Supplement of Biogeosciences, 18, 6517–6531, 2021
https://doi.org/10.5194/bg-18-6517-2021-supplement

Biogeosciences Open Access EGU

Supplement of

Strong temporal variation in treefall and branchfall rates in a tropical forest is related to extreme rainfall: results from 5 years of monthly drone data for a 50 ha plot

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Supplementary Material

Text S1, Tables S1-S2, and Figures S1-S10.

Text S1. Imagery processing

We horizontally aligned all orthomosaics and canopy surface elevation models to the first set (2 October 2014) using the centers of *Attalea* palms as manual control points. We resampled elevation models to 1m horizontal resolution and clipped them using the polygon of the 50 ha plot plus an extension of 25 m. We differenced surface elevation models for successive dates to obtain a raster of the canopy height changes for the associated interval. We assumed that the true median change in elevation between successive dates was zero and that any nonzero median elevation change for successive dates reflected systematic error in the vertical coordinates on one or both dates. We thus corrected rasters of canopy height changes for vertical positioning errors by subtracting the median observed elevation model difference.

Table S1. The mean, minimum, maximum, and the 25th, 50th, and 75th percentiles of interval length, number and area of canopy disturbances, and the respective monthly rates (i.e., per 30-day period) over measurement intervals. For these calculations, we included only the area of canopy disturbances inside the BCI 50-ha plot (including parts of canopy disturbances centered outside the plot), and we excluded the long interval between 24 September 2015 and 18 May 2016.

	mean	min	25%	50%	75%	max
Interval length (days)	35.8	14	26.2	31.5	36.8	91
Number (n)	19.5	2	7.2	10	17.2	214
Number (n.mo-1)	16.5	2.7	7.1	10.5	13.5	152.9
Area (m2)	1081.3	52.5	278.2	558.1	1099.1	11257.2
Area (m2.mo-1)	905.1	75	300.3	499	800.4	8040.9

Table S2. Rainfall events in mm per 15-min above than the 98.2th percentile that occurred during the measurement period. Bold highlights events during the measurement interval with the highest disturbance rate (June 1 to July 13 2016).

Time	Rainfall (mm)	Time	Rainfall (mm)	Time	Rainfall (mm)
2014-10-02 05:45	18.3	2016-10-03 15:15	18.5	2018-06-09 15:45	15.5
2014-10-03 07:45	14.7	2016-10-11 17:00	12.7	2018-06-23 15:30	20.1
2014-10-17 06:45	16.3	2016-10-11 17:15	21.1	2018-06-24 16:45	16.0
2014-11-10 02:15	13.0	2016-10-11 17:30	16.3	2018-06-24 17:00	17.8
2014-11-18 20:00	14.5	2016-10-11 17:45	29.0	2018-06-29 13:45	15.0
2014-11-21 16:45	27.2	2016-10-11 18:00	13.2	2018-07-02 10:15	13.7
2014-12-05 05:15	20.1	2016-10-30 18:00	22.6	2018-07-13 14:30	17.3
2014-12-07 10:45	12.4	2016-10-30 18:15	26.4	2018-07-22 17:00	14.7
2014-12-14 17:30	21.1	2016-10-30 18:45	13.2	2018-07-25 14:15	28.2
2015-02-15 02:15	14.5	2016-11-03 18:45	15.2	2018-08-04 05:00	13.5
2015-05-20 14:00	14.7	2016-11-03 19:00	19.1	2018-08-04 05:15	12.4
2015-05-21 15:00	22.1	2016-11-21 21:30	15.2	2018-08-09 14:00	18.8
2015-05-22 15:00	19.8	2016-12-07 04:30	15.7	2018-08-09 14:15	23.1
2015-05-29 22:45	16.3	2016-12-13 08:15	12.4	2018-09-24 12:15	12.4
2015-08-15 14:30	16.8	2017-04-30 11:30	15.7	2018-10-01 22:30	16.3
2015-08-17 08:30	16.3	2017-05-03 14:15	25.2	2018-10-01 22:45	21.3
2015-09-07 13:45	25.9	2017-05-03 14:30	22.1	2018-10-10 15:00	14.7
2015-09-21 11:15	14.7	2017-05-20 13:00	14.2	2018-10-12 14:15	17.5
2015-09-21 11:30	16.5	2017-05-31 21:30	19.1	2018-10-12 14:30	23.9
2015-10-01 15:30	17.8	2017-05-31 21:45	24.4	2018-10-21 15:30	18.0
2015-10-06 16:30	23.9	2017-06-05 12:45	16.8	2018-10-22 22:30	13.0
2015-10-06 16:45	19.6	2017-06-05 13:00	17.3	2018-11-01 00:30	16.0
2015-10-06 17:00	20.1	2017-07-21 03:30	16.5	2018-11-22 13:30	14.2
2015-10-13 00:00	12.7	2017-07-29 03:15	12.7	2019-05-19 13:15	19.6
2015-10-19 17:30	16.5	2017-09-20 13:45	26.9	2019-05-19 13:30	18.5
2015-10-19 18:00	12.7	2017-09-20 14:00	21.6	2019-06-01 12:45	13.0
2015-10-19 18:15	14.7	2017-10-28 06:00	19.8	2019-06-04 13:30	14.0
2015-10-31 14:00	22.9	2017-11-14 13:45	13.7	2019-06-09 21:45	17.5
2016-04-27 14:00	15.2	2017-11-29 16:15	18.0	2019-07-01 14:00	18.3
2016-04-27 14:15	12.7	2017-12-09 15:30	13.0	2019-07-10 13:15	15.5
2016-04-27 14:30	21.6	2017-12-09 16:00	14.7	2019-07-14 00:15	23.6
2016-05-26 16:45	13.0	2018-01-18 10:00	12.4	2019-07-14 13:30	17.3
2016-06-14 14:30	**12.4**	2018-03-23 12:30	12.4	2019-08-06 11:15	17.3

