Assessing the impact of hurricanes on Puerto Rico's forests

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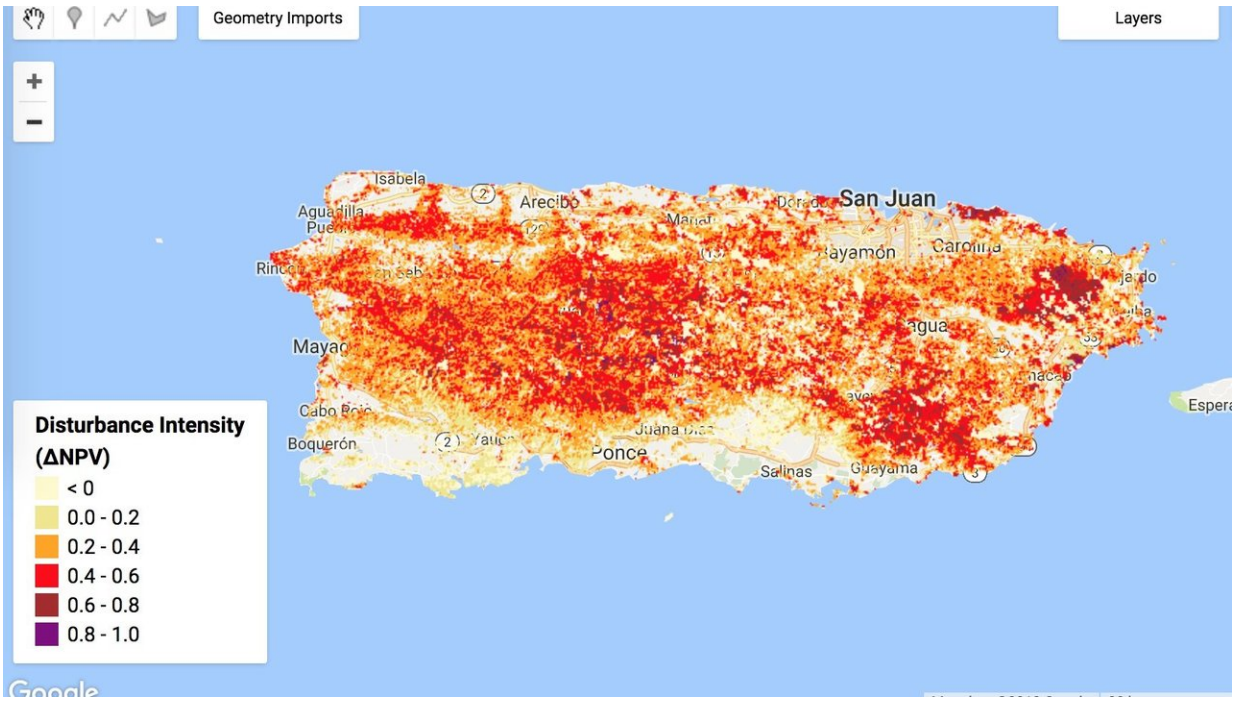

This map of Puerto Rico shows highest forest damage and tree mortality impact areas in with darker tones of red indicating more intense forest disturbance as tree mortality and crown damage. Grey areas represent non-forested areas or areas with cloud cover. Credit: Lawrence Berkeley National Laboratory

Building on methods they used to assess the impact of hurricanes such as Katrina, Gustav, and Rita on forests and tree mortality, scientists at the Department of Energy's Lawrence Berkeley National Laboratory

(Berkeley Lab) have produced a rapid mapping of the disturbance intensity across Puerto Rico's forests with the help of Google Earth Engine.

Battered by two intensely powerful storms with sustained wind gusts of more than 150 miles per hour last year – first by Hurricane Irma and then by Hurricane Maria – Puerto Rico suffered widespread and catastrophic damage to its urban infrastructure. Using satellite images combined with image processing techniques, a team led by Jeffrey Chambers, an expert in forest biogeography, found extensive ecological damage as well.

The researchers assessed the damage by looking at changes in the surface reflectance of both visible and invisible light. While the human eye can discern colors in the visible spectrum, by also measuring the spectral response of the surface in reflective infrared light a far more precise picture is provided of impacts to forest vegetation.

