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Science FINDINGS

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"Science affects the way we think together."
Lewis Thomas

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Planting Trees to Mitigate Climate Change: Policy Incentives Could Lead to Increased Carbon Sequestration

USDA Natural Resource Conservation Service

A private tree farm in western Oregon. Trees can mitigate climate change by absorbing atmospheric carbon. Carbon remains sequestered in any wood product for the life of that product.

IN SUMMARY

The 741 million acres of forestland in the United States play a role in mitigating the effects of climate change by sequestering nearly 16 percent of the atmospheric carbon dioxide emissions produced annually in our country. Reducing the conversion of forestland to other uses and planting even more trees, whether through afforestation or reforestation, would increase the nation's carbon storage capacity. The U.S. Department of Agriculture (USDA) has several incentive programs to accomplish these goals.

Researchers with the USDA Forest Service and Portland State University modeled various scenarios to determine how carbon sequestration would increase if the agency increased its financial investment in these tree planting and forest conservation programs. They also modeled how a 10-percent reduction in the area burned by stand-replacing wildfires could affect carbon sequestration. Because increasing levels of atmospheric carbon has a social cost, they calculated the monetary value of the carbon sequestrated.

The research team found that afforestation and reforestation policies yielded the greatest return in carbon sequestration. By 2050, 469 teragrams (Tg) of carbon dioxide equivalent per year (CO_2 eq/yr) could be sequestered compared to a baseline scenario of 323 Tg CO_2 eq/yr. They estimated the cost of expanding afforestation and reforestation programs at $6.5 billion, far less than the estimated $93.6 billion in monetary benefits that the increased carbon sequestration from expanding these programs was projected to yield.

"People acting together as a group can accomplish things which no individual acting alone could ever hope to bring about."
—Franklin Roosevelt

In 1935, President Franklin Roosevelt initiated a groundbreaking project, literally, in the hopes of stemming an ongoing ecological disaster. Over the previous 4 years, the Midwest and Great Plains experienced reoccurring annual droughts. With the prairies now converted to fields of wheat and other agricultural crops that weren't drought tolerant, the crops withered and died. Without roots to retain the topsoil, dust storms carried it as far away as New York City and even out to the Atlantic Ocean; it's estimated that 850,000 tons of topsoil was lost.

Through the Prairie States Forestry Project, Roosevelt wanted to create a shelterbelt of trees and shrubs spanning from the Canadian border to the Texas Panhandle. Carrying out this project was a multiagency effort that involved the U.S. Forestry Service (later named the U.S. Forest Service), the Works Progress Administration, and the Civilian Conservation Corps. By the end of 1930s, 250 million trees were planted, resulting in more than 18,000 miles of shelterbelts across the Midwest and Great Plains. Many of these legacy shelterbelts remain on the landscape. Several U.S. Department of Agriculture (USDA) programs, such as the Natural Resources Conservation Service and

Farm Service Agency's Conservation Reserve Program, encourage farmers and landowners to maintain or plant new windbreaks. Subsequent research has shown that the economic benefits of windbreaks, such as increased crop yield and livestock protection during the winter, outweigh the economic value of using the land for agricultural uses.

Now, nearly 90 years later, trees are once again seen as a solution to an ecological disaster. Climate change, caused by increased levels of carbon dioxide and other greenhouse gasses in the atmosphere from human activities, is resulting in an increased frequency and severity of natural disasters, such as hurricanes and wildfires. And, there are societal costs associated with these natural disasters: lives are lost, the health of millions can be affected by smoke inhalation and the stress of evacuation, followed by the costs of rebuilding.

Trees can indirectly mitigate the effects of climate change by sequestering atmospheric carbon as a product of photosynthesis, which converts sunlight into energy by splitting a carbon dioxide molecule into its raw components. Oxygen is released into the atmosphere while carbon is turned into a carbohydrate that is used to fuel growth. All plants sequester carbon, but trees, due to their longevity and size, are capable of sequestering significant volumes of carbon over the course of their lifetime.

There are calls to action both internationally and nationally to plant trees: the One Trillion Trees initiative calls for planting a trillion trees worldwide by 2030. In the United States, the proposed Trillion Trees Act would "establish forest management, reforestation, and utilization practices which lead to the sequestration of greenhouse gases, and for other purposes."

Yet, how much might the planting of more trees actually increase carbon sequestration? Coincidentally, 7 years prior to the launch of the One Trillion Trees initiative, a research team from the USDA Forest Service and academia ran a hypothetical exercise to answer that question.

