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INSIDE

Science FINDINGS

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

Colossal Carbon! Disturbance and Biomass Dynamics in Alaska's National Forests

Walter Foss

Sitka spruce forests in the Prince William Sound region of south-central Alaska have been increasing in biomass and numbers of trees.

IN SUMMARY

The Chugach and Tongass National Forests are changing, possibly in response to global warming. Forested areas within Alaska's temperate rain forests are creeping into areas that were previously too cold or too wet. These forests are also becoming denser. As biomass increases, the amount of carbon stored in the forest also increases.

Tara Barrett, a research forester with the U.S. Forest Service, Pacific Northwest Research Station, recently measured these changes. She and her colleagues compared Forest Inventory and Analysis survey data collected from 1995 to 2003 with follow-up inventories taken from 2004 to 2010. The comparison showed that carbon mass increased 4.5 percent in live trees in the Chugach. Carbon storage remained about the same in the Tongass; however, tree species there changed slightly. These observed changes in the Chugach and Tongass National Forests may be related to warmer temperatures and higher levels of carbon dioxide in the atmosphere.

This research is being used by the U.S. Forest Service and other government agencies to assess the vulnerability of Alaska's forests and to plan for their future. The Chugach National Forest, for example, used it to establish a baseline assessment of carbon stocks in accordance with 2012 forest planning rules.

"Planning is bringing the future into the present so that you can do something about it now."
—Alan Lakein, author

Trees in Alaska's Chugach National Forest are thriving. This vast, wild, temperate rain forest first set root after the last ice age, and because of its northern latitude—about six degrees below the Arctic Circle—it has been competing with the ice ever since. The Chugach is the northernmost of all the U.S. national forests, an area of glaciers and steep mountains surrounding Prince William Sound. About 30 percent of the forest is covered in ice. In recent years, the glaciers have retreated somewhat and the forest is filling in behind them, not only spreading laterally, but creeping up to higher elevations where the cold used to keep tree growth in check.

Meanwhile, in the Tongass National Forest to the southeast, most tree species are thriving too. Recent inventories showed increases of western redcedar and red alder, but a decrease of shore pine, a subspecies of lodgepole pine. The two national forests are the largest in the United States, comprising nearly 24 million acres–an area larger than the state of Indiana. Tara Barrett, a research forester with the U.S.

Forest Service, Pacific Northwest Research Station, has been studying these changes as they relate to disturbance dynamics and carbon storage.

Trees are living storage vessels of carbon. Greenhouse gases—such as carbon dioxide (CO_2)—released into the atmosphere are causing the earth's climate to gradually warm. During photosynthesis, trees and other plants pull CO_2 from the atmosphere and convert it to carbohydrates that fuel growth. The carbon remains stored in the cellulose of the tree's cell walls. When a tree dies and the wood begins to decay, carbon is slowly released back to the atmosphere.

Because increasing levels of CO_2 are contributing to global climate change, there is growing interest in managing forests to sequester and store carbon. The Forest Service established a forest planning rule in 2012 that requires new assessments for each national forest to include a baseline of carbon stocks. Managers are required to monitor changes in those baselines as they relate to management, climate change, and other stressors. To do so, forest managers need data-driven methods for conducting baseline assessments of current carbon stocks and to monitor change.

KEY FINDINGS

- Regionally patterned changes are ocurring in the unmanaged portions of Alaska's temperate rain forests. They are marked by many fine-scale (<1000 m^2) gains and losses in forest cover.
- The Tongass National Forest stores more carbon than any other national forest in the United States, and its forest area is increasing. However, forest biomass increases are highest in the Chugach National Forest and forest around Prince William Sound in south-central Alaska.
- Gains in forest cover are concentrated on northerly aspects, lower elevations, and higher latitudes. Naturally occurring disturbances that have removed some of the forest cover are skewed toward southerly aspects and lower latitudes.
- Tree species shifts have occurred in both the Chugach and Tongass National Forests.
- On the Tongass National Forest, areas managed for timber had substantially different carbon storage and flux than unmanaged areas. Managed forests had much higher growth, recruitment, and down-wood mass; they had much lower mortality and less mass of live and standing dead trees.

A LIVING LABORATORY

Barrett and her colleagues recently completed studies to measure the amount of carbon stored in the Chugach and Tongass National Forests, and to see how those amounts had changed over 10 years.

