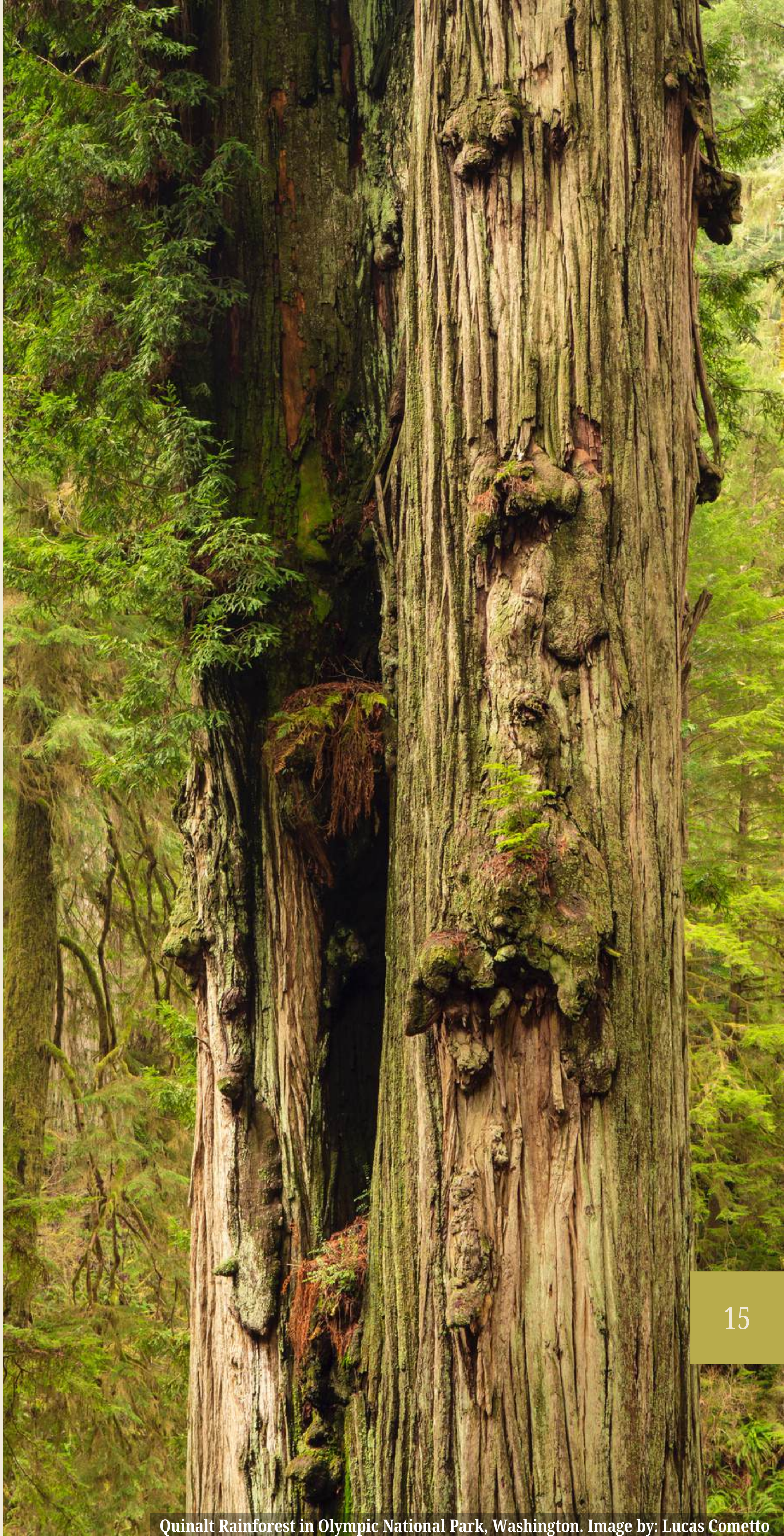
Title III - Mass Timber

The bill presents classifications of “mass timber", which includes various types of laminated wood. The Act places significant emphasis on promoting the use of mass timber. It establishes a Mass Timber Science and Education Program to provide practical research for architects, developers, and forest industries. The bill defines both residential and commercial tall wood buildings that would utilize mass timber in their construction.

A database of mass timber buildings will be created to assess their embodied carbon. These measures are designed to encourage the use of sustainable building materials and create new markets for forest products.

Title IV - Research

The Act aims to improve methods for measuring carbon stored in woody biomass and building materials. It calls for enhancing forest inventory and analysis using advanced geospatial technologies and facilitating research on new markets for low-value forest management byproducts. The Act expands services of Forest Health Threat Centers to inform climate-resilient forest management. It also requires monitoring of field plots and the development of more accurate and cost-effective forest carbon measurement tools using remote sensing technologies.



