Understanding Wildfire Effects to Inform Better Forest Management

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Scientia

UNDERSTANDING WILDFIRE EFFECTS TO INFORM BETTER FOREST MANAGEMENT

Forest wildfires are increasing in frequency and severity across the globe, and this trend is expected to continue as climate change worsens. However, measuring the impacts of wildfire on forest ecosystems is extremely difficult. Dr Bianca Eskelson from the University of British Columbia and her colleagues at the United States Forest Service utilise vast datasets and investigate conditions before and after wildfires, to quantify their immediate and long-term effects on forest ecosystems. The team's research is improving our understanding of the effects of forest wildfires to inform better forest management.

A Growing Threat

In recent years, forest wildfires have been increasing in frequency, severity and extent, and this trend is set to continue into the future. This is because our carbon dioxide emissions are driving up global temperatures, causing parts of the world to become drier, and substantially increasing the chances of wildfire.

Furthermore, the world's forests hold enormous amounts of carbon, and trees continuously remove carbon dioxide from the atmosphere as they grow, partially offsetting our emissions. Wildfires can release this stored carbon into the atmosphere, and reduce the number of trees available to absorb it, driving up levels of atmospheric carbon dioxide.

Therefore, it is critical to quantify the impacts of forest wildfires, in terms of the amount of carbon released to the atmosphere and the damage caused to forest ecosystems. It is now more important than ever before to closely monitor the world's forests, to identify forest ecosystem recovery trajectories, in order to fully understand wildfire impacts on carbon and devise management strategies that mitigate wildfire severity and ameliorate fire impacts on carbon.

Large-scale forest surveys have traditionally only focused on estimating timber production. However, over the last few decades, surveys have been updated to include the assessment of other forest resources and to consider ecosystem health. Of course, this means that the ways in which forests are surveyed have also changed to include more variables. This data can now be used to observe and quantify changes in forest resources caused by wildfires.

Dr Bianca Eskelson of the University of British Columbia, and her collaborator, Dr Vicente Monleon of the US Pacific Northwest Research Station, focus on observing forest conditions both before and after wildfires occur, and quantifying the impacts of fires. Because dead wood left over after fires can

continue to release carbon dioxide for years, some of their work focuses on investigating the post-fire dynamics of forest carbon.

Using Forest Inventory Data

Forest Inventory and Analysis (FIA) Program data is incredibly useful when carrying out any kind of study on US forests. It provides a spatially balanced sample across all forest regions of the US, with one plot for every 24 square kilometres. It also provides a large sample, representative of past wildfires across all burn severities, which can help improve our knowledge of wildfire effects and inform future forest management and policy decisions.

The use of FIA data for regional analyses has increased over the last 15 years. Yet most previous research on wildfire impacts has focused on individual, high-severity fires in small areas. However, using FIA data for large-scale studies to evaluate both the pre-fire and post-fire conditions of forests produces results that are highly accurate, not just for a specific area, but for anywhere with similar forests, meaning the findings of these studies can be applied to US forests in general and are not restricted to a single fire that was studied intensively.

Dr Eskelson and her colleagues overlaid FIA plots with existing Burn Severity Mosaics from the Monitoring Trends in Burn Severity program, which maps the location and severity of wildfires. This allowed them to identify unburned areas, and areas that experienced wildfires of varying levels of severity (low, moderate and high) for use in their studies. This provided the team with a dataset that offers the full picture of how wildfires of different severities affect forest carbon.

Changes in Woody Carbon

Carbon pool dynamics (a forest's capacity to store or release carbon) after wildfire represent a gap in our understanding of how fires can affect forest carbon storage many years after a fire occurred. Much previous research has been restricted to case studies of individual fires and has focused on very limited conditions.

Therefore, to gain deeper insight into how fire alters forest carbon pools, Dr Eskelson and her colleagues used data from the FIA Program based on 32 wildfires across California from 2002 to 2009. The team found that pre-fire carbon and post-fire carbon are highly linked regardless of burn severity, meaning the pre-burn state of a forest is important in predicting fire impacts.

Their results showed that, compared to a typically assumed 100% decrease in live woody carbon in high-severity wildfires, low-severity wildfires only result in a 3% reduction in live woody carbon, while moderate-severity fires lead to a 37% decrease on average. This result highlights that the amount of carbon dioxide released in a wildfire can vary greatly depending on the severity of the fire. It also confirms that using post-fire estimates for high-severity fires, which have been the focus of many previous studies, is not appropriate when estimating the likely damage to forests that are prone to moderate or low-severity fires.

