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Death of a spruce tree: Study of black spruce forest means trees might store more carbon than thought

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Forests affect the severity of climate change, and climate change affects the health of forests. Credit: PNNL/Ben Bond-Lamberty

Examining a long-lived forest, researchers have found that Black Spruce trees, which dominate the northern forests of North America, succumb about five years after being weakened by environmental stresses. Without rejuvenating fire, the dead trees aren't being replaced by new ones. The result will help researchers better understand how climate change affects the health of forests, and how forests affect the severity of climate change. The study also suggests trees might be storing more carbon than currently estimated.

"The take away from this is that a combination of short and long term processes shape forests," said lead author Ben Bond-Lamberty of the Department of Energy's Pacific Northwest National Laboratory. "Scientists have paid a lot of attention to potential climate change signals in forests—like them growing faster than expected due to an overabundance of carbon dioxide, or slower due to climate change-induced extreme temperatures. But that signal is hard to see because of past disturbances that the forests are recovering from."

Appearing in the journal *Global Change Biology*, the study showed that tree growth slows down as forests age, as expected. The study also allowed the researchers to examine tree mortality—information needed to figure out how much carbon dioxide trees can store—to improve climate models.

"Most climate models that incorporate vegetation are built on short-term observations, for example of photosynthesis, but they are used to predict long-term events," said Bond-Lamberty, who works at the Joint Global Change Research Institute, a collaboration between PNNL and the University of Maryland in College Park, Md. "We need to understand forests in the long term, but forests change slowly and researchers don't live that long."

Taking Inventory, Counting Rings

To explore the relation between climate and forests, Bond-Lamberty and his international group of colleagues combined data from tree rings and by watching how many trees died over 13 years in a northern Canadian boreal forest. Located in the northern latitudes, boreal forests have long cold winters and are full of evergreen trees. The forest has been studied well in the past—it was the site of the NASA-led BOREAS project in the 1990s, a study that provided scientists with a lot of what they know about forests and climate.

The tree ring data included tree core samples collected in three different years between 2001 and 2012 in a region called the Northern Old Black Spruce site. Such data tell scientists how fast trees grow every season over decades or hundreds of years. Slow-growth years suggest that rainfall was low or the temperature was very hot.

Researchers have been studying the boreal forests in Canada for decades to learn about the role of forests in climate. Credit: PNNL/Ben Bond-Lamberty

The team found that the oldest trees started growing in the mid-1800s.

Since then, the stand of trees has gone through at least three dry periods, evident from very thin rings during those periods. Although tree rings can show how trees grow over the years, they can't tell scientists when trees die. For that, researchers had to go walking through the forest, taking inventory of what was there.

To get the inventory data, researchers visited the same 200 square meters four times between 1999 and 2012. They counted every living and dead tree that had grown at least chest high and measured their diameters as well.

The researchers found that only three new trees of chest height entered the inventory during those 13 years, whereas many more died and others fattened. Meanwhile, leaf cover stayed the same. Bond-Lamberty said this isn't surprising to see in a forest that hasn't seen a wildfire in a long time.

When the team put the two sets of data together, though, along with climate data from the same 150-year period, they could clearly see the link between periods of slow growth and dead trees later on.

"We see a five-year lag between depressed growth in the tree core data and increase of deaths in mortality data," said Bond-Lamberty. "Trees are dying and not getting replaced, but the average tree growth is bigger. People usually say that young forests take up carbon dioxide fast and store it away, while older forests are probably neutral. Our study shows that as trees die in an old forest, middle-aged trees fatten up."

Thirsty Trees

This study also might cause scientists to reevaluate BOREAS results, said Bond-Lamberty. Data from BOREAS allows researchers to estimate how much carbon dioxide trees pull out of the atmosphere and store within their structures, a value used in some models to predict the role of forests in a future, warmer world. But the BOREAS study period turned out to be a rotten time for the forest.

"What we've discovered is that the 1990s was an unusual decade," said Bond-Lamberty. "Not the worst ever for growth, but pretty bad. That means instead of typical growth, we saw slow growth, and that raises questions about whether, on average, forests are socking away more carbon than we think."

Although this study in particular did not observe that trees are growing faster in the industrial age due to more carbon dioxide in the air, knowing how long it takes for trees to die will be important for scientists trying to work that out.

Another time of thirst for the forest appears to be in the first half of the 20th century. "From about 1920 to 1940 was a terrible time to be a tree. They were having a tough time staying alive, and you can see that in the forest's structure today," said Bond-Lamberty.

To determine whether these results applied more widely or if the stand was subject to unusual conditions, the team compared the Northern Old Black Spruce to a stand of slightly younger, 80 year old Black Spruce trees about three miles away. Comparing the two stands of trees to each other showed similar results, indicating that what was happening in the Northern Old Black Spruce forest was happening elsewhere as well.

"To understand current forest dynamics," said Bond-Lamberty, "we have to understand their past. Older forests contain surprises for climate science and ecosystem biology. We need to distinguish past disturbances from today's conditions."

More information: Ben Bond-Lamberty, Adrian V. Rocha, Katherine

Calvin, Bruce Holmes, Chuankuan Wang, and Michael L. Goulden. Disturbance legacies and climate jointly drive tree growth and mortality in an intensively studied boreal forest, *Global Change Biology*, October 24, 2013, DOI: 10.1111/gcb.12404

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