Quinalt Rainforest in Olympic National Park, Washington. Image by: Lucas Cometto

5 NATIONAL REVEGETATION AND REFORESTATION EFFORTS

One of the central solutions presented in the Act is the National Revegetation Effort. The Effort aims to restore at least 25% of targeted lands over a ten-year period using a three-step plan of Assessment, Prioritization, and Implementation.

Yosemite National Park | Image by Chateau du Sureau

5.1 ASSESSMENT AND PRIORITIZATION

The first stage of the National Revegetation Effort will be to assess the acreage of Federal land in need of revegetation. Objective revegetation assessment tools will be applied to determine which land is adequately occupied by well-distributed, countable, ecologically appropriate trees or other desirable vegetation. This will establish baseline conditions for Federal land and facilitate rapid assessment of revegetation needs. Once the survey of lands in need of revegetation is complete, a prioritization assessment will be undertaken. The Act specifies that areas with the highest concentration of degraded or lost forest

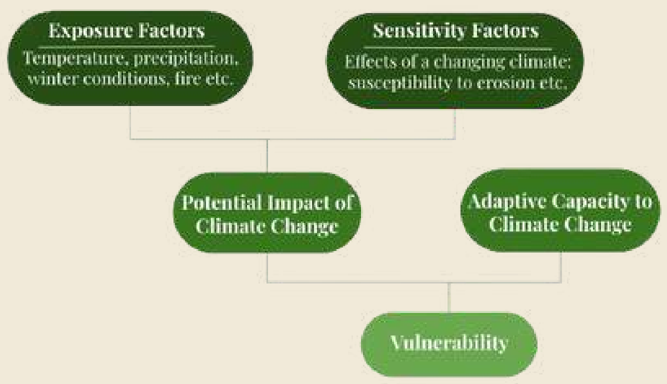


Figure 5: A vulnerability assessment considers the potential impact of climate change and an area's ability to adapt to those changes. Source: Swanston et al., 2016

and those with the highest potential for restoration success will be prioritized for revegetation - the process of restoring vegetation where it has been lost - and reforestation - replanting trees in areas that have been deforested or degraded (ClimateSeed, 2023).

5.1.1 Vulnerability Assessment

Prioritizing restoration activities involves assessing the ecological value and vulnerability of different landscapes (Swanston et al., 2016). One framework established by the USDA Forest Service is the vulnerability assessment, shown in Figure 5 the at bottom of the page, which examines a forest or rangeland's adaptive capacity, or ability to cope with climate change with minimal disruption, and the potential impact of climate change on the area. The potential impact is derived by evaluating exposure to climate-related changes such as temperature, precipitation, or fire and sensitivity to those changes in climate, such as susceptibility to erosion and changing growth rates based on climate change (Swanston et al., 2016). This framework establishes the forest as a natural resource, setting a foundation for the following prioritization efforts.

5.1.2 Prioritized Geographic Areas

The Act identifies five categories of land to consider when setting priorities: 1) burned areas and any other destabilized land that poses heightened risks to homes, roads, and public water supplies, 2) areas at high risk of establishing invasive species, 3) formerly mined land, 4) floodplains and riparian areas, and 5) areas with regionally significant carbon sequestration potential.

5.1.3 Landscape-scale Simulation Modeling

After estimating the vulnerability of the critical areas, spatial analysis and modeling are used to evaluate the regional performance based on each ecological criterion. This type of data-driven approach to prioritization is essential for improving revegetation efforts (Holl & Aide, 2011).

A study on the Wallowa-Whitman National Forest in eastern Oregon provides a practical example of how this prioritization can maximize ecological and socioeconomic benefits. Researchers evaluated five objectives for potential restoration projects: vegetation departure, insect risk, timber harvest potential, wildfire risk to human settlements, and potential wildfire hazard (Vogler et al., 2015). The study used various modeling techniques and data sources to assess forest stand dynamics, fire behavior, and the geospatial relationship between different types of land, finding that there were significant trade-offs between different restoration goals. No single project area ranked highest for all five objectives and some objectives were negatively correlated; areas with higher insect risk tend to be less valuable for timber production, for example (Vogler et al., 2015). This study illustrates that prioritization in national revegetation efforts is a complex process balancing multiple objectives, considering local ecological conditions, and utilizing advanced analytical tools and data to make informed decisions about resource allocation.

5.1.4 Prioritization Challenges

These guidelines create a foundation for prioritization strategy, but because no single area is generally the best candidate for reforestation across every priority (Vogler et al., 2015), resolving these tradeoffs requires policymakers to make difficult decisions.