The Chugach and Tongass offer unique opportunities to study carbon storage because relatively small portions have been harvested and fire is a rare occurrence. In forests with a history of timber production, replanting, and fire suppression—that is, most forests in the lower 48 states—assessing the reasons for changes in carbon stores is trickier.

Barrett has conducted numerous studies about the changing conditions of the Chugach and

Ray Koleser

With few roads in southeast Alaska, FIA field crew reach forest plots by skiff, float plane, boat, or helicopter and finally, by foot.

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Tongass. Recently she joined forces with Brian Buma at the University of Alaska Southeast to expand on earlier studies by assessing disturbance dynamics along with forest regrowth and ongoing changes in biomass and carbon. By focusing on the effects of insects, windstorms, landslides, and other natural events—they gained understanding of the roles these disturbances play in relation to shifts in forest cover and biomass.

Assessing Alaska's forests is complicated by a lack of previous research and relative scarcity of remote sensing and field-based information, Barrett explains. To find the information she wanted, Barrett and her colleagues used three very different approaches to understanding biomass dynamics in the forests: a field-based inventory assessment of recent change, a mathematical matrix modeling approach to predict short-term change, and a remote sensing-based assessment of how the shape of the forests was changing.

"I didn't do any of the field work, but I know what the field crew have to go through to collect data, and it's pretty amazing," Barrett says. Forest Inventory and Analysis data collection crews were stationed in a boat off the shore of the forests, living in very cramped quarters with no luxuries. Helicopters and small boats transported them each day into the forest, leaving early each morning and returning late in the evening. Crews faced daily challenges ranging from bears to steep terrain to snow and sleet. Three different shifts of personnel were continually rotated so that the work could continue every day of the week during Alaska's very short field season.

The crews inventoried forest plots in the Chugach and Tongass from 1995 to 2003, and then remeasured them from 2004 to 2010. Barrett and her colleagues used these data from the two time periods to determine how the forests were changing.

CHANGE IN THE CHUGACH

Nearly all of the Chugach National Forest was covered by ice during the peak of the last ice age, about 23,000 years ago. Pollen studies suggest that migration of coastal tree species into what is now the Chugach has been a long, slow process. Mountain hemlock and Sitka spruce moved into the Prince William Sound area about 3,000 years ago, which is just a few generations for these long-lived tree species.

Climate warming and CO_2 increases could be affecting forest changes in the Chugach in a variety of ways. Growth rates usually increase with increasing CO_2 or with warmer temperatures as long as the trees have enough water, Barrett explains. The same conditions could cause more dominant species such as Sitka spruce and western hemlock to displace lower biomass hardwoods and white spruce. They also could make trees grow larger and spread into more marginal habitats.

Biomass is increasing in the Chugach National Forest and around Prince William Sound—areas where the climate historically has made tree growth more difficult. In the Chugach, Barrett found a 4.5-percent increase in the carbon mass of live trees (a measurement that represents roughly half of their total biomass), largely driven by an increase in Sitka spruce.

It's not unusual for a national forest to experience increase in live tree biomass over time, Barrett explains, but usually it's the result of fire suppression or recovery from past timber harvests. That was not the case with the Chugach. The growth of carbon storage in these northern latitudes is due not only to the establishment of new trees where once there were none, but also because more trees are growing in existing stands and they're getting bigger.

A spruce-beetle outbreak that culminated in the 1990s caused extensive forest mortality throughout nearly 3 million acres of south-central Alaska. The Kenai Peninsula was hardest hit, but that outbreak area mostly falls to the west of the Chugach National Forest. This makes it less likely that the observed increase in biomass was recovery from the beetle outbreak and points back to climate change and higher atmospheric CO_2 levels as likely causes.

TONGASS TRENDS

The changes in the Tongass—which stores substantially more forest carbon than any other national forest in the United States—are more in the realm of species changes. Otherwise, the total carbon storage in the Tongass today in terms of live trees, snags, and logs is about what it was 20 years ago.