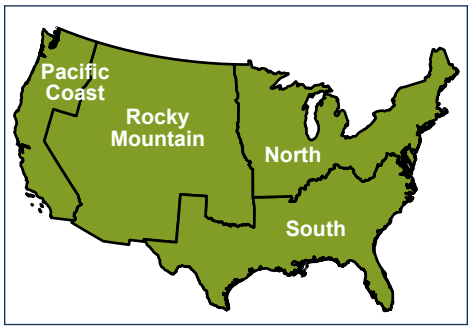
KEY FINDINGS

- Modeling showed that the greatest gains in carbon sequestration and monetary benefit resulted from increasing afforestation and reforestation efforts, followed by reducing forestland development. Reducing the area burned by stand-replacing wildfire by 10 percent yielded the smallest gains in sequestered carbon.
- By 2050, afforestation and reforestation policies could increase carbon sequestration from a baseline scenario of 323 to 469 teragrams of carbon dioxide equivalent per year. This increase is equivalent to the amount of carbon emissions produced to power 17 million homes in a year, according to the Environmental Protection Agency Greenhouse Gas Equivalents Calculator.
- The approximate cost of implementing the simulated afforestation and reforestation policy was estimated at $6.5 billion. This is about 7 percent of the estimated $93.6 billion in benefits projected to result from increasing the carbon sequestered in trees.

Modeling Carbon Sequestration

In spring 2016, Jeff Kline, a research forester with the USDA Forest Service Pacific Northwest Research Station, and Robert Haight, a research forester with the Forest Service Northern Research Station, traveled to Washington, D.C. for a meeting sponsored by the Council on Food, Agriculture and Resource Economics (C-FARE). They were among 30 other scientists from around the country, primarily from federal agencies, whose expertise C-FARE sought.

C-FARE is a nonprofit organization whose goals include connecting academic research and extension agencies to policymakers. They reached out to Chris Hartley in the USDA Office of Environmental Markets for assistance with a project they wanted to undertake. "C-FARE wanted to put values on the beneficial changes aside from production that result from USDA conservation programs, focusing on benefits that either previously had not been measured or were difficult to measure," explains Luanne Lohr, Forest Service Research and Development's national program lead for economic research.



Carbon assessment regions.

Specifically, C-FARE was interested in explicitly linking the improvements in human well-being to improvements in ecosystems that result from private sector adoption of USDA's incentive programs, such as the Conservation Reserve Program or the Environmental Quality Incentives Program, and federal investments in public lands. Eventually, C-FARE settled on creating case studies to value pollinator habitat, forest carbon sequestration, and water quality improvements.

"Chris and I were asked by C-FARE's project leaders to recommend Forest Service researchers to lead the carbon sequestration study," Lohr says. "That our researchers were sought out is a recognition that the Forest Service plays a really important role in USDA as the authoritative source on carbon accounting and valuation."

The Forest Service became the authoritative source on evaluating carbon and ecosystem services on forestlands in part because of two pieces of legislation. The Multiple Use Sustained Yield Act of 1960 required national forests to be managed for both market benefits, such as timber production, and nonmarket benefits, such as water quality, wildlife, and recreation. The 2012 Forest Service Planning Rule recognized carbon sequestration as another ecosystem service to manage because carbon sequestration plays a crucial role in mitigating the effects of climate change.

Purpose of PNW Science Findings

To provide scientific information to people who make and influence decisions about managing land.

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Forest Service

As a result of having to manage for ecosystem services, the Forest Service has supported research efforts to understand the economic of these ecosystems and how to manage them. What Kline and Haight would bring to the C-FARE project is experience conducting research on valuation of carbon sequestration and its management implications.

On day 2 of the 3-day conference, the 30 scientists broke into groups based on their ecosystem service specialty.

"Our group started talking about what would be useful to measure around carbon," Kline says. "If we as a nation wanted to do more to sequester carbon to address climate change, and if we tried to do that through the USDA, what could we do? What impact could we have on carbon sequestration through federal policies and programs at the USDA?"

"Valuing carbon sequestration has usually been done at the local level," adds Haight. "We would do it at the national level."

With the project topic and research approach decided upon, the team members returned to their respective workplaces and began working on two assignments: run models to simulate how policy scenarios would increase carbon sequestration by forests of the conterminous 48 states from 2015 to 2050, and calculate the monetary value of this sequestered carbon. This 35-year timespan was selected because "it's the forecasting period the Forest Service used in the 2016 Second Biennial Report of the United States of America under the United Nations Framework Convention on Climate Change," explains Haight. As for the second assignment: "If you can sequester a ton of carbon, you can avoid the climate-change related damages and costs associated with that ton of sequestered carbon," he adds.

