Wildland Fire Lessons Learned Center

Advances in Fire Practice

Wildfire and the Global Carbon Cycle

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Large fluxes of carbon into the atmosphere from wildfires can have an impact on the global carbon cycle, and with policy initiatives forming around carbon management and carbon budgets, researchers are scrambling to fill in the gaps regarding the role of fire in carbon emissions and sequestration. It has long been conventional wisdom that CO2 emissions were essentially neutral in global carbon fluxes since fires also promote vegetation regrowth and uptake of CO2. However, the more frequent and severe fires that the US and the world is experiencing as a result of climate change and fire suppression have made many begin to question whether that balance continues to exist.

Oregon's 2002 Biscuit Fire burned over 499,000 acres. In terms of CO2 emissions, the Biscuit Fire was also massive. Researchers estimate that the fire pumped 3.8 teragrams of Carbon into the atmosphere. That one fire equalled one third of all the carbon released through fossil fuel burning in Oregon annually.

Bernard Bormann, a forest ecologist and soil scientist with the Pacific Northwest Research Station, has been looking at the effect of the Biscuit Fire on some long-term ecosystem productivity plots that were established in the Rogue River – Siskiyou National Forest in Oregon. Using comparison with a wealth of soils data collected before the fire, Bormman and his team estimate that previous studies used sampling and analysis methods that undercalculated the amount of carbon lost from soils by nearly 50% and the loss of nitrogen by 25%. These findings suggest that calculations and models of greenhouse gas emissions from wildfires may be seriously off the mark.

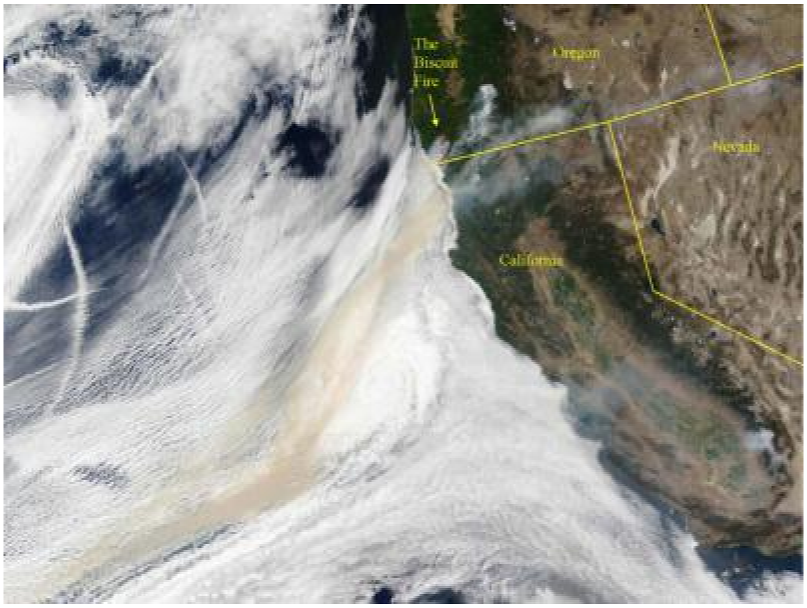
Taken on the heels of similar studies across the western US and given the changes in fire regimes being observed across many regions, the study also raises important questions about the impacts severe fires have on the long-term role of forests in carbon sequestration.

"It was shocking to see the changes to our plots one month after the Biscuit Fire," says Bormann. ""There was nothing left after the fire—some snags and a few downed logs, almost bare soil. The whole soil structure had changed—it was crusty and would collapse when you walked on it. The soil organic matter was lost and even fine mineral particles from the upper soil layer were gone. We believe that the upper soil mineral layer may have been pulled into the atmosphere in the fire plume."

Forests—Carbon sinks or sources?

Large fires like the Biscuit Fire can actually rival human sources of CO2 emissions on a state level scale. In fact, Christine Wiedinmyer and Jason Neff, researchers with the National Center for Atmospheric

Research, found that CO_2 emissions from fires in the US are equivalent to only 4 – 6% of anthropogenic emissions, but that there is a lot of variability from region to region and from year to year. So, in some cases, say at the state level, fire emissions of CO_2 can actually exceed that from fossil fuel burning.



Large plumes of smoke, some more than 900 miles long, were visible most days during the 2002 Biscuit Fire. New research shows that the plumes may have contained fine mineral-soil particles as well as partially burned organic matter. (Credit: Image courtesy of MODIS)

“Fires are a natural part of many systems,” says Wiedinmyer. “But, from an atmospheric chemistry standpoint, there is a need to mitigate these high emission events.”

The same pattern appears at global scales as well.

In 1997-98 the growth rate of CO_2 in the atmosphere doubled, reaching the highest point on record at that time. The cause of that spike was wildfires burning for months over large expanses of Indonesia. Researchers discovered that the main source of the carbon emissions were fires in deep peat bogs, which produced an estimated at .8-2.6 X 1015 gigatonnes of carbon. To put that into perspective, it is the equivalent of the total global carbon uptake by the terrestrial biosphere in a typical year, and it came from one tiny portion of the globe.

James Randerson, a researcher in the Department of Earth System Science at the University of California, Berkeley, points out that when you look at fires in systems like the grasslands of South America; you are looking at a neutral carbon emissions system—burning leads to a steady state of regrowth and uptake. But, burning in tropical rainforests and in boreal forests is resulting in a net loss of carbon.