2016-06-17 06:30	**22.9**	2018-03-23 13:00	17.5	2019-08-14 01:30	13.0
2016-06-17 06:45	**18.8**	2018-03-23 13:15	13.5	2019-08-21 14:45	21.3
2016-06-19 10:45	**19.8**	2018-05-04 22:45	23.1	2019-08-28 13:30	16.8
2016-06-23 01:30	**32.5**	2018-05-04 23:00	18.3	2019-08-28 13:45	14.2
2016-06-30 14:30	**23.9**	2018-05-13 03:45	12.7	2019-09-28 14:45	13.2
2016-06-30 14:45	**18.0**	2018-05-13 05:15	13.0	2019-09-30 07:30	22.1
2016-06-30 18:15	**18.3**	2018-05-13 05:30	13.2	2019-09-30 07:45	16.5
2016-07-04 10:15	**18.5**	2018-05-19 14:30	14.5	2019-10-08 14:30	17.0
2016-07-04 14:45	**17.5**	2018-05-19 14:45	15.7	2019-10-10 13:45	25.2
2016-07-04 15:00	**16.8**	2018-05-24 12:15	13.0	2019-10-16 10:15	15.7
2016-07-15 20:00	22.4	2018-05-29 14:15	17.3	2019-10-26 15:00	21.8
2016-07-15 20:15	14.2	2018-05-29 14:30	21.6	2019-11-02 03:15	13.2
2016-07-27 12:30	23.6	2018-05-29 16:15	16.3	2019-11-03 10:45	17.8
2016-09-25 15:30	14.0	2018-06-09 15:30	16.3	2019-11-16 10:15	16.3