Changes in Ground Fuels

Forest floor litter consists of freshly fallen, dead, non-woody plant material, such as leaves. Meanwhile, duff forms the layer below litter and is made up of partially decomposed organic material that is no longer identifiable. Together, litter and duff make up the ground fuel of a forest, which can facilitate the spread of a fire and determine its severity. During forest wildfires, duff and litter tend to burn away, and it can take a long time to recover this ground fuel layer. The amount of ground fuel present can also influence future fire behaviour and affect the productivity and nutrient availability of the surrounding forest ecosystem.

Dr Eskelson and her colleagues observed that the amount of duff changed very little in the first nine years following fire in the surveyed plots. They determined that this was likely due to the lack of litter available after a wildfire and the long time it takes for litter to decompose and replace the duff that was lost. This is especially true for forests in the dry climate of California.

Dr Eskelson and her colleagues discovered that the amount of forest floor litter was lower one year following a high-severity wildfire compared to that after a low- or moderate-severity fire. However, this difference was not as pronounced compared with the difference between the amount of duff one year after a high-severity wildfire and that present following a low- or moderate-severity fire. This suggests that the litter they observed one year post-fire fell and accumulated after the fire. In particular, they found that dry conifer plots have a higher litter input in the first year after a fire than hardwood plots, due to the fall of needles from scorched crowns.

The team's results offer new insights into ground fuel dynamics after wildfire, and the conditions are representative of what occurs in other similar forests. This means that the trends revealed in their research can be generalised to all wildfires in the region that burned with low, moderate or high severity in both hardwood and dry conifer forests in California.

Calculating Combustion Factors

By matching burned plots with similar unburned plots in the Pacific Coast states, USA, the researchers were able to analyse large-scale forest survey data in a way that was similar to a controlled experiment. This allowed them to more accurately quantify the effects that wildfires have on forests. Dr Eskelson and Dr Monleon used this matched data to estimate the average combustion factor of coarse woody material and determine how much wildfire decreases the amount of material present. The combustion factor is simply the fraction of coarse woody material that is consumed by fire.

Their estimated combustion factors were much higher than those previously reported in the regions surveyed. This means that wildfire decreases the amount of coarse woody material more than had been previously thought. As mentioned earlier, previous studies in the area have never been done on this scale and cannot be generalised in the same way that the team's results can, which are based on a large spatially-balanced dataset representative across a range of fire severities and forest types.

From their findings, the researchers conclude that the combustion of coarse woody material in wildfires should be taken into account as an important factor when estimating carbon emissions due to wildfire. Understanding the amount of carbon consumed in different pools across a range of fire severities, will prove extremely useful in mitigating or even preventing future fires, as well as informing climate change predictions.

Future Fire Management

As large wildfires become more common, post-fire management such as reforestation and fuel reduction are vital in reducing the likelihood of reburning. This is why Dr Eskelson's work on post-fire conditions and fuel dynamics is so important, as these factors determine burn severity. Understanding post-fire dynamics will allow forest managers to choose appropriate management strategies that reduce reburn probability and severity, resulting in conservation efforts that are truly effective.

The research team's approaches to analysing long-term monitoring data can be adapted for data collected in other regions and used to assess the effects of other natural disturbances, such as insect outbreaks, drought or storms. It may provide insight on the magnitude of such disturbances and guide future research directions, allowing effects to be quantified and management plans to be adapted accordingly. The team's results on surface fuel dynamics will help fire managers to assess the probability of reburning so that they can develop mitigation strategies.

Dr Eskelson's future work will focus on analysing more post-fire data as it is being collected by the FIA program, enabling future analysis of longer recovery periods in forests after a wildfire. Her team's research serves as a foundation for using long-term monitoring data to assess post-fire recovery, and more generally post-disturbance recovery, across US forest ecosystems.

Meet the researcher

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Dr Bianca Eskelson earned her Bachelor's in Forest Sciences and Forest Ecology from the Georg-August University, Göttingen and her Master's in Statistics from Oregon State University, Corvallis. She was then awarded her PhD in Forest Biometrics from Oregon State University in 2008. Dr Eskelson is currently an Assistant Professor of Forest Biometrics in the department of Forest Resources Management at the University of British Columbia, Vancouver, Canada. Here, she works on quantifying natural disturbance effects and assessing post-disturbance dynamics from forest inventory data.

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KEY COLLABORATORS

Dr Vicente Monleon, Pacific Northwest Research Station, US Forest Service

FUNDING

US Forest Service
NSERC (Canada)

FURTHER READING

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