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INSIDE

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"Science affects the way we think together."

Lewis Thomas

There's Carbon in Them Thar Hills: But How Much? Could Pacific Northwest Forests Store More?

Andrew Gray

Forests play a role in offsetting the carbon dioxide that is released into the atmosphere as a byproduct of fossil fuel combustion. Pacific Northwest forests that are older than 200 years can store large amounts of carbon in living and dead trees.

IN SUMMARY

As a signatory to the United Nations Framework Convention on Climate Change, the United States annually compiles a report on the nation's carbon flux—the amount of carbon emitted into the atmosphere compared to the amount stored by terrestrial landscapes. Forests store vast amounts of carbon, but it's not fully understood how a forest's storage capacity fluctuates as stands age or respond to disturbance.

To calculate the carbon flux in the forests of Oregon and Washington, scientists with the U.S. Forest Service Pacific Northwest Research Station compiled field measurements and quantified the amount of carbon accumulated or released in relation to a forest's age, disturbance history, and species of trees.

The scientists found that forested lands store carbon at a rate of 7 million metric tons per year. Although older forest stands and individual large trees store more carbon than younger trees, younger forests and small trees accumulate carbon at a faster rate per acre. Wildfires had a minor impact on regional carbon storage, while changes in management practices on federal lands since the 1990s are primarily responsible for the increase in carbon storage in Oregon and Washington forests.

"What once sprung from the earth sinks back into the earth."

— Titus Lucretius Carus,
1st century BC poet and philosopher

Carbon is the building block of every living organism on Earth. Pluck a cone from a tree or cut off one of its branches and in your hand is carbon. Plants acquire carbon through photosynthesis, the breaking apart of atmospheric carbon dioxide and water, using the energy from sunlight, to form glucose and oxygen. This glucose fuels a plant's growth, and its six carbon molecules remain stored until death. As the plant decays, its carbon is gradually released into the atmosphere, thereby completing one of many carbon cycles.

"Understanding the carbon cycle has been on people's radar for a couple decades now and has become more important in recent decades since the United States signed on to the United Nations Framework Convention on Climate Change in 1992," says Andrew Gray, a research ecologist for the U.S. Forest Service Pacific Northwest Research Station.

The UN Framework Convention's goal is to stabilize greenhouse gas concentrations in the atmosphere, one of which is carbon dioxide. The United States is a signatory to this framework so the Environmental Protection Agency compiles an annual report on the United States' annual carbon flux: the amount of carbon emitted into the atmosphere from human activity compared to the amount of carbon accumulated (or lost) by terrestrial landscapes. Of these terrestrial landscapes, such as grasslands, croplands, or wetlands, forests are capable of accumulating and storing the most carbon. However, because forest lands are dynamic and experience disturbances, such as wildfire or development, they are also capable of losing carbon.

The net change in our nation's forest carbon stores is calculated from the nationwide forest inventory conducted by the U.S. Forest Service's Forest Inventory and Analysis (FIA) Program. Since 1930, FIA has sent crews across the United States to collect vegetation measurements on a grid of forested and nonforested plots. On forested plots, crews measure tree heights and diameters, dead wood, understory vegetation, and forest floor thickness. They estimate causes of tree mortality; record disturbance history, such as logging or wildfire; and identify land use changes, such as the conversion of forests for development, or their reversion from farmland. With these measurements, researchers can monitor how the forests are changing over time.

Gray's research focuses on these changes, specifically in relation to biomass or carbon, and the effects of management and disturbance upon these changes. In 2012, he saw an opportunity to improve the calculations of the carbon stores and fluxes of Pacific Northwest forests because most of the previous work was heavily reliant on models of stand development and responses to disturbance.

"These models are generated from a small sample of forests that have been measured intensively, which might not translate to the wide range and variety of forest conditions that are found throughout the landscape," Gray explains. "Depending on the particular piece of forest land, it could be accumulating or losing carbon, or staying even-keeled based upon the stand's age, disturbance history, and management history."

Some modeling is necessary, particularly to meet the national requirements to estimate carbon flux back to 1990 when inventories were incomplete and fewer components of forest carbon were measured. However, Gray knew that land managers or state officials could benefit from knowing more about the carbon accumulation amounts in their region or state to help inform management decisions. He decided to minimize the use of models and go directly to the original source data.

