Strange bedfellows

"Fires are very old in our ecosystems."

Juli Pausas
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by Natasha Vizcarra

The humble shrub *Banksia media* can be an unsettling sight. After a bushfire, its flowers look like burnt corncobs that have sprouted clams with orange tongues sticking out. These protrusions are actually seedpods that had cracked open in the heat of the fire, an adaptation that took thousands of years to develop and allowed the shrub to thrive in the fire-prone West Australian bush.

Humans tend to think that plants and fires do not mix. But they are old friends, said Juli Pausas, a plant ecologist at the Desertification Research Centre in Spain. "Some plants flower only after a fire, and some develop thicker barks to survive," he said. "Evolution has shaped plants with traits that allow them to reproduce despite fires. This is why we know that fires are very old in our ecosystems."

"Yet, in some places you have more fires than is natural," Pausas said. "And when you depart from natural fire regimes, that's when problems begin."

Scientists are piecing together a global portrait of how fire behaves around the globe, in antici-

A prescribed fire is applied to a *Pinus nigra* stand in Portugal. (Courtesy P. Fernandes) pation of a much larger change in natural fire rhythms. If small disruptions can cause problems, how will larger, more widespread trends like higher global temperatures affect these delicate fire cycles?

A fragmented view

Plants and flames make fascinating, albeit counterintuitive, bedfellows. Caroline Lehmann, a lecturer in biogeography in the University of Edinburgh, remembers the bushfires near her childhood home in Sydney, Australia. "I remember walking through the bush three months after an incredibly intense fire," she said. "The bush was green, none of the trees had died, and I was like, 'What's going on here?'"

This is why many who study the behavior of fire also study the plants that these fires burn. Fire and plant ecologists read tree rings, collect plant specimens, and map plant species and wildfire zones. They observe how different plants and trees react to fires. "In the past, research on fire has been ecosystem-specific and as a consequence, regionally fragmented," Lehmann said. "For instance, some people studied the Ponderosa pine systems of the western United States, or they might specialize in the eucalyptus savannas of northern Australia. Historically, researchers have developed their ideas of fire from working in different regions quite independently."

Savannas, for example, love fire. "They are dominated by a contiguous layer of grass and a discontinuous overstory of trees," Lehmann said. This means savannas are always bathed in sunlight. The climate is hot and the grasses cure and ignite easily. "Savanna grasses grow rapidly and can sustain fire often, perhaps every year to every five years," she said. Tropical forests are the opposite. Dense tree canopies keep the understory dark. The climate is humid, which also keeps the understory moist. "It is difficult to light a fire in that environment," Lehmann said. "The fuel—in terms of what will sustain a fire—is simply too wet."

But there has been a growing need to look at fire patterns in larger geographic areas, across biomes and ecosystems, because of potential changes in climate patterns. Just as climate shapes vegetation and fire shapes vegetation, a changing climate will eventually alter patterns of fire. Researchers have tried to get a bigger view of fire by using aerial photography to examine historical fire scars. Now they are turning to images and data from Earth observing satellites. "It's mind blowing that now we can talk about these relationships at a global scale," Lehman said. "Coming to grips with a global picture of fire can't be undervalued."

The flammable middle ground

Like Lehmann, Pausas is one of those pursuing a global theory of fire. In a 2007 study, Pausas and colleague Ross Bradstock of the University of Wollongong found that fires in southeast Australia frequent a sort of middle ground in the productivity spectrum. On one end are unproductive ecosystems like arid deserts and tundra, and on the opposite end are highly productive systems like tropical rainforests. They found that fire favors ecosystems in the middle of this spectrum, where it is wet enough for some vegetation to grow but dry enough to accommodate fires. Now, he wants to know if satellites can see this pattern all over the globe.

