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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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RC2: General Comment This study integrated the observations both from in-situ and satellite platform for studying the dynamics of vegetation change in Luquillo Experimental Forest. Two canopy trimming experiments, one in 2004 and another in 2015, were designed as control experiments to reveal the vegetation recovery in response to the wind damage to the trees, especially for the case caused by the tropical storms (Irma and Maria) in 2017. The authors reported long term and continues time series of under-canopy solar radiation, throughfall, air temperature (under and above), soil

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water, and relative humidity and leaf saturation in the manuscript. This work can provide an insight into the vegetation recovery due to the wind disturbance in the tropical climate zone. However, the structure of the manuscript and approach for analysis the data are a bit confusing. I suggested that the authors provide a general review of the vegetation recovery in the introduction section and try to focus on the study results for the tropics. Here, I provided a few studies (listed in the reference) including observation and modeling works which are relevant for providing a general review of the wind disturbance research. The introduction of the canopy trimming experiment can move to the methodology section which can be the design of canopy trimming and natural disturbance events. Along with this discussion, the method applied for this study to identify the recovery period is questionable, and the authors didn't include or calculate the uncertainty caused by instruments, sampling approaches, or data analysis (smoothing). Regarding the issue for identifying the recovery period, I recommended the authors to analysis the annual maximum observations, for example the study made by Lin et al. (2016). By comparing annual maximum values over a long-term time series is helpful to identify the status of vegetation recovery period. I had several specific comments for the authors to improve the current version of this manuscript.

AUTHORS: Thank you for your detailed comments. We address those below. We moved the description of the experiment to the methods and we have also added the Mitchell (2013) reference in the introduction. We have greatly expanded the methodology description of the recovery metrics (with added results), citing Lin et al. (2016) as discussed under the comment 8. The papers on windthrow modeling and tree mortality do not seem to be on topic as we are concerned with the abiotic environment and not the geographical extent of the disturbance.

RC2: Specific comments 1.Using the measurement of wetness of litter leaves and soil water to understand the canopy recovery physically is not reasonable. Although the wetness of litter leaves and soil moisture can be affected by the coverage of the overstory canopy, the magnitude of soil moisture and litter leaves are fixed which might only depend only on the soil property and leaf types. Please explain how to use the observation of soil moisture and wetness of litter leaves to reveal the status vegetation recovery.

AUTHORS: We are not attempting to understand canopy recovery, but instead how the forest abiotic environment responds to the vegetation recovery, and when the abiotic environment is recovered to its pre-hurricane state. We added this sentence in the introduction "More than understanding when vegetation has recovered, it is important to understand how the abiotic environment affected by the vegetation changes recovers from the disturbance." We agree that the timeline of soil and litter moisture recovery very much depends on the types of soil and leaves involved. We are focused on the response, not the specific timeline. This comment has been added to the discussion in the section talking about the soil and litter patterns: "Specific timelines for recovery would be expected to be highly influenced by the tree species and soil types, and the rates seen here for all abiotic factors would not necessarily apply to all hurricane-effected tropical forests. Nevertheless, general patterns might be expected to hold." We have pointed out that similar patterns to the litter saturation response patterns seen here were also presented in Southeastern United States.

RC2: 2.P2L61: (wetness of canopy and litter leaves) How to determine the wetness of canopy leave and litter leaves.

AUTHORS: This is discussed in the methods, "Leaf saturation data were collected after 2015 by Decagon Devices dielectric leaf wetness sensors in the canopy leaves 5 m up from the ground and in the litter leaf layer."

RC2: 3.P3L79: "locally to the points", Can you show the original points in your results?

AUTHORS: We have added the points to the plots.

RC2: 4.P3L90: The MODIS only measured the sink temperature of the surface. Why did the authors compare the air temperature observations to the MODIS LST observations?

AUTHORS: We compared to see if any of the forest cover change seen in the field observations of temperature (above and below canopy) were comparable to the LST. We clarified this in the methods, saying "MODIS LST measures energy balance at the land surface, so is not representative of air temperature under the canopy but it will be affected by changes in air temperature. Annual maximums of LST and air temperature are highly correlated across the globe with correlation strongest in forested areas (Mildrexler et al., 2011), and LST has been shown to respond to forest cover changes in other areas of the tropics (van Leeuwen et al., 2011)." Again in the discussion, we clarified "The (MODIS LST-estimated) temperature satellite data plot between the field air temperature data measured below the canopy and that measured above the canopy at 30 m (black and gray lines respectively, Figure 1c), giving evidence that the satellite measurements were affected by a vertically averaged Earth, as might be expected from a LST representative of surface energy balance."

RC2: 5.P3L92: How many 5TM sensors were deployed for soil water observation? What is the minimum requirement for avoiding the spatial heterogeneity under canopy at this study site?

AUTHORS: We use several sensors in each of the 6 plots to avoid this problem. We added the number of sensors to each paragraph in the methods, for each type of sensors. At the beginning of the methods, we now explain "To account for spatial heterogeneity under the canopy, multiple sensors were used in each plot were used and the results were averaged in all control and treated plots (with quality control)."

RC2: 6.P4L115-L124: Too many details were lost or cannot be found. For example, the relationship between the 8-day MODIS LAI and 8-day in-situ solar radiation was built up for converting the MODIS LAI to solar radiation for the study site, but the authors didn't present this information and uncertainty.

AUTHORS: We clarified this section by expanding description to "The Beer-Lambert law (Monsi, 1953) was used to convert the LAI data into solar radiation estimates. Annual patterns of photosynthetically active radiation (PAR) extinction coefficients needed for the Beer-Lambert law were calculated by solving the Beer-Lambert Law for the coefficients with the field-measured control plot solar radiation, and the field-measured above canopy solar radiation, and the MODIS LAI data. The coefficients were solved for using with all data interpolated or averaged to daily values, and only using the two years of data before the hurricane (so excluding the 2015 drought)."

RC2: 7.P5L149-150: The reason for applying 1year smooth window is not clear, please explain in the method section.

AUTHORS: We added an expanded explanation to the start of the methods: "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."

RC2: 8.P5L159-161: The way for justifying the recovery period is not clear, please explain the method in detail.

AUTHORS: We have moved this section to the methods and expanded to explain the reasoning and make it clear that we ran sensitivity tests to find this method acceptable. We now say in the methods "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

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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. “

In the results, we say "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 ±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 ±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)." In the discussion, we added "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."

RC2: 9.P6L169-176: I didn't understand why the authors reported the residuals of the statistical analysis in this paragraph. Is this information helpful for understanding the uncertainty of various measurements?

AUTHORS: This is the method for correlating time series: we remove seasonality and trends and correlate what is left over. We had called these 'leftovers' as 'residuals. To make this clearer, we changed the words "residuals of [data]" to "the prewhitened [data]".

RC2: 10.In the Discussion section: It is very difficult for me to find/justify the information of the recovery periods, such 10 years, 2.8 years and others values from Figs 1 and 2. I recommended the authors to indicate such a piece of information both in this section and key Figs.

AUTHORS: We added a few more references to Table 1, where all the specific recovery information is at. We also added green points on Figures 1 and 2 at the point where recovery is calculated.

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