KEY FINDINGS

- Forests in Oregon and Washington currently store an estimated 2,100 million metric tons (mmt) of carbon and accumulate carbon at a rate of 7 mmt per year (an increase of 0.3 percent per year). In effect, forests are accumulating the equivalent of 24 percent of the carbon emissions from fossil fuel combustion in Oregon and Washington.
- Maturing younger forests and small trees (e.g., less than 150 years and less than 40 inches in diameter) accumulate carbon at a faster rate per acre compared to older forests and large trees.
- National forests in Oregon and Washington are storing 63 percent of their maximum carbon storage capacity. Wildfires on national forests resulted in a loss of 0.8 mmt per year (11 percent of the net increase in carbon across the region), with most of this loss occurring in wilderness areas.
- Land use change resulted in an estimated net loss of 2.4 mmt per year of carbon, equivalent to 25 percent of the net increase in carbon across the region. Although the area of juniper forests increased, this did not offset the conversion of Douglas-fir forests, which store more carbon per acre than juniper forests.


Andrew Gray

Not all forests accumulate and store carbon at the same rate. Forests in dry habitats, such as eastern Washington (above) and Oregon, store less carbon than forests growing on the wetter, west side of these states.

Purpose of PNW Science Findings

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

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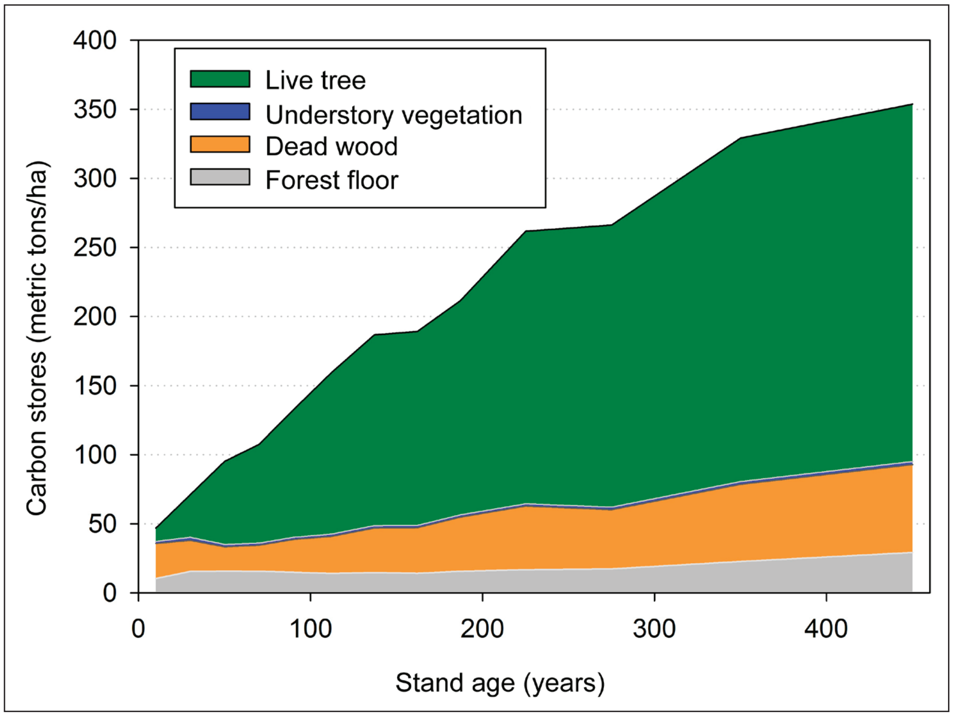
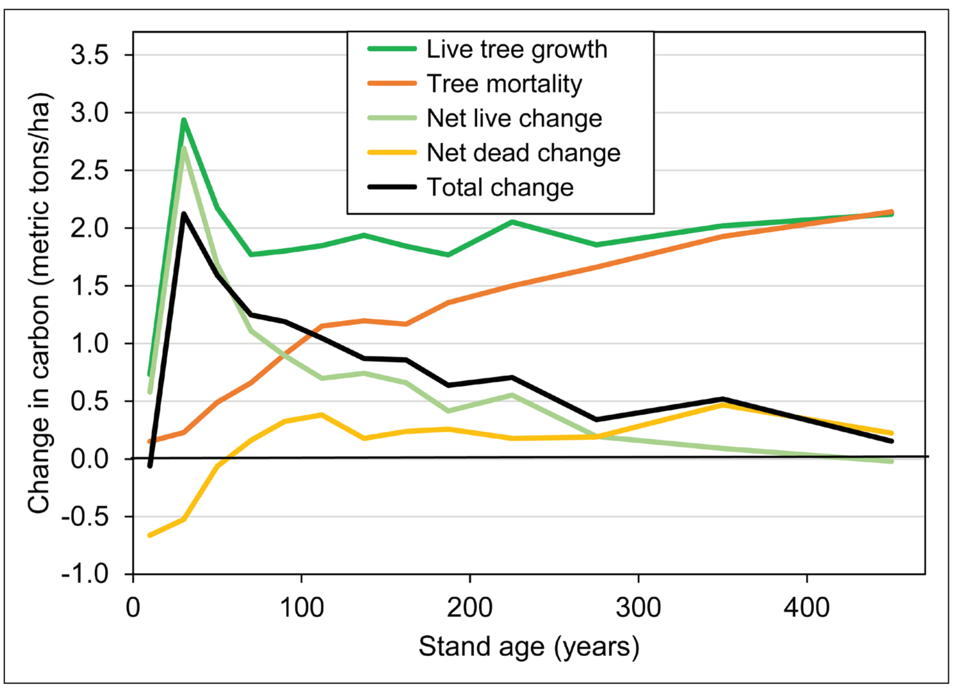