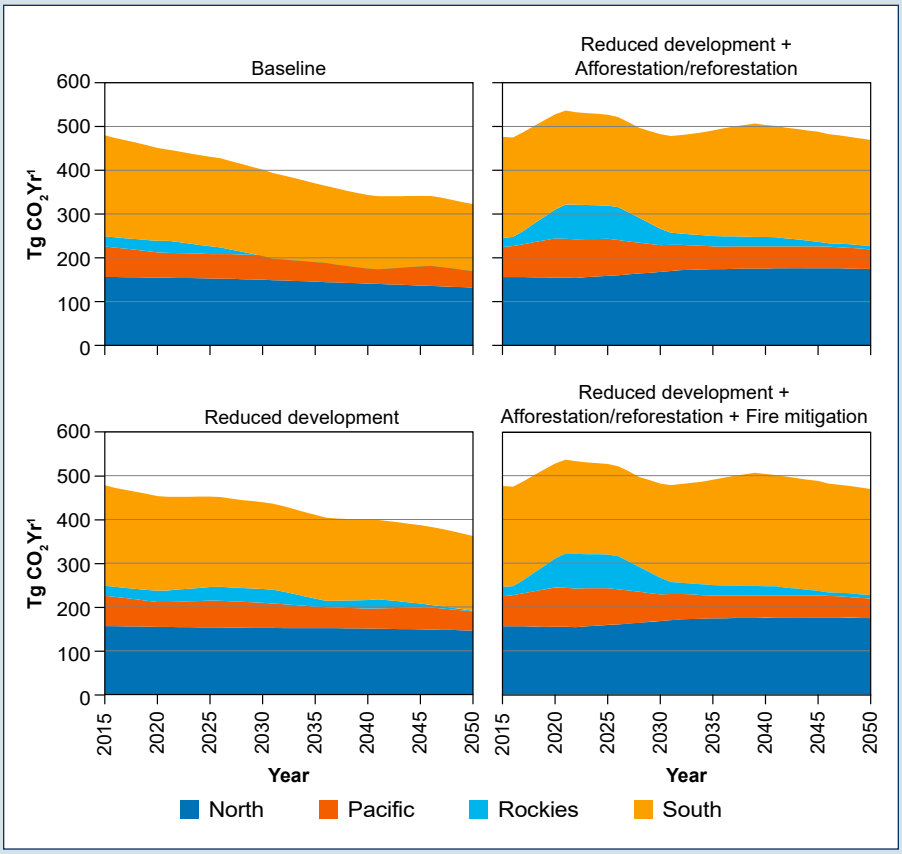
Possible Paths

The team identified three scenarios to compare to a business-as-usual (baseline) scenario: (1) protecting forestland from development, (2) increasing financial incentives for afforestation of private lands in the Eastern United States and investments in reforestation of federal lands in the Western United States, (3) and reducing the area consumed by stand-replacing wildfires by 10 percent. These model scenarios were based upon existing policies or desired outcomes of current USDA programs. For example, the afforestation scenario is based on the existing Conservation Reserve Program that encourages private landowners to plant trees in currently nonforested areas. (In contrast, reforestation is the planting of trees in areas that were previously forested, but the trees were lost because of natural disasters or timber harvests.)

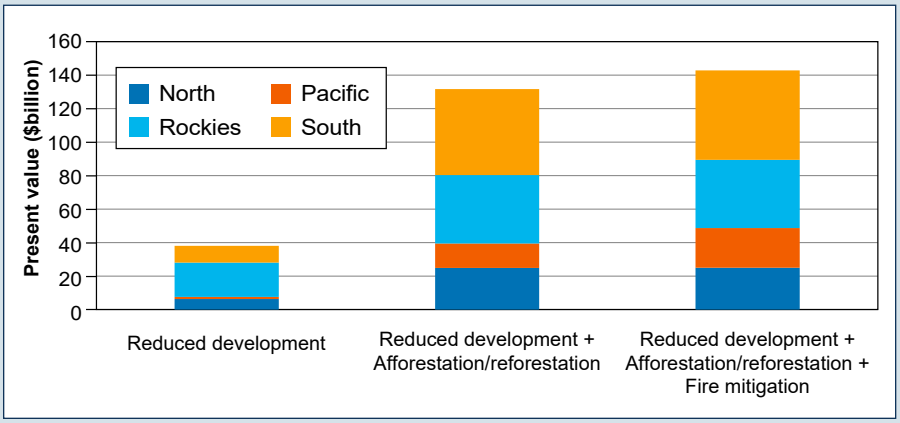
Scenarios for Increasing Forestland

Increasing forestland acreage increases carbon sequestration. The research team evaluated the effect that the following scenarios would likely have on carbon sequestration:

- Reduced development: no net loss to forestland.
- Afforestation through landowner incentives in the Eastern United States and reforestation of federal forest land in the Western United States.
- Wildfire mitigation: a 10-percent reduction in stand-replacing wildfires.
- Baseline: business as usual.



