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Clear-cuts in a Changing Climate

The long-term implications of forest disturbance on carbon cycling

BACKGROUND Forests play a key role in the natural carbon cycle. Each year, forests absorb billions of tonnes of carbon dioxide (CO_2) and, using the sun's energy, convert the carbon into living plant matter. While most of this carbon is released when trees respire and/or decompose, some of it is sequestered as long-lived biomass or in the soil as organic matter. With over 400 million hectares of forested land, Canada is in an ideal position to use its forests as carbon sinks to help fight climate change.

Before we can maximize carbon sequestration in our forests, however, we must understand the factors that can affect carbon cycling. Stand age, tree species, soil composition and weather are just some of the things that can influence the amount of carbon uptake in forests. Of these, stand age is arguably the most important, because the amount of carbon taken up during photosynthesis is largely dependent on tree size. Despite this fact, relatively little is known about carbon exchange in immature stands.

Immature forests are an important component of the forest landscape in Canada. Each year, one million hectares of forest are harvested for timber, while another 3-7 million are killed by fire or insect damage. Over time, such disturbances have created a patchwork of immature stands in various stages of regrowth. In order to develop a more accurate accounting of carbon stocks in different-aged forests (and in doing so, improve our estimates of Canada's overall carbon sink potential), it is critical that we identify how carbon sink/source dynamics change as forest communities regenerate following disturbance.

BIOCAP RESEARCH Fluxnet Canada is a national, BIOCAP-supported research network[1] that studies carbon cycling in Canadian forests. The network operates a series of "flux towers" across the country that continuously measure the exchange of CO_2 between forests and the atmosphere, and help researchers identify which forest ecosystems act as net carbon sinks and sources.

A SCIENCE POLICY PERSPECTIVE

WHY STUDY CARBON CYCLING IN DISTURBED FORESTS? Canada's >400 million hectares of forest are an enormous carbon sink, absorbing 10-20 times the amount of CO_2 emitted from fossil fuels each year. While forest sinks are an important component of Canada's carbon budget, they are vulnerable to different types of disturbance, including harvest, pest outbreaks, forest fires and a changing climate. Understanding the role of disturbance on carbon cycling is critical to determining the nation's carbon stocks in the near-term, and predicting the effects of a changing climate in the long-term.

WHAT WAS DONE? The production and uptake of CO_2 was measured continuously in coastal Douglas-fir stands at three different stages of regeneration: a 53-year old rotation-aged stand, a 15-year old pole/sapling stand, and a 3-year old seedling stand.

WHAT WAS DISCOVERED? Harvesting had a much greater and longer-lasting effect on carbon cycling than expected. The youngest stand was the largest terrestrial source of carbon ever measured, while the middle-aged stand remained a significant carbon source even 15 years after logging.

WHAT DOES IT MEAN? The study provides the first comprehensive assessment of carbon cycling following disturbance, and will help refine estimates of Canada's carbon stocks. It will also help improve our management of these ecosystems to enhance their sink potential and minimize carbon losses. Additional research is needed, however, to extrapolate the results to other types of forest disturbance. In a changing climate, understanding the long-term impact of disturbance on carbon sequestration will become increasingly critical. For example, the benefits of faster growth rates and longer growing seasons must be counted against the risks of increased pest outbreaks and forest fires, both of which are predicted to increase as the climate changes.

Dr. Andrew Black is a Fluxnet researcher at the University of British Columbia who maintains flux towers in three previously-logged Douglas-fir stands on the eastern coast of Vancouver Island. The research sites include a

53-year old stand nearing harvest age, a 15-year old stand at the pole/sapling stage, and a 3-year old stand at the seedling stage. Located within 50 km of each other, the stands share similar physical environments and climatic conditions, but are in three distinct stages of regeneration, providing an ideal opportunity to compare the effect of forest age on carbon sequestration.

RESULTS Tree age had a dramatic effect on net CO_2 exchange. The oldest Douglas-fir stand was a net carbon sink, sequestering on average about 9 tonnes of CO_2 per hectare each year. Not unexpectedly, the two younger stands were net sources rather than net sinks, due to the long-term decomposition of belowground carbon following logging. However, the magnitude of these carbon sources was startling. The 3-year old seedling stand released 22 tonnes of CO_2 per hectare annually - the largest carbon source ever measured for a terrestrial ecosystem. Even 15 years after harvest, the middle-aged stand was still a net carbon source, releasing up to 5 tonnes of CO_2 per year.

By collecting data over multiple years, Dr. Black and his colleagues also determined the consistency of the source/sink effect in each stand; such measures are vital if research results are to be extrapolated to national carbon budgets with confidence. Dr. Black found that the greatest year-to-year differences in carbon exchange occurred in the 53-year old stand, where the amount of carbon sequestered fluctuated by up to 67% each year. In contrast, the 3-year old stand, although a large carbon source, remained fairly consistent in its output, with the amount of CO_2 released never varying by more than 5% between years.

Not all types of forest disturbance will have the same impact on carbon sinks and sources, but Dr. Black's data provides the first long-term assessment of the effect of disturbance on carbon cycling. In a changing climate, the effect of disturbance and stand age on carbon sequestration will become increasingly important. Rising levels of CO_2 that have a "fertilizing" effect on tree growth are expected to result in faster tree growth, while warmer temperatures will extend the growing season and the geographical limits of tree growth. However, a warming climate also means increased decomposition of belowground organic matter, more frequent and severe insect outbreaks, and increased risks of forest fire. Large scale carbon losses from pests and fire could quickly negate the benefits of increased CO_2 sequestration in faster-growing, expanding forests. Such disturbances are the "wild card" in predicting how much carbon forests can take up in future climate scenarios. Although additional research is needed to determine the impact of other types of forest disturbance on carbon cycling, the results of the present study highlight the critical role that disturbance will play in the future net carbon balance of Canada's forests.

In the meantime, Dr. Black's results provide critical information regarding the potential size of carbon losses following harvest in at least some types of forest stands, and the expected duration of these losses. This information will be extremely valuable in calculating national forest carbon stocks and developing strategies to minimize long-term carbon losses following harvest.

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