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Biogeosciences Discussions

Interactive comment on "Understanding Tropical Forest Abiotic Response to Hurricanes using Experimental Manipulations, Field Observations, and Satellite Data" *by* Ashley E. Van Beusekom et al.

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RC1: Van Beusekom et al. present measurements of the forest abiotic environment following experimental and natural disturbances in the Luquillo forest in Costa Rica [sic, should be Puerto Rico] over a period of 16 years. They use this information to assess the recovery time of different variables. Measurements such as these can provide valuable insights into the mechanisms which govern a particular ecosystem response – particularly when combined with measurements or modelling of plant responses. The paper is clearly written and presented, and the measurements are well-described and,

as best as I can judge, appropriately controlled for changes in measurement technique. However, the key to the story of the paper is the definition of recovery time, and this appears to be somewhat arbitrarily defined with significant consequences for the results. On this basis, I cannot recommend the paper for publication in its current form.

Recovery time is defined in the paper as the point when the treated data timeseries crosses the control data timeseries and afterwards stays within 15

The choice of x and y is also critical, however. x=15

Even if one just eyeballs the plots, whilst one can be fairly confident about recovery for solar radiation, for throughfall it is much less clear (there is even divergence in 2014 following the supposed point of recovery, making it questionable whether recovery had even occurred). The definition of recovery time therefore needs some careful thought and sensitivity testing to give confident that the results are robust to the method used.

AUTHORS: We agree that recovery is an arbitrarily defined point, saying in the Introduction "This study attempts to quantify abiotic response as acute changes from a hurricane disturbance (experimental or otherwise) and recovery from the changes, for primary and secondary factors. Quantifying the responses makes it possible to assess if the experimental trimming data and satellite data are reasonable sources for studying the effect of hurricane disturbance and appear to be measuring the same abiotic system, as well as appreciate if different events cause substantially different responses. This study does not attempt to determine what amount of recovery is considered 'normal' conditions to biotic life, or in other words what would affect tertiary factors, but instead quantifies changes in the abiotic factors that can be used to frame the changes found in biotic factors post-hurricane in many previous studies including those of biotic abundance (Shiels et al., 2015), soil biochemistry (Arroyo and Silver, 2018), and plant reproduction (Zimmerman et al., 2018)."

We added a paragraph in the beginning of the Methods to explain the reasoning for the recovery metric. "The LOESS degree of smoothing is contingent on the size of

the local neighborhood, which here was always chosen to be one year of data around each point. The yearly smoothing was done to extract the larger signal from the data and to homogenize the different collection intervals of the data. The automated sensor field data captured larger amounts of background noise than the temporally smoothed rain funnel data and the geographically smoothed satellite data; and to a lesser extent, the geographically smoothed soil sample, litterbag, and canopy photo data. The one-year smoothing neighborhood was chosen to be longer than the longest length of time between repeat measurements across all data types and methods.

Calculations for abiotic responses were made on the resulting time series with the one-year smoothing. Recovery after a CTE experiment was defined as the point in time that the treated data time series crosses the time series of the control data, afterwards which the difference between the treated and control data stays within 15% of the control data for a year, or until the next event. This could be a conservative measure for biotic recognition, but from an abiotic point of view the 15% measure corresponds with visual recovery in the time series. Other studies have defined recovery as the year in which the annual maximum value (of the disturbed area) returns to a previous annual maximum value (assumed representative of undisturbed conditions; Lin et al., 2017). While the method used here is dependent on the size of the smoothing neighborhood; it is able to make use of the parallelly collected control data to calculate more precise recovery lengths than a year. Furthermore, in a frequently disturbed regime such as the LEF, it is difficult to say what year would be representative of undisturbed conditions. Time series were also analyzed to calculate acute change from disturbance. The acute change after the hurricane was defined as the change in the control time series or the satellite time series from right before the hurricane to right after the hurricane, September 20, 2017. The acute change after an experiment disturbance event was defined as the maximum difference between the treated and control time series (in relation to the control time series) on any day between the last day of the canopy trimming (spring 2005, December 2014) and of the next September 20 (year 2005 and 2015, respectively), so that the experimental changes could be compared

to the hurricane changes. Sensitivity tests were performed to see how the calculated recovery lengths and disturbance changes differed with smaller and larger smoothing neighborhoods than the one year. “