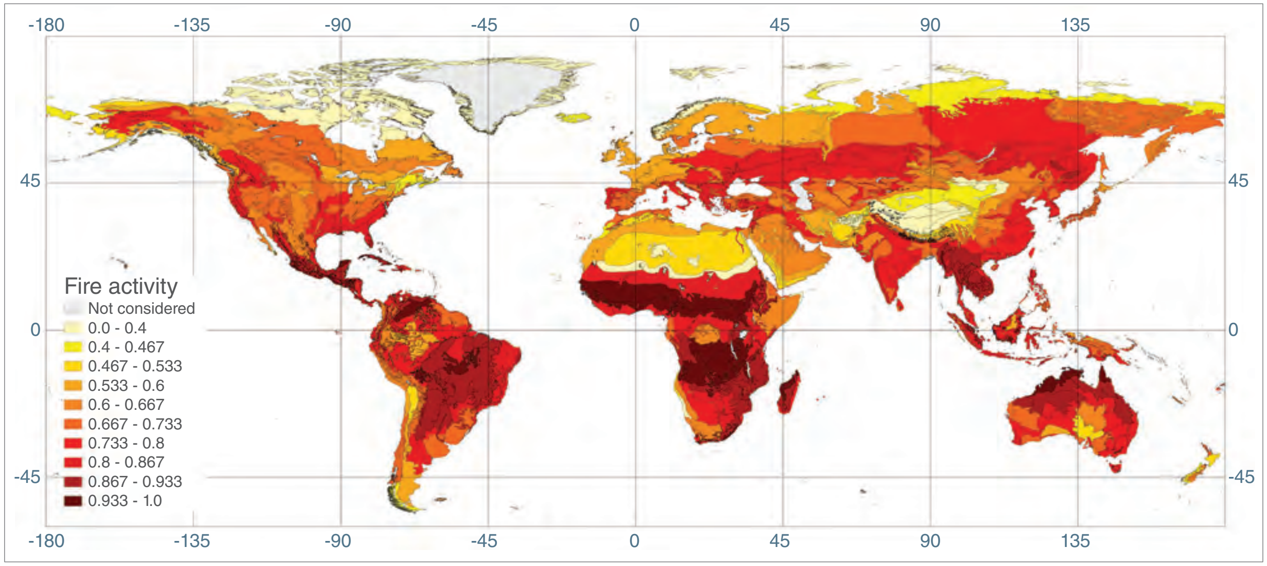
"We want to understand how productivity in ecosystems influence fire activity on a global scale," Pausas said. The lushness or scarcity of plants in an area affects how often wildfires occur and how intensely they burn. More importantly, it tells scientists how sensitive an ecosystem might be to droughts or unusually hot summers.

This photograph shows *Banksia media* before and after a fire. (Courtesy B. Miller, left, and S. Walsh, right)

Researchers have used remote sensing data to look at Earth's fire and vegetation balance, some dividing Earth into grids with squares a few kilometers wide and some partitioning the globe into its major biomes. The problem with the first approach, Pausas said, is that the grid is a very artificial system. "You can't see biological boundaries between grid squares," he said. A single square could contain two areas similar in fire activity, but totally different plant types and plant coverage. "It limits understanding of the patterns we might find," Pausas said. Biomes, like deserts, forests, grasslands, and tundra, are also too big. "Each biome contains lots of variability," Pausas said. "They are very large and span different continents."

A new fire map

Pausas turned to a smaller scale. He divided Earth into ecoregions, which contain roughly



The image above shows a new ecologically-based global fire map derived from fire activity data, Net Primary Productivity (NPP) data, and Normalized Difference Vegetation Index (NDVI) data. The color intensity in each ecoregion represents an ecoregion's fire activity index (from 0 to 1, unitless). The NPP data set was developed by Marc Imhoff, former Terra project scientist at the NASA Goddard Space Flight Center, and colleagues. (Courtesy J. G. Pausas and E. Ribeiro, 2013, *Global Ecology and Biogeography*)

the same kind of vegetation, climate, and fire rhythm, and excluded areas like Antarctica that lacked burnable vegetation. "It's an easier and statistically powerful way to study patterns," Pausas said.

Using this scale, he plotted how many fires burned in each ecoregion by using fire activity data from the NASA Fire Information for Resource Management System. Pegging each ecoregion's productivity level was trickier. To find out the lushness or scarcity of vegetation for each ecoregion, Pausas used Net Primary Productivity (NPP) data from the NASA Socioeconomic Data and Applications Center. NPP data map an area's net solar energy, converted to plant organic matter through photosynthesis. Pausas then double-checked productivity levels by comparing the NPP data with Normalized Difference Vegetation Index (NDVI) data, a measure of Earth's greenness from space. And to tease out the relative role of fuel and climate on fire activity, Pausas sought aboveground biomass data and climatic data from other sources.

The result is "a new, ecologically-based global fire map," Pausas said. It shows that fires occur in nearly all of the world's ecoregions. Fire activity peaks in tropical grasslands and savannas, and significantly decreases in arid deserts and moist tropical rainforests, confirming his hypothesis. Curiously, the highest rate of fire activity did not register right smack in the middle of the productivity scale as he expected. These would have been areas like the sprawling savannas of Africa and Australia and the dry tropical forests in southern Mexico, central India, Madagascar, and South America. Instead, many fires happened closer to the high productivity end, where one might find denser savannas or thinning tropical forests.

