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In the Eye of the Storm: Warmer Temperatures Affect Tropical Forest Recovery Following Hurricane Disturbance

Tana E. Wood[1*], Molly A. Cavaleri[2], Sasha C. Reed[3], Jennifer Pett-Ridge[4], Karis McFarlane[4], and Xaiojuan Yang[5]

[1] USDA Forest Service, San Juan, PR;
[2] Michigan Technological University, Houghton, MI;
[3] US Geological Survey, Moab, UT;
[4] Lawrence Livermore National Laboratory, Livermore, CA;
[5] Oak Ridge National Laboratory, Oak Ridge, TN

Contact: tanawood@fs.fed.us

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Hurricanes affect nearly every continent in the world and are among the most intense weather disturbances in forest ecosystems. In 2017, the coastal United States (US) and Puerto Rico were devastated by a series of major hurricanes that caused more than $200 billion in damages, the effects of which will have long-lasting implications for the economics and natural resources of US forests. At the same time, models project that temperatures in the tropics and subtropics will increase by 3-5ºC within the next 20 years. The combined effects of hurricane disturbance and warmer temperatures could fundamentally alter the trajectory and duration of forest recovery following disturbance, resulting in altered ecosystem states that are difficult to predict from historical data alone. Yet, despite both the immediate and significant effect of hurricanes on forest carbon (C) and nutrient stocks, as well as the potential to affect the long-term trajectory of forest C cycle recovery, hurricanes are not currently represented in Earth System Models (ESMs), and no studies have captured the potential interactions of hurricanes within the context of a changing climate. Here, we capitalize on a once in a century opportunity to investigate responses of key C cycling processes to experimental warming in the wake of two major Hurricanes within the Luquillo Experimental Forest in Puerto Rico. We conducted 12 months of field-level understory warming using infrared heaters arranged in six 4-m diameter plots (three +4°C heated and three control) as part of the Tropical Responses to Altered Climate Experiment (TRACE). We investigated effects of warming on soil respiration, root specific respiration, photosynthesis, and foliar respiration of understory shrubs as well as changes in root biomass and production. After one year of warming, Hurricanes Irma and Maria struck the island of Puerto Rico. We then followed forest recovery for 1-year following hurricane disturbance.

After 8 months, warmed plants showed increasing signs of stress, where increases in photosynthetic temperature optimum (T*opt*) were less pronounced and optimum photosynthetic rates (A*opt*) declined. Root specific respiration was significantly lower in warmed plots after 6 months of warming, demonstrating rapid acclimation to increased temperatures. At the same time, root biomass was significantly reduced but root production was not affected. Soil respiration rates were significantly higher in warmed plots. Overall, these results suggest that tropical understory plants will take up less carbon dioxide (CO_2) in a warmer world, but may also respire less CO_2 via roots, likely due to reduced belowground C allocation. While soil respiration rates increased significantly in warmed plots, root biomass was lower, suggesting increases were microbially-driven. Results could indicate a shift towards a net negative C balance in tropical forested ecosystems as global temperatures increase. Following hurricanes Irma and Maria, root production was initially reduced in warmed relative to control plots.

Interestingly, root specific respiration patterns reversed, with high root specific respiration in warmed relative to control plots. In addition, understory vegetation height was approximately 20 cm shorter in warmed relative to control plots after one year of forest recovery. These initial responses of the warmed plots to hurricane disturbance could be a consequence of reduced C cycling in warmed plots prior to disturbance.