Beyond the challenge of assessing present conditions, future conditions will likely be different because of climate change. Climate models generally agree that global temperatures are rising and will continue to rise, but many disagree on how dramatically and quickly they will rise, how precipitation patterns may change, and which areas will be most impacted (Alizadeh, 2022). These uncertainties complicate efforts to predict which areas will be most susceptible to drought or fire risk, and thus how best to prioritize for both today's needs and tomorrow's needs.

Land Scar from Mining Activities in the Western United States

Double Creek Fire at Wallowa-Whitman National Forest

Figure 6: Examples of high-priority areas for reforestation |Images by West Coast Aerial Photography (left) and KATU News (right)

5.2 IMPLEMENTATION AND FOREST MANAGEMENT

5.2.1 Revegetation, Reforestation, and Forest Management Practices

Revegetation and reforestation efforts will begin after prioritizing acreage in need of rehabilitation. The Act sets a goal to rehabilitate 25% of targeted lands within 10 years, ultimately improving the carbon sequestration potential of forests in the western United States. Since productive forests sequester more carbon and resilient forests maintain this production over time, forest management tactics are employed to promote three intermediate objectives - soil health, heterogeneity, and biodiversity - that lead to greater forest resilience and productivity.

5.2.2 Objectives: Soil Health, Heterogeneity, and Biodiversity

Healthy soils support plant productivity, regulate a forest's hydrologic cycle, hold and supply key nutrients, and regulate carbon fluxes. Healthy soil maintains its structure and stability, absorbing and retaining water and providing a growing medium and source of nutrients for trees (Aerts & Honnay, 2011). Disturbances such as wildfires decrease an ecosystem's resilience to future disturbances and decrease forest productivity.

Biodiverse reforestation aims to create plant communities that contain a mix of native species supporting different key functions of the community (Andres et al., 2023), which can improve resilience in several ways. Small increases in tree diversity can greatly reduce the risk of planted trees dying or failing to grow as expected, known as planting failure (King et al., 2023). The species or individuals within a species that do survive, known as selection, generally do so because they are best adapted to climatic conditions, making the forest more resilient (King et al., 2023). As conditions change, the performance or abundance of some species may be adversely affected. In more biologically diverse forest areas, though, it is more likely that those declines will be offset by other species or phenotypes which are better adapted to the new conditions. Because of this, diverse plant communities should provide more stable ecosystem services than homogenous ones (Loreau et al., 2021).

Gifford Pinchot National Forest, Washington. Image by Lucas Cometto

This also provides a buffering effect that makes vegetative cover more stable; the risk of planting failure decreases in plots with a wide variety of species because species have different survival rates (Van de Peer et al., 2016). Finally, trees require different resources at different points in their lives, and different species may require different resources. Thus, plantings that are diverse across age and species reduce competition for resources and alter the environment and soil in ways that are favorable to other species in the planting (Feng et al., 2022; King et al., 2023).

5.2.3 Management techniques: Prescribed Fires, Thinning, and Planting

A century of fire suppression policy has led to a build-up of fuel that can lead to severe wildfires. To reduce the risk of a severe fire, practitioners use the techniques of prescribed fires and thinning.

Prescribed fires are the controlled application of fire under specified weather conditions to restore health to ecosystems (Miranda & Ballaron, n.d.). They reduce the likelihood of a stand-destroying wildfire by burning the existing fuel load, particularly surface fuels and ladder fuels. Surface fuels such as dead and downed trees, grasses, short shrubs, and other dried-up plant materials create the biggest risk of wildfires, as they are generally the initial fuel for a wildfire. Fires can then spread to ladder fuels, the small trees or tall shrubs that provide fires with vertical access from the surface to the crown of the forest (Stephens et al., 2012).

Fire managers carefully plan prescribed fires based on weather and wind conditions and coordinate with numerous stakeholders to carry out the burn safely. Despite these precautions, there are still risks associated with prescribed fire. Any fire will create smoke and pollution, reducing air quality and posing a risk for people and animals in close proximity to the fire (Kala, 2023). Further, fire can be unpredictable, and even carefully planned prescribed fires pose the risk of becoming uncontrolled. New Mexico's largest recorded wildfire, the Calf Canyon or Hermit's Peak blaze in the spring of 2022, began as a prescribed fire aiming to thin out dense pine woodlands (Romero, 2022). Despite these risks, protocols for managing prescribed fires are highly effective. Across the U.S., roughly 4,500 prescribed fires are lit each year with a containment rate of 99.84%, resulting in the treatment of 1.4 million acres (USDA, 2022).