We have also now reported the results of the sensitivity tests, as suggested. The recovery times and disturbance changes reported in the Table results are for the most part robust against smoothing amounts. In the results, it says “Sensitivity tests were performed using LOESS smoothing neighborhoods from half as large to twice as large. The calculated recovery times are very robust to altering in the size of the neighborhood, with a mean of less than $\pm$0.2 years for any neighborhood size. Larger neighborhoods than the one-year reported in Table 1 disproportionally effect the calculated recovery times of the coarser data, throughfall and CTE1 litter saturation (Figures 1b, 2e). Smaller neighborhoods than the one-year reported in Table 1 disproportionally affect the calculated recovery times of the noisier data and the data with many missing observations, throughfall and CTE1 air and soil temperatures, respectively (Figures 1b-d). The calculated changes after an experimental disturbance event are fairly robust to altering the size of the neighborhood (absolute changes are on average less than $\pm$15% different), but the calculated changes after the hurricane can be quite affected if the neighborhood is expanded, making the time series smoother at the end points before and after the hurricane (Figures 1, 2).”

We also added some discussion around this, saying “The results in the sensitivity tests showed that quantifying recovery times using smoothed time series to homogenize data from several sources was a worthwhile effort, in that the abiotic factors can be sorted into quicker and slower recoveries, with results robust to the smoothing method. However, the definition of the ‘recovered point’ in time will be dependent on what biotic life considers ‘normal’, necessarily different for every organism. This study used a set metric of ‘within 15% agreement between control and treated plots’ once the experimental response is finished, in order to quantify the length of abiotic recovery as a starting point to for other researchers to frame the changes found in biotic factors

post-hurricane. The quantification of the acute changes in the experimental setup is useful as a measure of the effect of a hurricane on the abiotic environment, while the quantification of the acute changes from the actual hurricane serves best as a comparison between the field and satellite data, and between the CTE and hurricane relative effects on each abiotic factor. “

RC1: Minor comments: Line 94. Were Campbell sensors used after 2015 as well? In the previous paragraph it indicates not, but here that they were.

AUTHORS: Campbell temperature 107 sensors were only used before 2015, and after 2015, soil VWC was measured by CS616 sensors, which are also made by Campbell. We changed the wording in this paragraph to refer to the sensors as ‘107 sensors’ instead of Campbell sensors to avoid this confusion.

RC1: L187. Is this really resilience? There is presumably just less vegetation to be disturbed, which naturally leads to a smaller fluctuation. I would argue it just leads to lower amplitude of variability.

AUTHORS: We clarified this statement, pointing out that the treated plots are closer to recovery after the hurricane than the control plots are. “The passage of hurricane María, 2.8 years after the second experiment, showed a smaller effect on the treated plots than the control plots, such that the absolute level of abiotic disturbance on the treated plots was smaller than on the control plots (Figures 1, 2). It is expected that the abiotic fluctuations from the hurricane would be smaller in the unrecovered treated plots than in the control plots since there is less vegetation to disturb. The fluctuation is smaller, but furthermore for most of the abiotic factors, the treated plots are closer to the recovered state after the hurricane than are the control plots. For example, there is more solar radiation reaching the forest floor in the treated plots than in the control plots before hurricane María, but after the hurricane there is less solar radiation reaching the forest floor in the treated plots than in the control plots (Figure 1a). The same scenario can be seen in the throughfall (Figure 1b), the temperatures to a lesser extent

(Figures 1c,d), the soil moisture profile (Figure 2c), and the litter saturation (Figure 2e). The relative humidity has the opposite scenario, showing treated plots closer to the recovery state of less relative humidity after the hurricane (Figure 2a).

RC1: L188. “greater disturbance” is not clear. Perhaps, “greater fluctuations in the measured abiotic variables due to disturbance”?

AUTHORS: Changed to “larger abiotic fluctuations due to disturbance”.

RC1: L190. What exactly does it mean that “tree demographics were . . . dynamic”? Does this refer to the mix of ages in the forest, the rate of growth, the rate of turnover?

AUTHORS: All of the above. We added an explanation “(the rates of species and stem mortality and growth)”

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