"We look for a change in the spectral signature from before and after the storm," said Chambers, a scientist in Berkeley Lab's Earth and Environmental Sciences Area as well as an associate professor of geography at UC Berkeley. "When the sunlight bounces off green vegetation it looks one way, and when it's bouncing off vegetation where the leaves are all stripped off or trees have toppled it's very different. We find dramatic changes in the spectral signature of the forests associated with damage, tree mortality, uprooted trees, stripped leaves, and canopies."

A preprint of their study, "Hurricane Maria Impacts on Puerto Rican Forests," has been published online. "Mapping disturbance impacts and publishing results can take years," said Yanlei Feng, a UC Berkeley graduate student in geography who is the study's first author. "This new approach employing the Google Earth Engine platform enables the

delivery of data products that are more timely; for use in hazard assessments, for example."

The researchers estimate that 23 to 31 million trees may have been killed or severely damaged by Hurricane Maria but note that field investigations are required to attain more accurate estimates. A similar analysis they conducted after Hurricane Katrina estimated that 320 million trees died or were severely damaged in Mississippi and Louisiana.

Why study tropical forests?

Forests cover about 54 percent of Puerto Rico, and they are the only tropical forests in the United States outside of Hawaii. However, unlike Hawaii, which has few native tree species, Puerto Rico's forests are much more diverse, with hundreds of species.

Berkeley Lab has been studying Puerto Rico's forests for several years as part of the Department of Energy's Next Generation Ecosystem Experiments-Tropics (NGEE-Tropics) initiative, a multi-institutional project launched in 2015 and led by Berkeley Lab. "One of our goals is to demonstrate that tropical forests are important to the U.S.," Chambers said.

Studying and understanding forest disturbances is important for many reasons, including natural resource management, watershed protection and impacts on soil erosion, and examining the direct effects of tree-falls on the energy distribution grid. Tropical forests are especially important because, even though they cover only 7 percent of the Earth's surface, they contain the largest vegetation carbon stocks, and are also important carbon sinks.

As part of NGEE-Tropics, Berkeley Lab has been studying the forests in

Puerto Rico as a pilot study site to help improve modeling of the Earth system. "Fluxes of water, energy, carbon, and the biogeochemical cycling of nutrients are all highest in the tropics," Chambers said. "So if you want to build an accurate Earth system model, you've got to get the tropics right."

Advanced image processing

The Berkeley Lab researchers looked at images from Landsat 8, a satellite that takes detailed images of the entire Earth every 16 days, comparing images from before and after the hurricanes and eliminating effects due to clouds and shadows.

Data is collected by Landsat 8 as images of 30-square meter pixels. The researchers quantified the spectral signature of each forested pixel before and after the storms to determine the change in the fraction of the surface that is considered non-photosynthetic vegetation. They found that the damage was not evenly spread across the island's forests.

"The intensity of the spectral shift varied a lot across the island," Chambers said. "Now we want to better understand why some forests were more vulnerable than others, and what factors controlled the differences in how forests were impacted. Was it the species, was it the slope, was it the aspect – whether you're on the windward or lee side as the storm is rotating counterclockwise? The soil type and rooting depth are also important factors."

For example, cypress and tupelo trees in Louisiana weathered Hurricane Katrina just fine. "The oak trees right next door all went down," Chambers said. "Cypress trees have buttressing and rooting structures which confer resistance to wind."

Carbon source or carbon sink?

Forests remove carbon dioxide from the atmosphere by photosynthesis. When storms, fires, or other disturbances kill a great number of trees, the dead biomass is decomposed by fungi, insects, and the like, releasing carbon dioxide into the atmosphere. When tree mortality is especially high, a forest can go from being a carbon sink to a carbon source.

But Chambers points out that it can take decades for a tree to decompose and emit all its carbon. "All forests are disturbed every year at some background rate; carbon cycle changes occur if this background rate increases as storms become more frequent or intense," he said. And Puerto Rico has experienced devastating hurricanes before, including the 1928 San Felipe Segundo hurricane, which was even stronger than Maria, as well as hurricanes Georges in 1998 and Hugo in 1989.

Another recent NGEE-Tropics study found Puerto Rico's subtropical dry forests will remain resilient to hurricanes. However, if hurricane frequency increases significantly, forests will not have enough time to regenerate. "If the return frequency of a disturbance increases, you can get long-term decline in total carbon storage," Chambers said.

More information: Yanlei Feng et al. Rapid remote sensing assessment of impacts from Hurricane Maria on forests of Puerto Rico, *PeerJ* (2018). DOI: 10.7287/peerj.preprints.26597v1

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