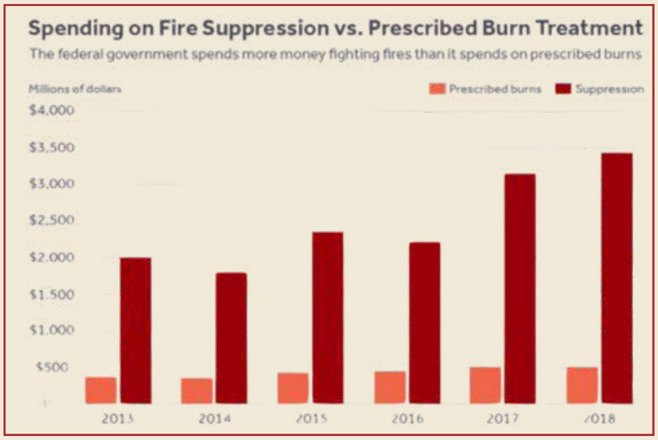


Figure 7: The federal government has historically spent significantly more money on fire suppression efforts than on management tactics such as prescribed burns
Source: Climate Central, 2019

Often paired with prescribed fire is the tactic of thinning, a process that typically involves removing small trees, piling brush, pruning branches, and creating fuel breaks in dense forest stands. Thinning reduces the density of a forest stand, generally targeting ladder fuels, which makes it useful when used in tandem with prescribed fires (Stephens et al., 2012). Thinning can also increase biodiversity in a forest by removing tree species that are overly abundant (Dinkey Project Planning Forum, 2010) and reducing competition for soil nutrients (North et al., 2022), both of which lead to healthier, more resilient forests.

Despite these benefits, the effectiveness of forest thinning is still debated (Banerjee, 2020). While there have been a number of studies highlighting the success of thinning for improving forest resiliency against wildfires (Davis et al., 2023; Flathers et al., 2016; Knapp et al., 2021), thinning can also degrade soil (Whicker et al., 2008), reduce soil carbon sequestration (Akburak & Makineci, 2016; Yang et al., 2022), or increase wildfire intensity (Cram et al., 2015). Intensive research on the effect of individual tree species, spatial distribution, and fire regimes are critical for understanding when and where thinning management will have positive effects. Forest thinning is a management tool that, if implemented effectively, can reduce the risk of wildfire, restore historic tree density and species distribution, and protect natural resources (USDA, 2021).

Figure 8: Bootleg Fire, Fremont-Winema National Forest where the wildfire met an area treated with prescribed burning and vegetation thinning | Image by Steve Rondeau, Natural Resources Director of the Klamath Tribes. Source: USDA Climate Hubs

While some areas are in need of prescribed fires and thinning, others may require the planting of new trees for reforestation. This multi-step process is managed by the USDA Forest Service, beginning with oversight of the seed repositories and nurseries used to collect and cultivate a diverse range of species for reforestation (USDA, 2024). Trees of different ages and species should be planted depending on the soil, slope, and aspect of the landscape to maintain soil health and increase chances of stand survival (Dinkey Project Planning Forum, 2010). This principle is illustrated in the strategy for the Dinkey Collaborative Forest Landscape Restoration Project, a 154,000-acre reforestation project that has been conducted in the Sierra Nevada National Forest since 2010. In 2020, the Creek Fire, then the largest fire in California's history, did not burn into the land managed by the Dinkey Collaborative, largely because of forest management techniques that had reduced fuel load and increased biodiversity (Bliss, 2020).