In Pacific Northwest forests, carbon accumulation increases more rapidly in stands that are younger than 200 years; carbon accumulation slows after 200 years. Most of the carbon in a forest stand is stored in live trees and dead woody debris.



The carbon storage capacity of a Pacific Northwest forest fluctuates throughout its lifetime because of tree growth and mortality. Live tree carbon storage rates peak early in stand development, but this growth is offset by tree mortality as the stand ages. In young stands, the amount of carbon stored in dead wood decreases, but it increases at low rates in older stands.

Calculating a Tree's Carbon

From the recent FIA and national forest inventory data in the Pacific Northwest, Gray selected plot data where individual trees had been remeasured so he could calculate carbon flux. "The best way to talk about change is to have a tree-to-tree remeasured inventory, because you can see what changed and what factors are related to that change," he says.

One dataset consisted of 1,073 plots across 14.7 million acres of nonfederal forest land in Oregon that were first inventoried in the 1980s and again in the 1990s. Another dataset contained 11,435 inventory plots across 25 million acres of Pacific Northwest region national forest in Oregon, Washington, and parts of California and Idaho that were inventoried twice between 1993 and 2007. Gray also summarized changes in carbon across 11.0 million acres of nonfederal forest land in Washington in the 1990s.

Gray's reasoning for selecting these datasets was twofold. "These were the best estimates of what was going on in these forest lands at the time," he explained. "The other reason is because the UN Framework Convention has 1990 as a baseline, these datasets give us a really good estimate of the net change, the balance of accumulation and loss, of carbon into the atmosphere, for these forest lands during the 1990s."

Such large datasets can be unwieldy and make running the statistical analysis challenging. For this work, Thomas Whittier was hired as a senior faculty research assistant because of his knowledge of forest ecology and expertise in managing large datasets. "I had been working on large-scale Environmental Protection Agency projects for 20 years and was comfortable with multiple hundreds of sites-worth of data at one time," Whittier said. "When working with such a large dataset, the issue is how do you deal with a lot of data and not get bogged down."

The inventory data for the 12,508 plots had to be reviewed to identify inconsistencies, such as a tree listed with a height and diameter that weren't proportional. Whittier found himself reviewing the manually filled-out inventory cards to better understand the conditions encountered and interpreted by the people who collected the data. Then, using the measurements of a tree or standing snag's measured height and diameter, Whittier generated biomass totals for each respective tree and plot. Once biomass was calculated, he could calculate carbon, which comprises half of the weight of most organic material.

From there, the statistical analyses determined if management, disturbance history, forest age, or species composition affected its rate of carbon accumulation. Wildfires are a disturbance that releases carbon into the atmosphere, and therefore should negatively affect carbon storage. However, Gray explains that although many trees may die, relatively little forest carbon is consumed by the fire. Even as the dead trees decay, this release is offset by the regeneration of the young forest.

"There's short-term and long-term effects following a wildfire, and you can't just pick one part of the carbon cycle and say all the carbon is going away," he says. "There's outgoing and incoming carbon."