Oil and water

Pausas has a few theories. First, fire suppression practices in temperate coniferous forests, like those in the United States, may have contributed to the skewed pattern. Not enough fires are happening in areas that are historically adapted to more frequent fires. Pausas also thinks that deforestation has increased fire activity in tropical rainforests. Lehmann said, "At this stage, humans are driving the change in the instances of fire in the tropical region." Deforestation allows more flammable grasses and woody plants to invade cleared areas while human activity provides an ignition source. "Historically, tropical forest systems burned very, very infrequently," Lehmann said.

Overall, the map suggests that in addition to human-caused fires, a scenario of higher global temperatures will make lush subtropical forests and temperate forests even more vulnerable to an increase in wildfires. "It's much easier to increase fire in a wet ecoregion with lush vegetation than in a dry region," Pausas said. "That the sensitivity of fire to high temperatures is much stronger in high-productivity areas implies that small changes in temperature have a much higher effect on fire activity in high-productivity areas."

A warmer Earth also means more droughts. In wet tropical forests, a change in temperature can influence how moisture evaporates from the land, which in turn influences rainfall patterns. "We may find that we have an increasing frequency of droughts in those systems," Lehmann said.

"Drought in this closed canopy system causes trees to die and fall over; this will allow the vegetation to dry out and create spots where fire can ignite and spread."

Pausas' map shows that fire has already begun to spread from fire-friendly biomes like savannas to tropical forests. Whether tropical forests can adapt quickly enough to become fire-friendly regions is the million-dollar question. "Tropical forests and tropical savannas are essentially like oil and water," Lehmann said. "Forests and savannas are systems that can't mix because the properties that are fundamental to each vegetation type are just so different. Plants in each ecosystem have adapted to their climate and fire conditions over tens of thousands of years. We are changing that very quickly."

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About the data

Satellite	Terra	
Sensor	Moderate Resolution Imaging Spectroradiometer (MODIS)	
Data sets	Global Active Fire Data	Global Patterns in Net Primary Productivity
Resolution	0.5 degrees	0.25 degrees
Parameters	Global fire activity	Net primary productivity
Data centers	Fire Information for Resource Management System (FIRMS)	NASA Socioeconomic Data and Applications Center (SEDAC)

About the scientists

Caroline Lehmann is a lecturer in biogeography in the School of GeoSciences at the University of Edinburgh. Her research focuses on the ecology and evolution of tropical ecosystems and plant-fire coevolution. Australia's Macquarie University supported her research. (Photograph courtesy C. Lehmann)

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References

Imhoff, M. L., and L. Bounoua. 2006. Exploring global patterns of Net Primary Production carbon supply and demand using satellite observations and statistical data. *Journal of Geophysical Research* 111, D22S12, doi:10.1029/2006JD00737.

Lehmann, C. E. R. et al. 2014. Savanna vegetation-fire-climate relationships differ among continents. *Science*, 343: 548, doi:10.1126/science.1247355.

NASA Fire Information for Resource Management System. Global active fire data. College Park, Maryland, USA. https://earthdata.nasa.gov/data/near-real-time-data/firms/active-fire-data.

NASA Socioeconomic Data and Applications Center. Global Patterns in Net Primary Productivity. Palisades, New York, USA, doi:10.7927/H40Z715X.

Olson, D. M., et al. 2001. Terrestrial ecoregions of the world: A new map of life on earth. *Bioscience* 51, 11: 933–938.

Pausas, J. G. and Ribeiro, E. 2013. The global fire–productivity relationship. *Global Ecology and Biogeography* 22: 728–736. doi:10.1111/geb.12043.

Pausas, J. G. and Bradstock, R. A. 2007. Fire persistence traits of plants along a productivity and disturbance gradient in Mediterranean shrublands of SE Australia. *Global Ecology and Biogeography* 16: 330–340.

For more information

NASA Socioeconomic Data and Applications Center (SEDAC)
http://sedac.ciesin.columbia.edu

NASA Fire Information for Resource Management System (FIRMS)
http://earthdata.nasa.gov/firms

Global Patterns in Net Primary Productivity
http://sedac.ciesin.columbia.edu/data/set/hanpp-net-primary-productivity