Climate change and the catastrophic wildfire

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Diverse meadow post fire in Bald Eagle State Forest. Credit: Nicholas A. Tonelli creative commons license

Over the past several months news of widespread wildfires has coursed through the media from every corner of the world. In the United States, the wildfire season is now two months longer than it was 100 years ago. In 2015 alone, over 9.3 million acres of land have burned in the U.S. (the

2nd largest amount on record) and with current elevated fire risk in California and Texas (as of 11/12/15) that number seems likely to rise by the end of the year. The manifold economic costs of fires to land and business owners have fueled a culture of fire suppression in spite of changes in policy at the national level.

Yet fires, even severe ones like the ones that burned 1.2 million acres of land in Yellowstone National Park in 1988 or the infamous blaze in Mann Gulch, Montana provide many benefits for ecosystems and often serve to promote diversity.

However, as disturbances increase in their frequency and severity due to climate change the role of fire in forest ecosystems may change as well.

Lightning strikes, discarded cigarette butts, and other (often anthropogenic) factors cause fires which create minor disturbances in forest ecosystems. Minor fires provide an influx of light and nitrogen to a forest that previously was light and nutrient limited. Low severity fires do little damage to large trees and belowground structures, allowing re-establishment of seedlings and herbaceous species as little as two weeks post-fire. Forests can recover from low-severity fires fairly quickly. In fact, some have noted a return to pre-fire composition in as few as three years.

Severe fires have become more common in the western U.S. due to multi-year droughts and the increase in fuel availability due to fire suppression efforts. But even these severe fires do not seem to have a large effect on belowground biomass and thus regeneration is likely. Indeed, in recent work in PLoS One, Dennis Odion and colleagues note that mixed severity fire regimes, even those that include high intensity burns, are more likely to result in a patchy distribution of successional stages throughout a forest than low and moderate intensity burns.

Ultimately, these mixed intensity burns result in greater diversity of these forests: both at small and large scales.

Furthermore, Odion et al. demonstrate that mixed severity fire regimes were common throughout the northwestern United States prior to U.S. Forest Service intervention. Long-term fire suppression, however, has resulted in less fire adapted ecosystems throughout many regions where disturbance-prone forests used to be present. Thus fire may no longer have the same effects on diversity as predicted, when we are basing these predictions on historical data.

What happens when fire interacts with climate change?

Climate change has and will continue to increase the severity and frequency of ecological disturbance due to fire. Beyond this, climate change is also affecting natural species distributions and exotic species invasions. The co-occurrence of increased fire due to climate change and increased invasions due to climate change may sometimes be disastrous. In western North America, pine bark beetles are ravaging populations of pine trees across several mountain ranges. These beetles caused disturbances in the past but the current epidemic is an order of magnitude worse than prior invasions. Recent research suggests that this increase in severity is due to the increase in air temperature in these mountain ranges. Pine bark beetles reproduce during summer months when the temperature is warm in the northern hemisphere.

Over the past 20 years, air temperature in Colorado has increased by > 1.5 degrees C, resulting in earlier emergence of the pine bark beetle by more than a month. This increased temperature means that pine bark beetles can reproduce twice during a single season rather than once.

Often the effects of even severe disturbance, like the unprecedented pine bark beetle outbreak in the western United States, are dependent upon the forest community that precedes the disturbance. Recent work by Gregory Pec and colleagues, also in PLoS One, demonstrated that forests may sometimes respond positively to pine bark beetle invasion: beetle invaded forests had nearly double the species diversity of their non-invaded counterparts two years after beetle disturbance. However, these same higher diversity bark beetle forests are likely more susceptible to severe fires in the future.

Evolution may provide forests with the tools needed to cope with increased disturbance in a world of constant climate flux. If disturbance removes species that are less resilient to disturbance and more resilient species remain or recolonize, the ecosystem may become more disturbance resistant! Evidence for this type of evolutionary response to changes in disturbance regimes is beginning to emerge. Hollingsworth et al. (2013) found that in Alaska (which has warmed at twice the global average rate over the past 50 years – meaning that it is now 1.3 degrees C warmer, as of 2011, than it was 50 years ago) an increased prevalence and higher severity of fires has resulted in a shift in the community towards species (and functional traits) that are better able to cope with fire. Importantly, these shifts in community composition and functional traits are predicated on the presence of sufficient variation within the community – an assumption that may not be true as populations get smaller and species become more limited in their ability to move around the landscape.

Climate change may directly exacerbate the negative effects of fires via increased greenhouse gas emissions. In 2011, Niboyet et al. demonstrated that the combined impacts of climate change and fire will increase emissions of greenhouse gasses (N2O) from the soil in multiplicative ways. Rising atmospheric CO2 stimulates soil production of N2O, a potent greenhouse gas.

Fire stimulates the release of N2O. When these two processes are combined with nitrogen enhancement, as is the case in many fire driven ecosystems, the result is a six-fold increase in soil N2O emissions.

Under current climate change predictions fire regimes are likely to change rapidly and unpredictably across ecosystems worldwide. These unpredictable changes in fire regime may challenge even forest ecosystems' ability to adapt to climate flux. As the effects of climate change intensify, fire may play an increasingly adversarial role in forest ecosystems, particularly at human-forest interfaces where the results of fire are often devastating. The complex interactions between forest fires and climate make these disturbances an important component of any conversation about global biodiversity and climate change. Coming into the climate change talks in Paris in two weeks, we'll want to see a continuation of these conversations alongside conversations about forest ecosystem degradation and deforestation (so called REDD+ targets).

More information: Dennis C. Odion et al. Examining Historical and Current Mixed-Severity Fire Regimes in Ponderosa Pine and Mixed-Conifer Forests of Western North America, *PLoS ONE* (2014). DOI: 10.1371/journal.pone.0087852

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