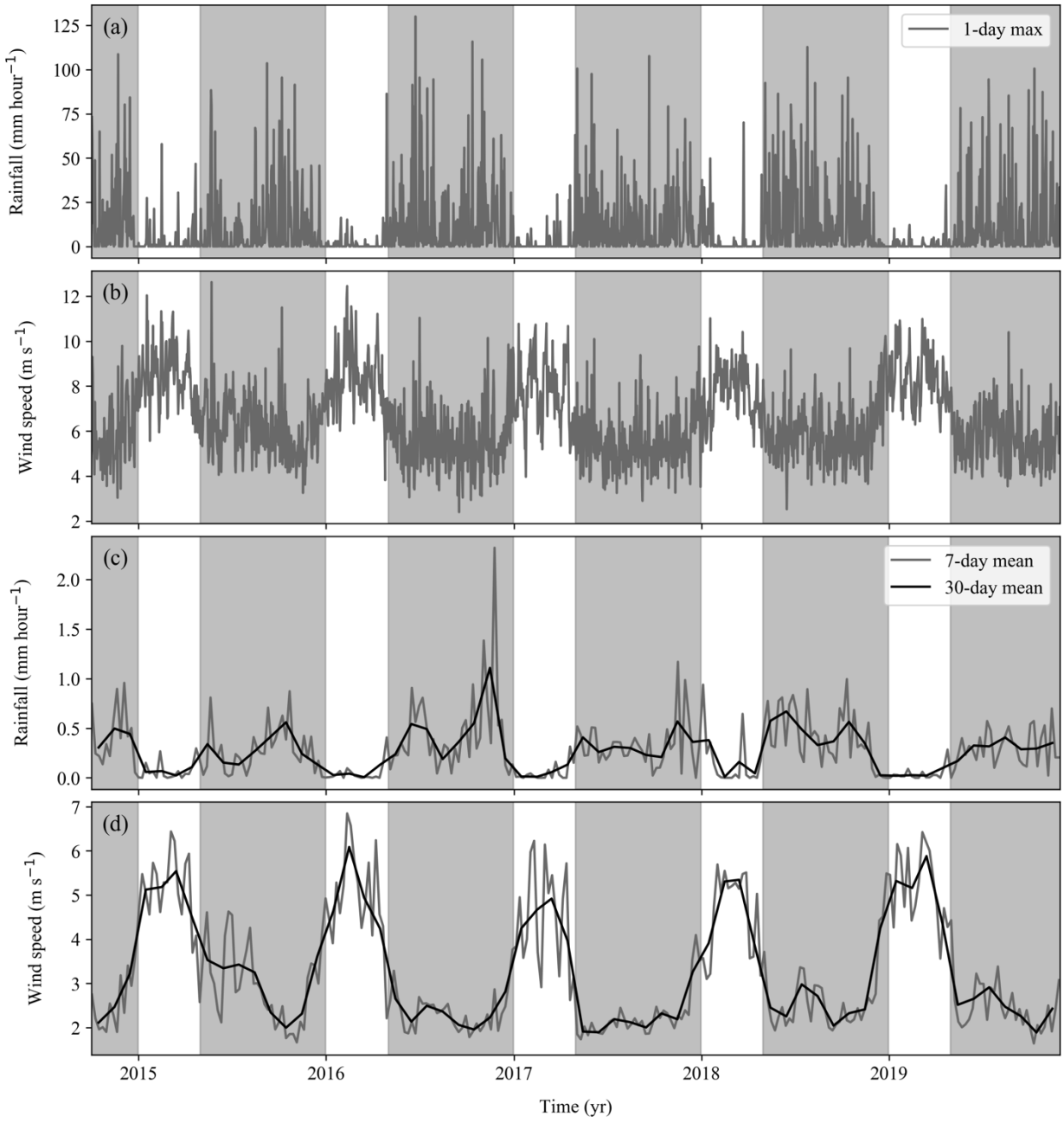

Figure S1. Temporal variation in rainfall rates and wind speed measured on Barro Colorado Island during the study period. Gray shading indicates the wet seasons (1 May to 31 December) of each year. (a) 1-day maxima of the 15-minute total rainfall. (b) 1-day maxima of the 10-second maximum wind speed. (c) 7-day and 30-day means of the 15-minute total rainfall. (d) 7-day and 30-day means of the 10-second maximum wind speed. We note that the windspeed measurements are taken every 10 seconds, with means, minina and maxima of these measurements recorded

every 15 minutes.