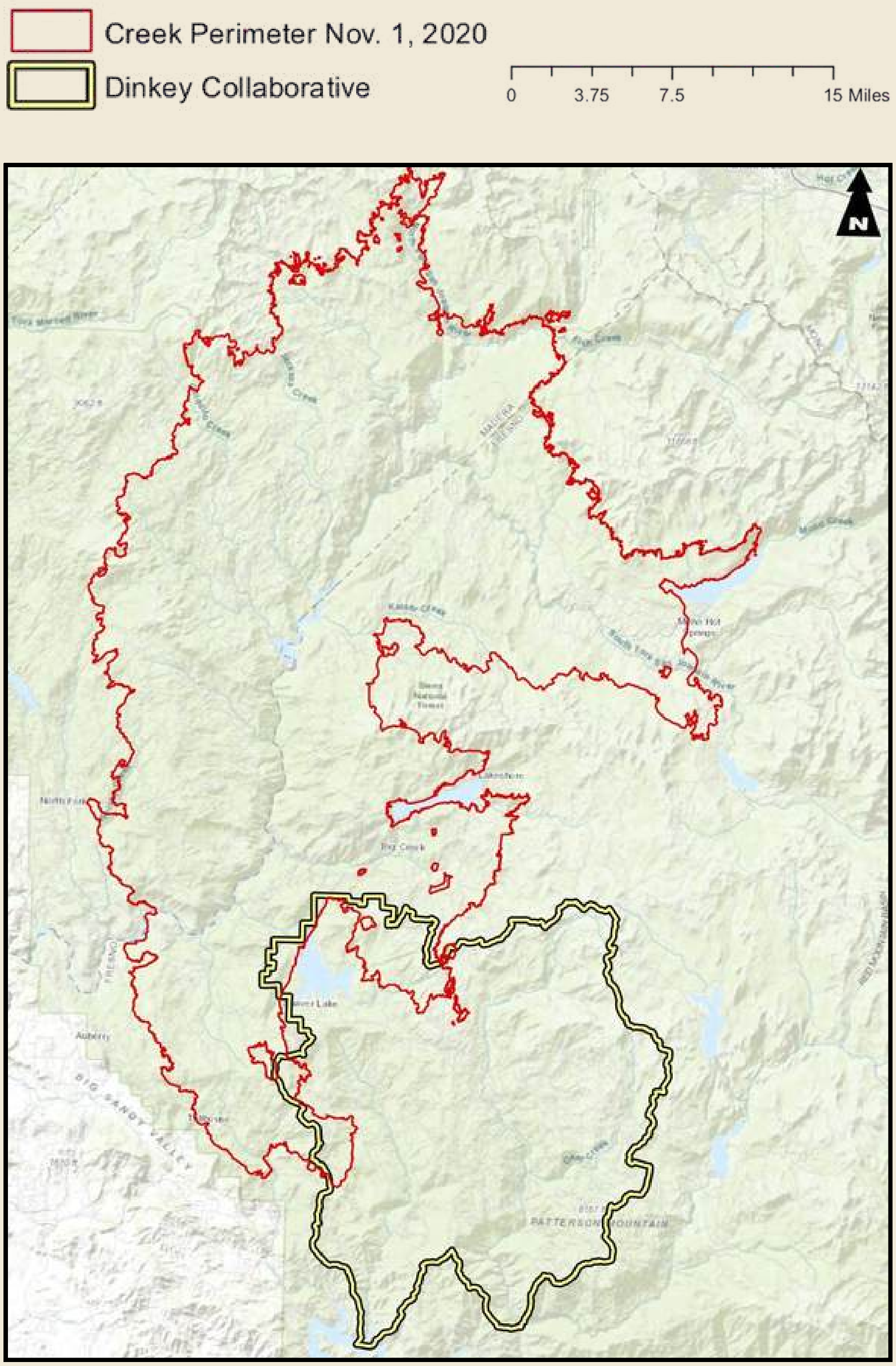


Figure 9: The Creek Fire did not extend into the forest area managed by the Dinkey Collaborative. Source: Bliss, 2020

5.3 ADDITIONAL STRATEGIES FOR REFORESTATION AND REVEGETATION

The National Revegetation Effort is the primary tool that the Act would employ to increase forest extent and productivity, but it also features several additional measures including experimental forests, reclamation projects, and creating new markets for forest products.

The Act establishes a general requirement that all public forest management efforts consider resiliency and climate change. Anticipating the impacts of climate change has been one of the biggest challenges for reforestation efforts in the western United States, so requiring consideration of climate adaptation and resilience in revegetation efforts will be the foundation of future successful efforts (Bierbaum et al., 2013).

5.3.1 Experimental Forests

The Act formally authorizes the creation of a network of experimental forests where climate resiliency research can be undertaken to better understand the environmental functions forests perform and how they react to certain pressures and disturbances (Youngblood, 2009). Climate resiliency research will focus on the mechanisms of seedling establishment, developing sustainability metrics for reforestation, and tree planting designs, all of which will contribute to the success of revegetation and reforestation efforts.

