Burned but not forgotten

"After a fire, things happen that we didn't necessarily think about."

Anne Nolin
Oregon State University

by Agnieszka Gautier

On August 23, 1996 lightning struck north of Waldo Lake in the Cascade Mountains of Oregon. In five days, the Charlton Fire burned 10,000 acres of forest, killing 95 percent of its trees. Almost twenty years later, the area has barely recovered. Dead, bare trees still stand. Regrowth is stunted. With a drier West prompting more fires, scientists are looking to the longer-term impacts of charred forests.

Fires release a lot of carbon into the atmosphere, increasing carbon dioxide, a greenhouse gas. On a short time scale this heats up the climate. Also, most scientists connect burned forests with

In this photograph, taken eleven years after the Charlton Fire in Oregon's Willamette National Forest, a majority of snags still stand while gradually new vegetation is recovering. (Courtesy M. Spencer) decreased carbon absorption, further tipping the carbon cycle balance towards warming. But understanding how certain environments respire or store carbon dioxide—crucial for carbon cycle analysis—can be much more complex. This is just what researcher Thomas O'Halloran learned when he looked at the Charlton Fire.

Disturbing events

How disturbed forest patches affect global climate piqued O'Halloran while doing post-doctoral research at Oregon State University (OSU). "The climate impact of forest disturbances extends beyond the carbon budget," said O'Halloran. "To be able to understand and predict carbon in the atmosphere, Earth system models need to include insect outbreaks, wildfire, and hurricanes."

Kelly Gleason, another postdoctoral student at OSU, also looked at the post-fire environment, only from a different angle. O'Halloran analyzed forests before and after disturbances, while Gleason and her team focused on the snowpack in high elevation, burned forests. "No one had studied the effect on snowpack and hydrology," Gleason said. "It's the same process with an interesting paradox." Together, the two studies came together to shed light on the complex relationship between ecosystems and climate.

Life on Earth has synchronized into a symbiotic exchange of oxygen and carbon dioxide. Plants absorb carbon dioxide to make sugars, releasing oxygen; animals eat the sugars, releasing carbon dioxide. Carbon dioxide is only a tiny fraction of the atmosphere, about 0.04 percent, but carbon dioxide and other greenhouse gases trap heat on Earth. Wildfires, burned fossil fuels, and damaged ecosystems all help accrue this heat in

Burned woody debris falls off a charred tree. The area around the tree, with a darkened surface, is melting faster than surrounding snow, which appears lighter. (Courtesy K. Gleason)

the atmosphere, warming the climate and changing our ecosystems.

O'Halloran wanted to measure how disturbances change the way ecosystems exchange carbon dioxide and reflect solar radiation. He utilized the Department of Energy AmeriFlux program, a network of tower sites geared to measure these transfers, but the towers did not sample many insect outbreaks. So O'Halloran looked into the Moderate Resolution Imaging Spectroradiometer (MODIS), a sensor on the NASA Terra and Aqua satellites that can see Earth's entire surface.

Using a subsetting tool from the Oak Ridge National Laboratory Distributed Active Archive Center, O'Halloran could retrieve the exact MODIS pixel that corresponded to the AmeriFlux tower site, and then extrapolate beyond that. In other words, satellite and tower observations could be combined to get more value from the data. "I could poke around and find these disturbances, and easily zoom in and grab MODIS data," said O'Halloran. "And that's where all this started." Now he could compare rates of carbon exchange with albedo and reflected radiation.

Winter reflections

In the Waldo Lake area, the 300-year-old mountain hemlocks measure 20 to 40 meters (65 to 130 feet) tall, and 2 to 3 meters (7 to 10 feet) in diameter. Bark furrows in broad, grey contours. Its needle-like leaves litter the understory. Little light penetrates their continuous canopy, draped in stringy lichen. When fire struck, it vaporized the crowns, leaves, and most branches.

These bare, scorched trunks fracture the landscape. Inside the bark and close to its surface is the foundation of tree life, cambium, a living tissue responsible for growth. If enough heat from a fire kills the cambium, the tree dies. The trunk may stand for decades, but its life has essentially been squelched. From the perspective of solar reflection, these snags, or standing dead trees, behave like living trees. The black of charred bark absorbs sunlight, just as the foliage once did, except it no longer ingests carbon dioxide.

Summer is a time of rejuvenation. "In the summer, vegetation starts to come back, little flowers and herbs initially, and then shrubs and baby trees. As things grow back, the albedo starts to increase again," O'Halloran said. When life reenters these dead patches, green appears. Green, being lighter than black, reflects more light and increases albedo.

