frontiers in Ecology and Evolution

OPINION
published: 05 June 2018
doi: 10.3389/fevo.2018.00068

Increasing Humidity Threatens Tropical Rainforests

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Keywords: leaf temperature, humidity, plant apparent temperature, climate change, transpiration, stomatal conductance, tropical forests

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Specialty section:
This article was submitted to Biogeography and Macroecology, a section of the journal Frontiers in Ecology and Evolution

Received: *26 January 2018*
Accepted: *02 May 2018*
Published: *05 June 2018*

Citation:
Perez TM and Feeley KJ (2018) Increasing Humidity Threatens Tropical Rainforests. Front. Ecol. Evol. 6:68. doi: 10.3389/fevo.2018.00068

Li et al. (2018) discuss how global climate change is leading to faster increases of human-perceived temperatures (apparent temperature; T_{AP}) than air temperatures (T_{air}), and that the predicted increases in T_{AP} relative to T_{air} is fastest in the tropics. While Li et al. (2018) highlight how increasing T_{AP} will lead to greater thermal discomfort and contribute to the substantially higher temperature-related mortality of humans, it is also important to consider how rapid increases in T_{AP} will affect non-humans. In particular, global warming may lead to especially rapid increases in leaf temperatures (leaf temperature; T_l) potentially leading to decreases in growth rates and higher mortality in plants.

Leaf temperatures are a function of both the environment and the physiological characteristics of leaves that influence plant thermoregulation. Although several physiological traits act synergistically to influence leaf temperature, transpiration is a primary component of leaf thermoregulation that regulates heat dissipation (Lin et al., 2017). When transpiration rates are low, T_ls can rise several degrees above ambient air temperature and beyond the optimal temperatures for photosynthesis (Doughty and Goulden, 2009; Leigh et al., 2012; Slot and Winter, 2017b). Extreme leaf temperatures can cause photosynthesis to cease, and in some cases, lead to permanent damage of photosynthetic machinery (Krause et al., 2010). Ultimately, the impairment of photosynthesis can diminish the capacity for carbon fixation, lead to decreased plant growth rates, and even death.

The ability of plants to transpire, and hence dissipate heat, is highly dependent on available soil moisture and atmospheric vapor pressure deficit (which is itself dependent on relative air humidity) (Damour et al., 2010). Under dry soil conditions, plants may close their stomata in order to limit water loss, and the resulting reduction in transpiration can lead to marked increases in leaf temperatures (Oren et al., 1999). Conversely, plants can maintain open stomata when soil moisture is not limited (Tibbitts, 1979). However, high relative humidity decreases the leaf-atmosphere vapor pressure gradients that reduce the efficacy of transpiration—again leading to higher T_l (Tibbitts, 1979). Soil and atmospheric moisture will both be affected by future global climate change, either directly through changes in precipitation patterns or indirectly though changes in temperatures. In other words, deleteriously high T_l may become more frequent in some species because of drought conditions or high humidity, causing carbon starvation or photosynthetic thermal damage, respectively.

If the greatest increases in T_{AP} and humidity occur within tropical latitudes as Li et al. (2018) suggest, then tropical forests and their constituent plants are likely to face increasing thermoregulatory challenges. Tropical plant species tend to have large leaves with small boundary layer conductances and they rely heavily on transpiration to avoid lethal high leaf temperatures (Wright et al., 2017). By reducing the efficacy of transpiration, future increases in relative humidity may edge the T_l of many tropical plant species' upwards and beyond the thermal limits of photosynthesis. If T_l's are increasing as Li et al.'s (2018) findings suggest, then photosynthetic thermal stress may contribute to the decelerations in tree growth observed in some parts of the tropics. Several studies have documented decelerating tree growth in tropical forests. These decreases in growth are typically hypothesized to be caused by increased respiration due to elevated nighttime temperatures or the increased frequency and severity of droughts (Clark et al., 2003; Feeley et al., 2007; Brienen et al., 2015). Another potential explanation is that if tropical plants were already operating close to their thermal limits of photosynthesis (Doughty and Goulden, 2009; Krause et al., 2010), global warming may be causing thermal damage to photosynthetic machinery. This physiological mechanism for the deceleration tropical tree growth deserves further exploration.

Increased respiration as the hypothesized physiological mechanism for decelerating tree growth was developed from observational studies, but has received limited experimental support (e.g., Cheesman and Winter, 2013; Slot and Winter, 2017a). To reconcile the results from observational and experimental studies, additional mechanisms such as photosynthetic thermal stress should be evaluated for their effects on tree growth and fitness. Given the importance of the many ecosystem services provided by tropical ecosystems and plants (e.g., the provisioning of food, timber, and non-timber products, as well as carbon capture and sequestration) the dangers imposed by rapidly rising temperatures, and even more rapidly rising plant apparent temperatures, are cause for serious concern.

AUTHOR CONTRIBUTIONS

TP and KF conceived of the study and wrote the manuscript.

ACKNOWLEDGMENTS

The authors are supported by the US National Science Foundation 128 (DEB-1350125 to KF).

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The reviewer SBZ and handling Editor declared their shared affiliation.