5.3.2 Long-term Contracts to support Tree and Seed Planting

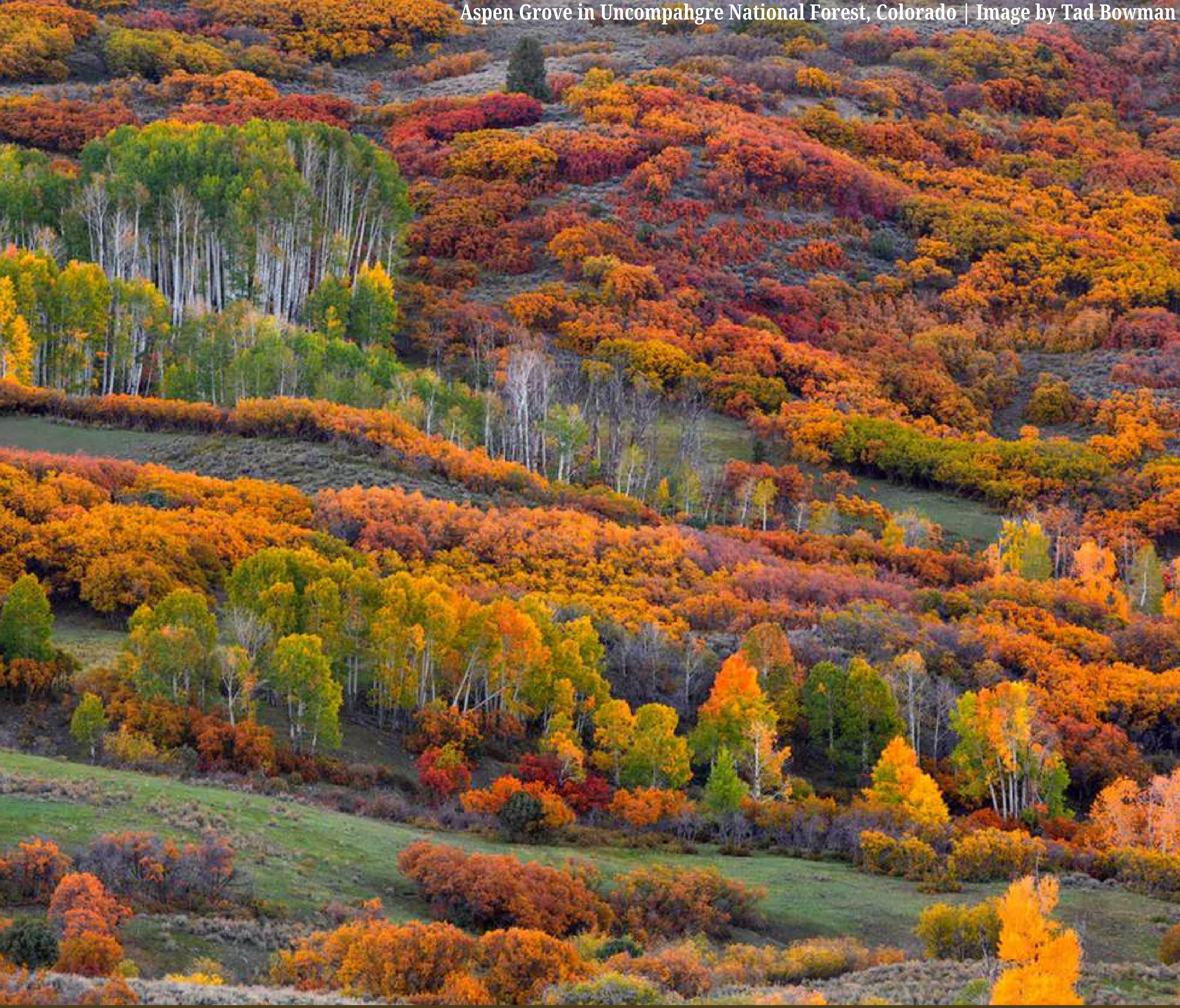
The Act authorizes long-term contracts or cooperative agreements to re-establish vegetation on federal land and aims to develop a career and technical education program focused on tree planting or tree maintenance. Both measures are intended to increase the supply of skilled workers who can support rehabilitation efforts. Tree and seed planting projects will be established through grants with states, Indian tribes, local governments, nonprofit organizations, and retail power providers.

5.3.3 Revegetation on Abandoned Mine Land

Researchers have estimated that roughly 2 million acres of abandoned mine land have been environmentally damaged by past use (Iverson & Wali, 1993), and their revegetation is called for in the Act. In most cases where mine lands have been revegetated, on-site soil and water quality improved, and habitats for plants and wildlife were restored. This has led to increased visitation to these areas, providing revenue and incentives for additional restoration efforts (United States Bureau Of Land Management, 2007).

Foliage grows over the site of an abandoned coal mine in Tennessee | Image by Jacob Ian Wall

Aspen Grove in Uncompahgre National Forest, Colorado | Image by Tad Bowman



6 CARBON SEQUESTRATION THROUGH FOREST MANAGEMENT AND INNOVATION

6.1 FOREST MANAGEMENT FROM CARBON CREDITS

Another important goal of the Act is to outline improvements for forest management activities to increase carbon sequestration, ensure long-term carbon storage, or to avoid carbon emissions on National Forest System land. Collaborative efforts including funds, programs and commercialization plans are needed to increase the carbon sequestration.