"We knew that for summer and even spring, albedo went up; that had been shown," O'Halloran said. And yet something unexpected was happening in winter. In high-elevation forests, the albedo continued to increase for ten years or more after a wildfire—in winter. "This hadn't been seen before; no one had a good explanation for it," he said.

Into the woods

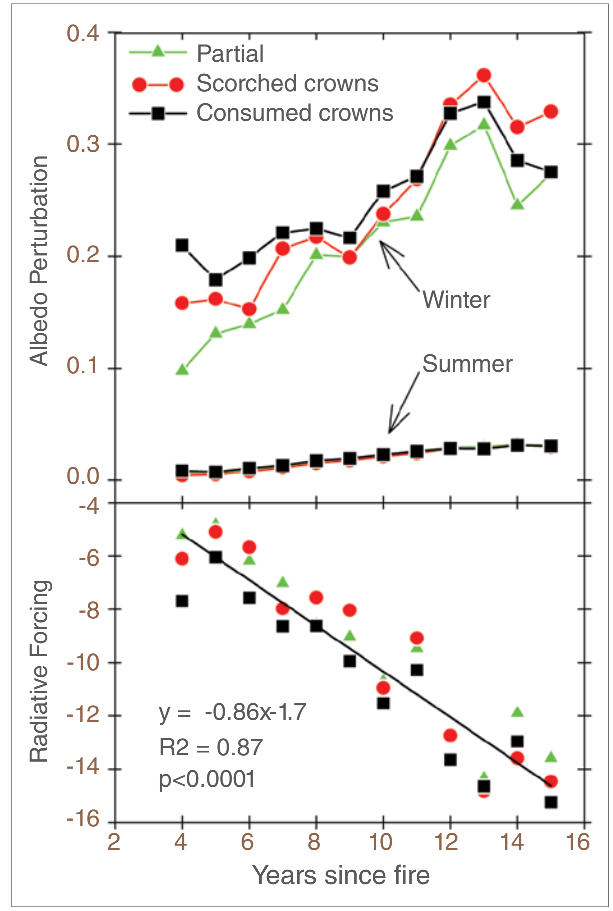
Disturbed forests modify the carbon and radiation budget for several decades. But how can scientists predict their effect on the climate in the long-term? "This data set extends fifteen years, and the albedo is still high," O'Halloran said. "That's a pretty big climate signal."

While looking at the Charlton Fire, O'Halloran realized that a team of ecologists had long been measuring trees in the Willamette National Forest in Oregon. So O'Halloran could add fifteen years of post-fire field observations to the satellite and tower data, offering the opportunity to investigate the winter increase in albedo.

Steve Acker, an ecologist for the National Forest, joined O'Halloran's study. "It's rare in vegetation ecology to have direct observations," Acker said. Where the fire blazed, the forest elevation rises to 1,700 meters (5,600 feet). "These higher elevation forests haven't received much study," Acker said. "We were able to fill a gap."

Acker observed that over time the burned forest changed. The density of snags decreased. Smaller snags fell first, leaving many of the larger snags to shadow a modest, slow regrowth. O'Halloran said, "The environment is harsh after a fire. It's so cold in the winter. There's no protection. Trees recover slowly."

With just snags standing, sunlight easily penetrates to the surface. In a high-elevation forest, like the Willamette National Forest, snow shrouds the ground from mid-November to about mid-June, as deep as six to seven feet. Only snags stick out of the snowpack. Fallen trees sink beneath. As trees begin to fall, there is less and less dark surface absorbing sunlight.



The plot at top shows a time series of the Moderate Resolution Imaging Spectroradiometer (MODIS) albedo, or solar reflection. The effect of fire greatly increases albedo in winter, but only subtly in summer. Three fire classes are presented: partial burn; high severity, scorched crowns; high severity, consumed crowns. The bottom plot of radiative forcing, in watts per square meter, shows that the effect increases linearly with time and is still increasing fifteen years after the fire. (Courtesy T. O'Halloran)

"That's going to keep happening until all the snags fall," O'Halloran said. Eventually, saplings will be taller than the snowpack, and then solar reflection will decrease as new trees take up more light.

A slow fall

Anne Nolin, a professor at OSU and co-author on Gleason's study, said, "After a fire, things happen that we didn't necessarily think about." Gleason's study also used MODIS, but focused on snow cover. "If you burn down a forest, albedo increases hugely," Nolin said. "The albedo of vegetation might be around 40 percent; the albedo of snow is about 80 percent."

Initially fire sends plumes of carbon into the atmosphere, warming it. Over time as snags fall, the landscape gets bleaker. "With a treeless surface, the albedo increases, and more albedo means more sunlight is being reflected, and that's a cooling affect," O'Halloran said. So albedo can offset the warming from carbon dioxide. "They're sort of canceling each other out," he added.