“In areas where the fire regime is changing rapidly we are no longer in equilibrium with respect to carbon flux,” says Randerson. “Tropical rainforests rarely burned before human settlement and now they are burning on large scales. With the collapse of the Soviet Union there has been a strong uptick in fires in boreal forests—even averaged over long time periods, it is apparent that these fires are contributing to much more carbon loss into the atmosphere.”

Closer to home and on smaller scales, the fire and carbon equilibrium is also getting out of balance. A whole host of factors—fire suppression, climate warming, and an increase in fuels—has created a context in which larger, more frequent, more severe fires are the norm, rather than the exception, in the western US. Research is starting to show that the changing fire environment is impacting the carbon cycle as well as long-term forest productivity.

In calculations of the global carbon cycle, most forests are carbon sinks, absorbing a good portion of the CO_2 released by human activities. Fires cause a sudden conversion of stored carbon into CO_2, which is released to the atmosphere. The effect of a fire on the carbon balance can last for a number of years, depending on the intensity of the fire and the recovery of the ecosystem. In healthy ponderosa pine forests subject to high frequency, low-intensity fires, it may only be 2-5 years before a disturbed forest shifts from being a net carbon source to a carbon sink. However, Northern Arizona University researcher, Sabina Dore, has recently provided findings showing that more severe fires can shift the source/sink timeline considerably. She examined the net CO_2 exchange of the ecosystem, as the balance of CO_2 fixed by plants and lost in respiration, in a ponderosa pine forest hit by a severe, stand replacing fire ten years after the event.

“There was nothing left after the fire, and there is still nothing on the site today,” says Dore. “Some snags and logs, almost bare soil. Ten years later, only sparse herbaceous vegetation has returned, and the site has been seriously impacted by wind and water erosion.”

These photos show post-fire forest conditions following the Rodeo-Chediski fire. The photo on the left was taken approximately one year after the fire and of an area that had been thinned and pile burned in 1997. The area in the photo on the right, taken immediately post-fire, was not thinned prior to the fire. Photo Credits: left: D. Maurer, U.S.D.A. Forest Service, Apache-Sitgreaves National Forest, Black Mesa Ranger District, right: Arizona Division of Emergency Management.

Dore’s research in Arizona has shown that after severe, stand-replacing fires carbon losses can continue for 10-20 years because of the productivity loss, and that it may take up to 50-100 years to replace the carbon lost during the fire.

“If some of the canopy would have survived the ecosystem would recover more quickly. This would allows the pines to regenerate and there would be less erosion and loss of organic matter.”

As these high intensity fires become more common, Dore warns that there is the danger of a large US forest carbon sink, the southwestern ponderosa pine forests, shifting to a decadal-scale carbon source.

Bormann also sees long term implications for increasingly large and frequent fires in the Douglas fir forests of the Pacific Northwest, especially in regards to the time it will take to replace lost humified soil organic matter. Losses in long-term productivity mean reduced rate of photosynthesis which means a non-neutral carbon balance after fire (less carbon will be taken up annually after fire than before).

“Most of the carbon in the mineral soil is not at all like the carbon in woody debris or live vegetation,” says Bormann. “Mineral soil carbon, or humus, results from successive decomposition forming more and more stable carbon forms over hundreds of years. This stable carbon plays important roles in nutrient retention, soil structure, water-holding capacity, etc. Its loss cannot be restored quickly, like carbon sequestered in above-ground biomass."

Solutions: Can carbon offsets drive forest management and fuel treatment?

In forests that are likely to be impacted by future intense fires, the key is "preemptive reduction of intense-fire risks," according to Bormann. Strategies like using prescribed fire, reducing fuels, and changing the distribution of fuels across the landscape are essential strategies to reduce losses in long-term productivity, lower greenhouse gas emissions, and improve carbon storage ability.

Of course, land managers have struggled for years to develop fuel reduction strategies that are economical and effective. The scale of the problem is now so large that land management is falling farther and farther behind the growing problem.

Matt Hurteau, a forest ecologist with Northern Arizona University, thinks that the increased interest in forests for carbon sequestration may actually help drive a new approach to managing forests and treating fuels. Carbon sequestration programs help carbon producers offset their emissions by paying to store carbon in standing forests. One liability of these programs has always been the forests' vulnerability to fire—one big fire can potentially wipe out an entire program.

Hurteau says that if you keep the forests from burning to the ground, you keep the carbon in forests as live trees. "If we just keep managing forests based on our scientific understanding of the processes that promote a fully functioning system, we are going to end up in the best position with regards to carbon storage."

This increases the ability of the forest to store carbon over the long term, and may provide the financial mechanism that has been lacking to start getting a handle on the fuels problem.

The key is quantifying the effectiveness of different management techniques in promoting long-term carbon storage. Hurteau has begun to tackle the problem through a series of research projects addressing the following—what is the payback ratio for fuel reduction treatments compared to high severity wildfires?

"We need to develop an equation valuing carbon in a forest based on the risk of loss to fire," says Hurteau.

Under Hurteau's scheme, forests in which the vulnerability to severe fires has been reduced would be more valuable than those which had not been actively managed. "If you have a fire-prone forest and you thin the forest, the carbon stock is better protected," says Hurteau.

Over the next few years, carbon management programs and policies will likely become a big part of our national energy policy, and forests play a large part in some of the proposed programs. But, fire remains the wildcard in those plans, even more so now that research is showing that a changing fire regime is fundamentally altering the delicate balance between forests and carbon cycles.

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