"I expected that, given all the focus on wildfire, even those with high severity, they would have had a large impact upon carbon stores," Gray adds. "I didn't find that—basically wildfire is a small blip." He found that wildfires affected less than 1 percent of national forest per year and only resulted in the loss of 0.04 percent per year of total carbon stores in Oregon and Washington—or an 11-percent reduction in the net accumulation of carbon storage.

In contrast, changes in land use from forested to nonforested lands had three times the impact on regional carbon stores compared to wildfire. Forest land increased by 32,000 acres per year in eastern Oregon, primarily owing to encroachment of western juniper onto rangelands. However, this was offset by the development of forest into residential or agricultural uses, such that the regionwide increase was only 5,700 acres per year. The net effect on carbon stores was a loss of 2.4 teragrams per year (0.1 percent per year of total stores, or a 25-percent reduction in the net accumulation). The increase in juniper forest area couldn't offset the carbon storage decrease because the new juniper forests store much less carbon than the more productive forests being developed elsewhere in the region.

"Because you're removing an entire forest, rather than just cutting a few trees, it ends up being a fairly large impact," Gray says.

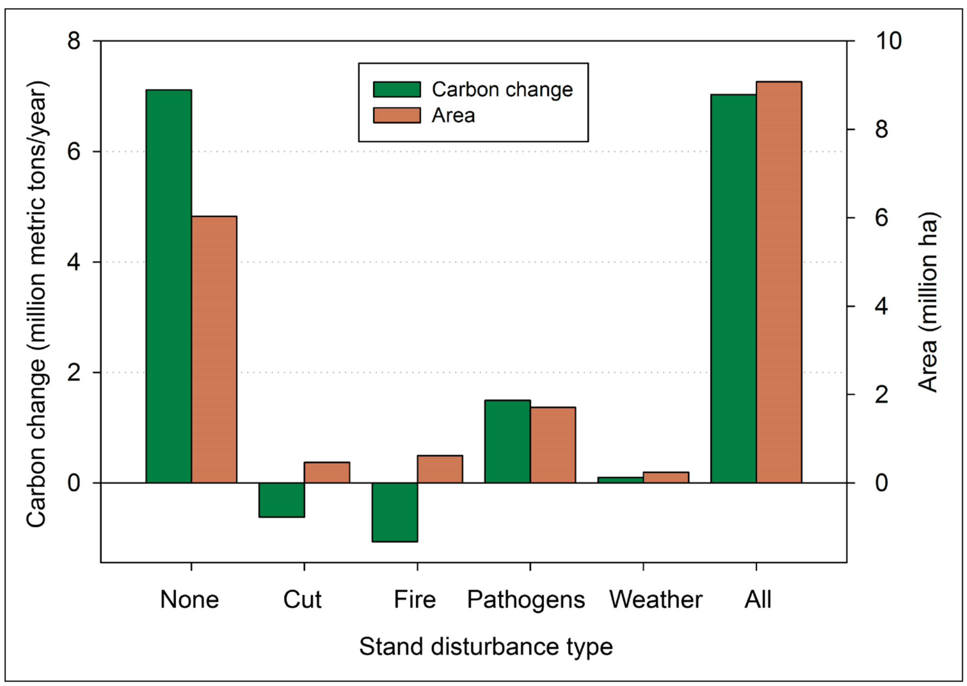
While disturbance can reduce carbon storage, management practices could increase it, the analyses revealed. "Many private forest lands are being managed to maximize income, so stands are being managed on short rotations, down to 40 years or less in western Oregon," Gray explains. "Those lands could be storing quite a bit more carbon if they were managed on a longer rotation. They would not only be storing more carbon, but the landowners could be harvesting more volume per acre per year… Private landowners that manage on longer rotations may be able to obtain additional income from carbon credits."

A forest's age also affected carbon sequestration, although not in ways that Gray anticipated.

"What surprised me was regardless of how old forests get, they're absorbing the same amount of carbon per year. But as a stand gets older, more of that carbon gets transferred into dead wood, which decays fairly steadily. There's a lot of carbon coming in, but there's a lot going out." Although old forests and big trees (i.e., trees older than 150 years and larger than 40 inches diameter) store a lot of carbon, Gray found that they don't accumulate additional carbon per acre nearly as quickly as younger forests and smaller trees. The primary reason carbon stores are increasing in the region is that, on average, forests on federal lands are getting older, and the number of large trees is increasing.