In the Tongass, Barrett and her colleagues found that multiple small-scale gains and losses of forest cover are adding up to a gradual movement of trees into areas that were previously too cold, such as higher latitudes and areas on the north slopes of mountains. They were surprised to find gains in the lower elevations, too, often in areas where it had been too wet for trees to grow well. Those wet, marshy areas, called muskegs, are shrinking in places, probably because of changes in precipitation and temperature, Barrett says. Most small-scale losses of forest area in unmanaged forest are likely caused by disturbances such as windthrow, avalanches, and landslides. "Even

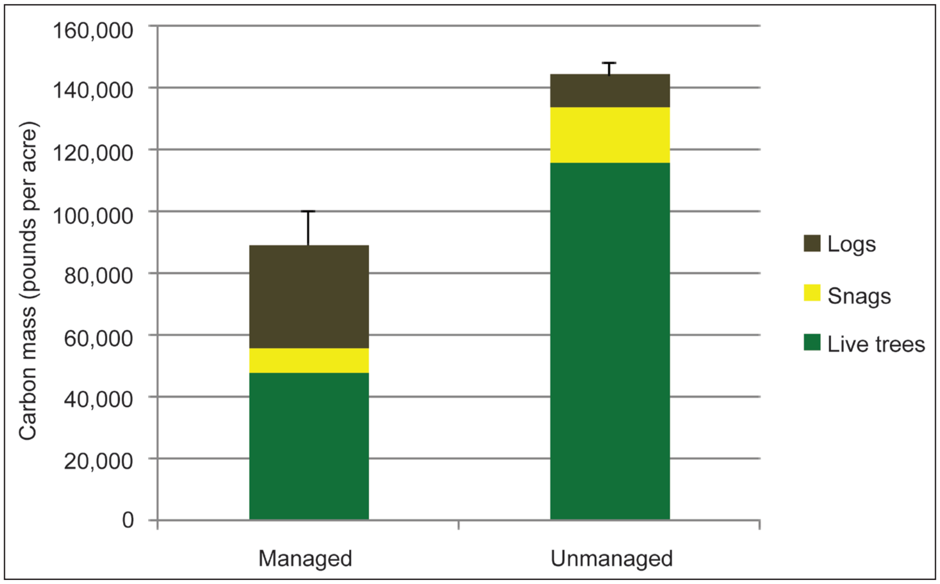
Robin Mulvey

Shore pine, a subspecies of lodgepole pine found in southeast Alaska, has been decreasing, with slower growth associated with cool cloudy days and warmer nights.

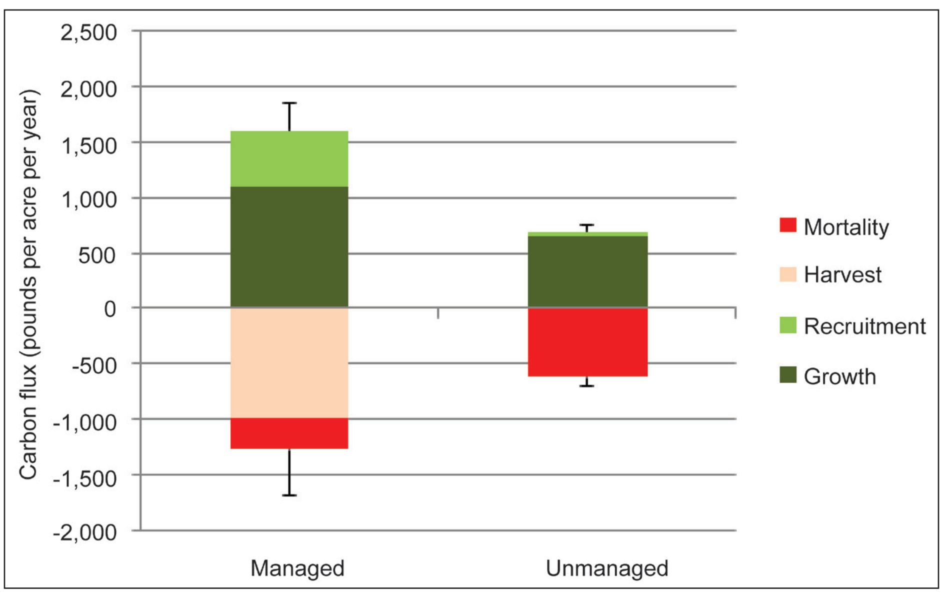
though we're not seeing big differences overall, we're seeing shifts," she says.

On one hand, it's hard to argue against expanding forests when it means more trees absorbing and storing atmospheric carbon. The flip side, however, is that global warming is the likely factor leading to expansion in these temperate rain forests. And the expansion comes at the expense of meadow, alpine, and muskeg habitats.

About 5 percent of the nearly 10 million forested acres on the Tongass National Forest have had timber harvest in the past. Separating out these two types of forest—managed and unmanaged—showed substantially different patterns of carbon storage and flux. Managed forest had much higher growth, recruitment, and down-wood mass and much lower mortality and live and standing dead-tree mass.