In addition to the revegetation efforts, the Act authorizes the carbon credit program to supplement funds for forest management. The carbon market encourages the maintenance of carbon stores on a landscape to slow climate change, attributing an economic value to greenhouse gas emissions and sequestration by issuing exchangeable carbon credits (Rodrigues, 2017). The Act directs the U.S. Forest Service to design and potentially implement a system to attribute carbon credits to publicly-owned forests, creating a new market for them.

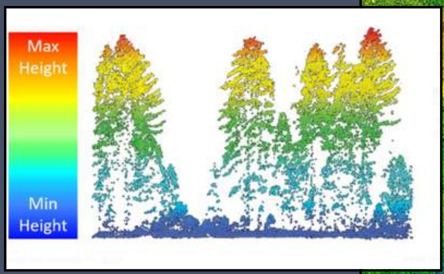
Carbon credits can be generated through forestry by 1) preventing degradation of existing, healthy forest, 2) reforestating degraded or deforested areas, 3) afforestation, which is planting a forest where none previously existed, and 4) improved forest management (Vacchiano et al., 2018).

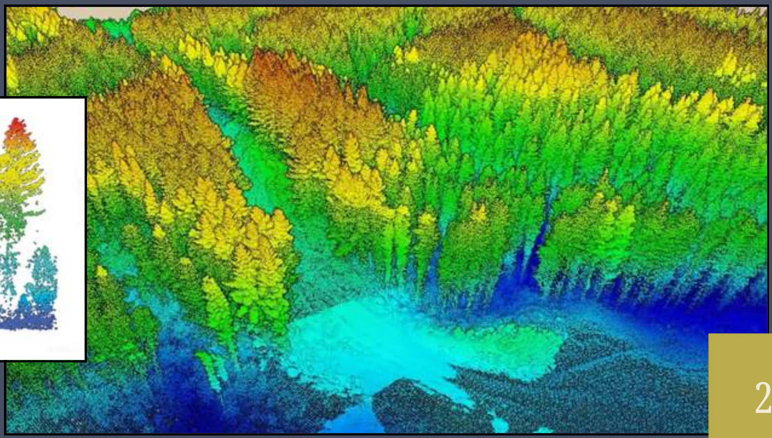
Metrics to track these strategies include retention of canopy cover, rates of tree mortality, number of non-forest acres converted to forest, and carbon sequestration rates of a forest before and after implementation of forest management techniques. Remote-sensing technology can provide spatial and temporal observations of forest characteristics at the landscape and regional scales . For example, Light Detection and Ranging (LiDAR) in Figure 10 is commonly used for reforestation projects. LiDAR uses measurements by satellites, aircraft, or ground-based systems to provide insights into the three-dimensional structure of the ground surface, such as forest height and canopy coverage (Massey et al., 2023).

Figure 10

Left: Canopy Height Model: (USFS 2024)

Right: LiDAR-generated image of a forest (Herries, 2017)





6.2 RECOVERY AND RESTORATION TREATMENTS FOLLOWING STAND-REPLACING DISTURBANCES

The high risk of "stand-replacing disturbances," intense natural disturbance events that destroy the tree canopy, is identified in the Act. Plans for post-disturbance land and resource management and will be used to create or revise existing management plans (Westerling, 2016). Management plans already exist for restoration treatments following stand-replacing disturbances and have been fairly successful in establishing forests (Wimberly et al., 2008). However, due to the increased extent, severity, and frequency of wildfires from climate change these management systems will be amended to reflect changing conditions and to adopt best practices. The amendments include directions for management including salvage logging and reforestation activities to achieve desired conditions and other planned content on the applicable unit of the National Forest System.

A high-intensity prescribed fire consumes trees on the Fishlake National Forest in Utah | Image by Roger Ottmar, USDA Forest Service

6.3 BIOCHAR AND WOOD WASTE

The Act tasks the Food and Drug Administration (FDA) and the United States Geological Survey (USGS) to establish commercialization plans for the production, use, and sale of biochar.

Biochar as shown in the image on the right is a charcoal-like form of black carbon. It is produced through a process called pyrolysis in which organic biomass is heated in the presence of limited oxygen (DeLuca & Gao, 2019). Studies have found that biochar additives have promoted nitrogen and phosphorus uptake for plants into the soil (DeLuca & Gao, 2019). In addition, biochar decreased the concentration of heavy metals such as cadmium, lead, copper, and zinc in plant tissue by 17 - 39% (Joseph et al., 2021). Biochar's porous nature also improves the water holding capacity of soil and reduces soil compaction (Neukirch et al., 2022).