Andy Gray

Fire-killed trees in the Mt. Jefferson Wilderness, Oregon. After analyzing plot data from over 12,000 plots across Oregon and Washington, researchers discovered that forests retain substantial carbon stores in standing snags and downed wood even 7 years after high-severity fires.



The severity of carbon fluctuations on Pacific Northwest national forests depends on the type of disturbance. Researchers found that although forests experienced a loss of carbon owing to wildfires, the amount of carbon lost was relatively low, such that the forests still had an overall accumulation that equaled 7 million metric tons per year.

The Value of Understanding Carbon Storage

Now that a method has been developed for using inventory data to generate carbon sequestration analyses, “We’re getting more and more interest from the individual states for these types of analyses on their carbon flux,” Gray says. “We have a very important role in providing a carbon flux baseline that people can refer to.”

Andrew Yost, a forest ecologist with the Oregon Department of Forestry, says that Oregon is one such state, because policymakers are, “taking the initiative on how they’re going to handle, or account for, greenhouse gas emissions at the state level.”

In 2007, the state formed the Oregon Global Warming Commission with the goal of reducing greenhouse gas emissions by nearly 30 percent by 2020. Each economic sector, such as energy/utilities, agriculture, and transportation, was assigned a technical subcommittee that analyzed the current state of carbon emissions and developed reduction recommendations. The forestry subcommittee researched forest carbon storage and flux in Oregon’s forest ecosystems.

“The reason for this is to look at policy on carbon emissions and forest management practices focused on maintaining and increasing carbon sequestration,” Yost says.

In 2010, the commission issued the *Roadmap to 2020* report, which detailed the analyses and recommendations for each economic sector. Yost says the forestry section in particular received criticism, because it didn’t produce as detailed of an analysis as the other sectors, owing to budget restrictions. It also was criticized for using outdated information, although, at the time, it was the most current data available.

To address this criticism, in early 2016 the commission convened a taskforce to revise the *Roadmap to 2020’s* forestry section. Having worked with Gray and aware of his current work in calculating carbon storage, Yost knew that Gray’s expertise and the updated FIA inventory data would align with the taskforce’s goals. This in turn would ensure that any policies suggested by the taskforce would be informed by the latest data.

“We asked Andy and Jeremy Fried to participate in the taskforce, and the FIA folks were very helpful in supplying the annual inventory data,” Yost explains.

LAND MANAGEMENT IMPLICATIONS

- Wildfires in Oregon and Washington have not substantially affected overall carbon storage because high-severity fires tended to occur in forests with low carbon storage. Most of the carbon from fire-killed trees remains stored on the landscape for decades and does not immediately enter the atmosphere.
- Maximizing carbon storage does not always align with other management goals, such as reducing wildfire severity. Forests that naturally experienced frequent fires and forests where fire has been suppressed for decades may be storing more carbon than they did historically.
- Private forests that are managed for timber on short harvest rotations could store more carbon than they currently do, if economic incentives become available.

Currently, Gray and Fried, a research forester with the Pacific Northwest Research Station, are analyzing the carbon storage capacity of Oregon’s forests and examining the net carbon effects of forest product use and biomass energy projects.

Another important factor they are looking at is the carbon storage differences among ecoregions. “If policies were made with respect to forest sequestration without taking into account the differences in ecoregions, those policies would be less informed than they could be, and I don’t think they would be very reliable,” Yost explains. “One size doesn’t fit all. We can’t expect forests on the east side of the Cascades to store the same amount of carbon as (those) on the west side.”

Yost expects to have the analyses finished in 2017, and the updated forestry report will be delivered during the legislature session.

Of the preliminary results reported thus far, Oregon forests are functioning as a carbon sink, but that still needs to be confirmed. And Yost is quite pleased with the cooperation between the Oregon Global Warming Commission and the FIA program. “At the Department of Forestry, we value these partnerships because the FIA analysts have already done most of the analyses we need. This project is a great example of the strong partnerships that are possible with the states and the FIA program.”

“He plants trees to benefit another generation.”

—Caecilius Stratius, 2nd century BC poet

For Further Reading

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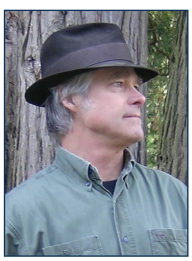

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