Projected annual forest carbon sequestration by region under four scenarios. Reduced development and the afforestation/reforestation scenarios yielded the greatest projected increase in carbon sequestration in the Rocky Mountain and Southern regions.



The projected increase in present financial value (billions of dollars) for each scenario, relative to the baseline scenario (discount rate = 3 percent). The estimated costs associated with the tree planting scenario are a fraction of the carbon benefits.

The third scenario that calls for reducing the area burned by stand-replacing wildfire was proposed because "as a result of these wildfires, a big chunk of stored carbon is lost," Kline says.

Team members John Coulston and David Wear, both research foresters with the Forest Service Southern Research Station, ran the projections of how carbon sequestration would change in response to increasing forestland. Although some research projects require collecting brand new data, for this project, the data and models were readily available thanks to decades of research investment by the Forest Service. The models to estimate current carbon stocks and flux were developed by the agency's Forest Inventory and Analysis and the Resource Planning Assessment groups.

"These models were developed for the main purpose of carbon reporting," explains Haight. "The Forest Service developed the U.S. Forest Carbon Accounting Framework, which includes an annual inventory of forest carbon that has been emitted and sequestered by U.S. forests. This annual inventory is submitted to the U.N. Framework Convention on Climate Change." After generating the current carbon stock and flux estimates, Colston and Wear imported these data into models they had developed to estimate future forest carbon stocks under the three scenarios. Each of the scenarios had a land use change assumption built into the projection. For example, in the scenario with reduced development of forestland, they assumed that there would be no net loss of forestland beginning in 2025. Increasing afforestation and reforestation would be achieved by planting trees on 29.8 million acres of nonforested private land in the Eastern United States between 2015 and 2020. In the Western United States, reforestation would occur on 7.0 million acres of understocked federal forestland during this same period.

Concurrently, Randall Bluffstone, professor of economics and director of the Institute for Economics and the Environment at Portland State University, led the work to estimate the monetary benefits of carbon sequestration. To calculate these benefits, "We used the U.S. Interagency Work Group on Social Cost of Carbon that was published in 2015," explains Kline. "The social cost of carbon is the present value of monetized damages associated with an additional ton of carbon dioxide emissions in a given year."

The interagency work group arrived at the social cost of carbon by modeling the impacts of climate change and the corresponding economic value of the damages. "These integrated assessment models look at how changes in climate affect agricultural productivity, human health, and property at spatial scales ranging from regional to global and estimate the costs of damages," says Haight.

Bluffstone reported the societal cost of carbon with three discount rate scenarios—5, 3, and 2.5 percent—and the team selected the societal cost of carbon estimates calculated with the moderate discount rate of 3 percent. Now the team had all the numbers they needed to complete the final portion of the project—generate the total value of carbon sequestration of each policy scenario. "When you multiply the annual carbon sequestration forecast times the estimate of the societal cost of carbon, you get the total value of sequestration in that year," Haight explains. "Discounting those annual values and summing them up over the 35-year horizon, you get the total value of sequestration for the policy scenario."

How to Increase Carbon Sequestration

A year after the team's formation, it presented C-FARE with their report, *Estimated Values of Carbon Sequestration Resulting From Forest Management Scenarios*. The effort revealed that ramping up afforestation and reforestation efforts had the greatest effect on increasing carbon sequestration at a fraction of the program's cost. By 2050, afforestation and reforestation policies could increase carbon sequestration from a baseline scenario of 323 Tg CO_2 eq/yr to 469 Tg CO_2 eq/yr, an increase equivalent to the amount of carbon emissions produced to power 17 million homes in a year according to the Environmental Protection

USDA Forest Service

Tree planters at work after a fire on the San Bernardino National Forest, California. Researchers found that reforestation and afforestation initiatives have the potential to yield the greatest return in carbon sequestration, compared to policies to reduce stand-replacing wildfires by 10 percent.

Lance Cheung

A young stand of planted longleaf pine in the Magnolia Branch Wildlife Reserve, Alabama.

Agency Greenhouse Gas Equivalents Calculator. With an estimated $6.5 billion price tag to increase tree-planting programs, the projected monetary benefits of increased carbon sequestration were $93.6 billion. In comparison, reducing wildfires resulted in a projected benefit worth $11.1 billion.