The western U.S. has more than 200 million tons of wood harvest that could be used for bioproducts such as biochar. If its capacity were fully utilized, these products could be worth close to $6 billion (Page-Dumroese et al., 2022), and these figures are expected to grow due to Forest Service plans to thin an additional 50 million acres (USDA Forest Service, 2022). However, at present, most of this biomass is considered "stranded," as it would not be economical to transport it to a facility where it could be used to produce bioproducts (Robillard, n.d.). As a result, it is either burned, releasing the sequestered carbon and pollution into the atmosphere, or left to decompose, releasing that carbon into the atmosphere slowly (Pierson et al., 2024). Both scenarios represent a missed opportunity to keep that carbon sequestered, but increased production of biochar could change that dynamic (Pierson et al., 2024).

Biochar (right) is the carbon-rich solid produced from wood waste (left) | Image by Skagit Soils Inc.

Despite its numerous benefits, several key factors limit the production of biochar and would need to be addressed by an effective commercialization plan. First is substantial price volatility. Multiple studies have found that price was the most influential factor for biochar's production profitability and desirability (Campion et al., 2023), and at present, this price volatility is coupled with inconsistent demand. Given the high capital investments needed for equipment to produce biochar, and the costs associated with

6.3 BIOCHAR AND WOOD WASTE

2024). A successful commercialization plan should aim to create more predictability and scale in biochar markets, instilling confidence in producers and incentivizing investment (Pierson et al., 2024). A secondary effect of this would be to create economies of scale, further driving down costs (Campion et al., 2023).   transporting the wood biomass or biochar , uncertain sale prices are a large disincentive to investment in biochar production (Campion et al., 2023; Pierson et al., 2024).

Finally, there are several policy constraints that create barriers to investment including lengthy and expensive permitting processes and incomplete regulatory guidance on the disposal of unmerchantable wood and residues, which makes it difficult to utilize slash piles for bioenergy or biochar (Pierson et al. 2024) A successful commercialization plan should aim to create more predictability and scale in biochar markets, instilling confidence in producers and incentivizing investment (Pierson et al., 2024). A secondary effect of this would be to create economies of scale, further driving down costs (Campion et al., 2023).

6.4 ERADICATION OF INVASIVE GRASSES

Invasive grasses are influential in determining the health and overall resiliency of U.S. forests, and several species have increased rapidly over the past century (Bansal et al., 2014). There are many challenges that come with the invasive grasses in the western United States; invasive grass species and abundance will lead to more extensive and severe wildfires, proliferating the cycle of grass invasion.The invasion of these grasses can affect fuel characteristics, fire behavior, and fire regimes, resulting in a feedback cycle that is challenging to address due to the adaptability of invasive grasses (Chambers et al., 2019). The main means of controlling these invasive species are to promote resiliency through conservation easements, which are contracts between landowners and governments to restrict the type and amount of development on private land (U.S. Fish and Wildlife Service 2024), maintain or increase native grasses and forbs which can compete with invasive species, and "early detection", which means to quickly detect and eliminate invasive grasses when they first appear in an area (Chambers et al., 2019). Ideally, these management strategies, which can be employed both before and after a fire, will prevent invasion by non-native grasses to make way for the growth and reestablishment of native species, increasing ecosystem resilience.

7 | CONCLUSION

Breckenridge, Colorado. Image by Amanda Biscoe

Based on the declining carbon sequestration capacity of forests in the United States, it is clear that steps need to be taken to interrupt the forest degradation feedback loop and mitigate the impacts of climate change. America's Revegetation and Carbon Sequestration Act addresses this challenge with a three-pronged approach that prioritizes revegetation efforts, the commercialization of forest management byproducts, and continued forest management research. Utilizing this approach, the Act aims to revegetate 25% of targeted lands within the next ten years, increasing the carbon storage potential of forests in the U.S. and reducing the amount of existing carbon dioxide in the atmosphere, thereby lessening the effects of climate change. While the provisions of this act authorize mechanisms that would result in significant progress toward climate change mitigation, this Act will not address climate change alone. It will have the most impact when executed in tandem with other mitigation measures. If implemented as one element of a portfolio of climate mitigation strategies, America's Revegetation and Carbon Sequestration Act could foster a more sustainable future for generations to come.

"A NATION THAT DESTROYS ITS SOILS DESTROYS ITSELF. FORESTS ARE THE LUNGS OF OUR LAND, PURIFYING THE AIR AND GIVING FRESH STRENGTH TO OUR PEOPLE"

-FRANKLIN D. ROOSEVELT

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Gifford Pinchot National Forest, Washington. Image by: Lucas Cometto