On the Tongass National Forest, aboveground carbon in areas managed for timber had lower live tree and snag density, but higher log density.



Although carbon mass in the Tongass National Forest's live tree pool was relatively stable between inventories for both unmanaged and managed forest, carbon flux in and out of the live tree pool differed. Managed forest had greater recruitment, greater growth, and lower mortality than unmanaged forest.

On the unmanaged forests, carbon is constantly being shifted among the pools—from the atmosphere to live trees, from live trees into snags and fallen logs, and then from the snags and woody debris back into the atmosphere as the wood decays. Barrett's research shows that the overall amounts stored in the different pools are pretty stable over time, and those amounts are very high in the Chugach and Tongass compared to most other forests in the United States.

On the managed forests, the picture is very different. When a stand of trees is harvested, some of the carbon is pulled out of the forest in the form of forest products, but a lot of it also moves into the snag and fallen log pool. Over time the woody debris decays. New trees become established and grow, gradually increasing the carbon in the live tree pool. "Given the very dynamic nature of carbon pools in harvested areas, I was expecting to see overall changes occurring in the managed forest," said Barrett. But as it turned out, the carbon in the managed forest was stable between inventories of the forest as a whole, just like the unmanaged forest. The reasons have to do with the timing of past harvests.

Most of the past clearcutting on the Tongass occurred between 1960 and 1995, resulting in second-growth stands that ranged from 9 to 50 years old at the time of the second inventory measurement. Those young stands hadn't reached their peak growth rate in terms of live-tree carbon accumulation. So while average growth per acre was shown to be higher in the managed forest than in the unmanaged forest, it hasn't yet peaked. At the same time, although the area harvested between the two inventories (from 1995 to 2010) was much smaller than in earlier decades, it was primarily in very dense old-growth forest. The net result—moderate growth on most of the half-million acres of managed forest and harvest on a relatively small area of dense old forest—meant that the total aboveground carbon in managed forest stayed about the same between the two inventories.

USING THE DATA

"Managing for carbon is a relatively new thing," says Barrett. "Because it's a new area, there's quite a bit of debate on the topic. For example, competing interest groups have made contradictory claims about carbon dynamics and storage in old-growth vs. second-growth forests."

For example, she says, people point to second-growth forest as proof that forest management is positive. Those new trees, after all, are storing carbon. A competing claim is, yes, but you're harvesting old growth and transferring carbon to the atmosphere.

"With our research, we can attach numbers to what's actually happening," Barrett says.

Barrett's research is being put to work. The Chugach National Forest used Barrett's information on carbon stocks in its forest planning assessment. The carbon report for the Chugach and Tongass National Forests may serve as a model for how other national forests can use data to assess aboveground carbon stocks and their fluctuation.

And a multi-agency effort that includes the Forest Service, U.S. Geological Survey, National Park Service, U.S. Fish and Wildlife Service, the University of Alaska, and others is using some of the information on species change in a climate vulnerability assessment of the Chugach, a larger effort that may influence decisions ranging from what kinds of trees to plant in the region to the size of culverts to use in roaded areas.

"After years of both studying forests and managing them, we tend to think we understand forest system dynamics," says Greg Hayward, a wildlife ecologist with the Forest Service's Alaska Region. "Tara's analysis of change in live tree biomass, like her modeling of spruce tree distributions, forces us to look at the forests in the region differently."

He continues: "As managers on the Chugach and throughout south-central Alaska contemplate management under climate change, Tara's results, combined with the other evaluations in our assessment, demonstrate that climate change is a global phenomenon. But the specific outcomes for ecological and social systems differ dramatically among regions—geographic, ecological, and social context is important."

"The future is already here–it's just not evenly distributed."

—William Gibson, author

LAND MANAGEMENT IMPLICATIONS

- Because fire is exceedingly rare in the temperate rain forests of Alaska, and large areas have never had any kind of vegetation management, these forests are an ideal laboratory for studying climate-related impacts on forest expansion, growth, and mortality.
- Detection of early changes helps land managers anticipate how a warming climate will affect forest dynamics in both managed and unmanaged forest in Alaska.
- This research provides straightforward carbon estimates for the Chugach and Tongass National Forests that can be used to develop baseline assessments of carbon stocks.

Kathleen Galloway

Most second-growth stands in southeast Alaska are young, so regionally the live-tree carbon accumulation rate in managed forests has not yet peaked.

FOR FURTHER READING

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