For Gleason, also looking at snow, something else developed. Three years post-fire, during snowfall, she found little difference in snow surface albedo between burned and nearby, unburned forests. "Once snow stopped falling and started melting, the debris that sloughed off charred snags concentrated on the snow surface, darkening it and lowering its albedo," Gleason said. The predominant source of energy for snowmelt is sunlight. With a darker surface and no canopy to block sunlight, the snowpack absorbed 200 percent more sunlight. As a result, snow melted three weeks earlier in the burned forest.

"It's an interesting paradox," Nolin said. On the one hand, snow albedo cools the atmosphere, but the charred debris absorbs more heat, melting snow sooner and faster. "Studies have shown that an earlier snowmelt drives more forest fire disturbance," Gleason said. "The West gets its precipitation in the winter, stored as snow. Snow-

Pileated woodpeckers excavate nests within snags, bringing life to charred forests in Oregon. (Courtesy S. Russell)

This close-up of a dead tree shows depressions and pockets that are key areas for animals to excavate cavities. Pileated woodpeckers, raccoons, and squirrels shelter within. The photo was taken in a subalpine burn on the upper slopes of Mount Harvey, British Columbia at an elevation of 1,600 meters (5,000 feet). (Courtesy D. Brayshaw)

This close-up of charred bark unveils the tree's delicate living tissue. Cambium (orange areas) is the foundation of tree life and growth, giving a tree its rings. If enough heat from a fire kills the cambium, the tree dies. The dead tree may stand for decades. (Courtesy C. J. Reed)

melt provides a moisture subsidy. If snow melts earlier, there is a longer period of drought stress." Gleason hopes her research will help hydrological forecasters, the people on the ground trained to predict how much water is coming out of the mountains and when.

Still, fires are natural. "Fires are ecosystem machines," Gleason said. "They maintain healthy ecosystems." Post-fire environments create heterogeneity in the landscape. Instead of a monoculture of clogged fuels, they increase diversity in forest densities, form microclimates, and open the land to new species. "It's just now we have bigger fires, more intense, higher burn severity, a longer fire season, and more fires," Nolin said. "It's not necessarily bad. It's just that we're still learning what this means."

To access this article online, please visit https://earthdata.nasa.gov/sensing-our-planet/burned-but-not-forgotten.

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For more information

NASA Land Processes Distributed Active Archive Center (LP DAAC)
http://lpdaac.usgs.gov

NASA National Snow and Ice Data Center DAAC (NSIDC DAAC)
http://nsidc.org

NASA Oak Ridge National Laboratory DAAC (ORNL DAAC)
http://daac.ornl.gov

NASA Moderate Resolution Imaging Spectroradiometer (MODIS)
http://modis.gsfc.nasa.gov

About the remote sensing data

Satellites	Terra	Terra	Terra and Aqua
Sensors	Moderate Resolution Imaging Spectroradiometer (MODIS)	MODIS	MODIS
Data sets	Vegetation Continuous Fields Yearly L3 Global 250m (MOD44B)	Terra Snow Cover 8-Day L3 Global 500m Grid, Version 5 (MOD10A2)	Albedo (MCD43A)
Resolution	250 meters	500 meters	500 meters
Parameters	Vegetation	Snow cover	Blue-sky albedo
DAACs	NASA Land Processes Distributed Active Archive Center (LP DAAC)	NASA National Snow and Ice Data Center DAAC (NSIDC DAAC)	NASA Oak Ridge National Laboratory DAAC (ORNL DAAC)

About the scientists

Steven Acker is a zone ecologist with the Northwest Oregon Ecology Group, stationed at the Willamette National Forest. His research interests include effects of fire and fluvial disturbance on vegetation; tree mortality and dead wood accumulation and attrition; and long-term monitoring. The National Science Foundation, the Pacific Northwest Research Station of the U.S. Forest Service, and the Willamette National Forest supported his research. (Photograph courtesy L. Bishop)

Kelly Gleason is a postdoctoral student at Oregon State University. Her research focuses on the interactions of ecosystem disturbance and mountain hydroclimatology, and their implications to snow-water resources in the changing climate system. The National Science Foundation supported her research. (Photograph courtesy K. Gleason)

Anne Nolin is a professor in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University where she leads the Mountain Hydroclimatology Research Group. Her research focuses on the interactions of climate with mountain snowpacks and glaciers. NASA, the National Science Foundation, and U.S. Geological Survey supported her research. (Photograph courtesy A. Nolin)

Tom O'Halloran is a research assistant professor at Virginia Polytechnic Institute and State University. His research focuses on the role of vegetation, and particularly forests, in regulating Earth's climate. The Department of Energy supported his research. (Photograph courtesy T. O'Halloran)