The results were not what Haight and Kline expected. "I thought that reducing the area of wildfires would have the biggest reduction in carbon emissions because when you see a wildfire, you see all the smoke and there must be a huge carbon emission and loss," Haight says.

"What surprised us was just how much bigger the effect of the tree-planting scenario was compared to the other scenarios, especially compared to how small the effect was of the wildfire-reduction scenario," Kline says.

However, these increases in carbon sequestration are only possible if the USDA invests in expanding the current tree planting incentive programs. What if the status quo is maintained? Fortunately, even under the baseline scenario, there is still positive news. "Under the baseline scenario, we're projecting that, using a moderate 3-percent discount rate, the value of carbon sequestration from 2015 to 2050 is over $500 billion for the public and private forestlands in the lower 48 states," says Haight. "That is a huge amount, and I didn't expect that."

What's Next

As the report circulated throughout the Office of Environmental Markets and other programs, the positive reactions have justified why it was valuable for C-FARE to have initiated the project and include carbon sequestration.

"The report provides sound science on the value of different carbon sequestration strategies," Anne Marsh, the national program lead for bioclimatology and climate change research shared via e-mail. "Monetized scenarios provide useful information to decisionmakers as they weigh policy alternatives and assess tradeoffs in managing for carbon."

Kline admits there are still some gaps in the project that weren't addressed, such as developing more refined cost estimates for implementing the policy scenarios. However, "tree planting programs really don't cost that much relative to their return in public benefits," he says. "We have a long history with them, and it's fairly easy to predict how much they cost and the return you get, in particular with how many farmers will plant on marginal crop land."

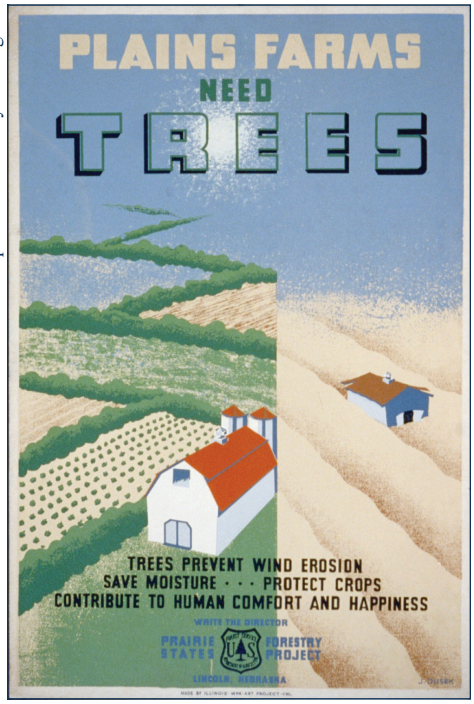
LAND MANAGEMENT IMPLICATIONS

- Afforestation and reforestation policies have long played roles in USDA conservation efforts, and are viable approaches if the USDA chooses to pursue further opportunities for increasing carbon sequestration in the United States.
- If the goal is increasing the amount of atmospheric carbon that is absorbed and stored by trees, afforestation and reforestation initiatives yielded the greatest benefit compared to policies designed to reduce forestland development and reduce wildfire. No other policy alternative examined was found to be as effective.

Additionally, for their wildfire scenario, "we assumed that somehow we could reduce the area burned by 10 percent through increased spending on fire prevention and suppression," Haight explains. "We don't know how much spending is required to reduce area burned by 10 percent, and that wasn't the purpose of our analysis. Instead, we wanted to know the benefit of reducing fire area by 10 percent in terms of carbon gain and sequestration."

In reflecting upon their work, both Kline and Haight are proud of the team's accomplishments. "What I like about this work is we were able to gather up existing data and research that is well trusted," Kline explains. "We were able to do analysis to show that if we were to implement policies similar to previous polices, that we could have a measurable impact upon carbon stored."

"As we move forward toward the broader acknowledgment of the impact of climate and the need for doing forest restoration or carbon sequestration, whether it's the ocean or terrestrial, it does matter more than people are giving it credit for," Lohr says.



Joseph Dusek/Library of Congress

Poster created for the 1930s Prairie States Forestry Project that resulted in 250 million trees planted across the Midwest and Great Plains. USDA programs, such as the Natural Resources Conservation Service and Farm Service Agency's Conservation Reserve Program, continue this tree planting legacy.

> *"If a tree dies, plant another in its place."*
> —Carl Linnaeus, Swedish botanist

For Further Reading

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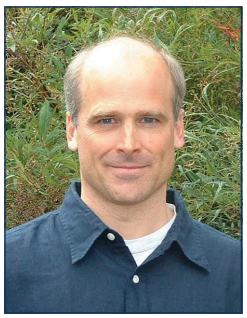

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