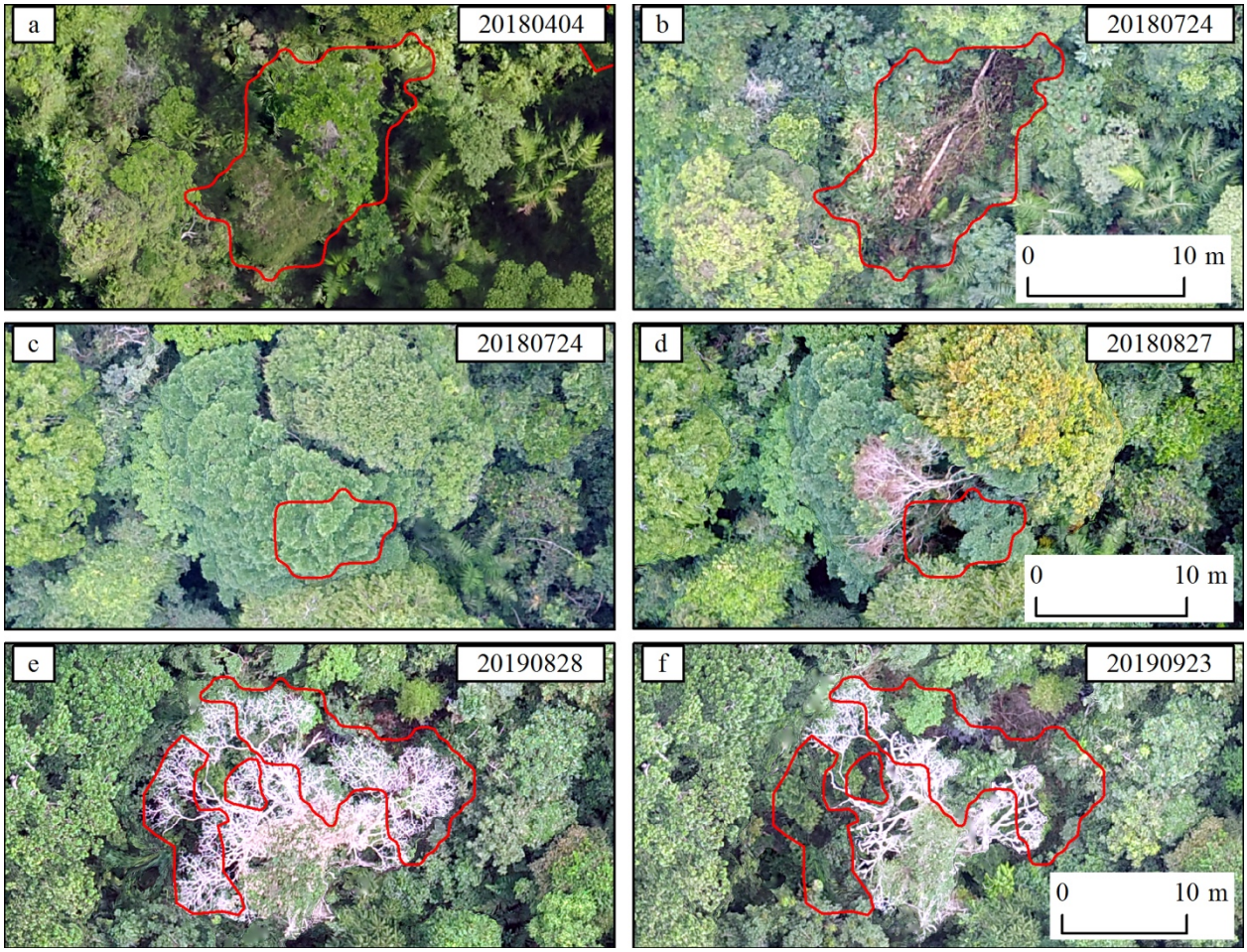

Figure S2. Examples of before (left) and after (right) orthomosaic imagery for new canopy disturbances (indicated by red polygons) classified as a treefall (a,b), a branchfall (c,d), and decay of a standing dead tree (e,f). Note that separate polygons (red) were counted individually.

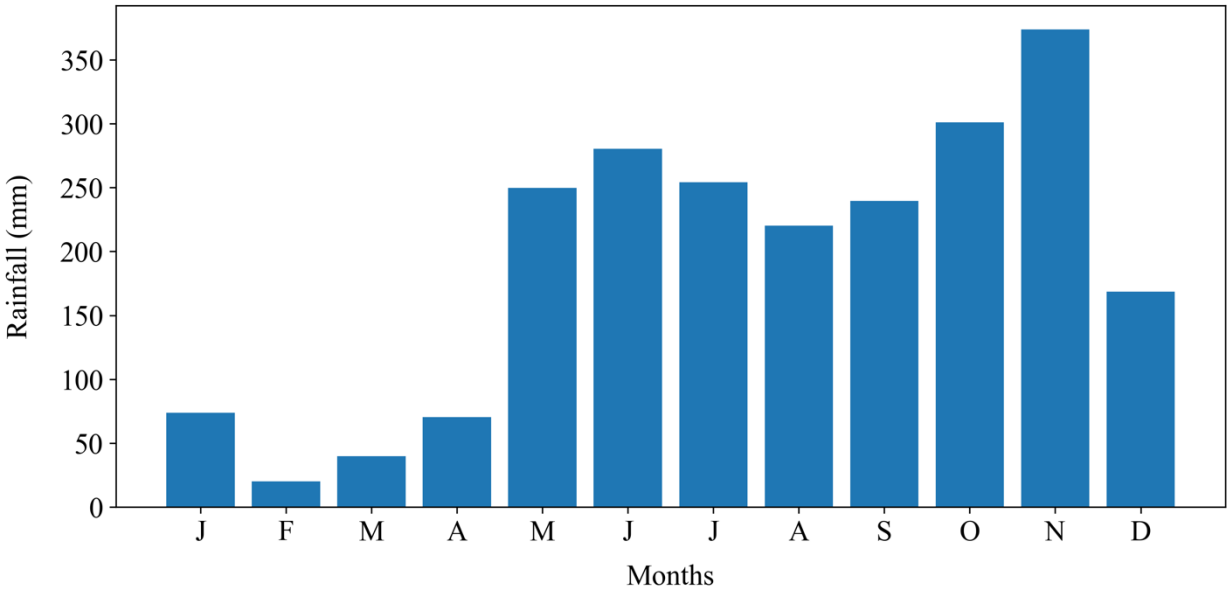

Figure S3. Mean monthly rainfall measured on Barro Colorado Island during the study period.

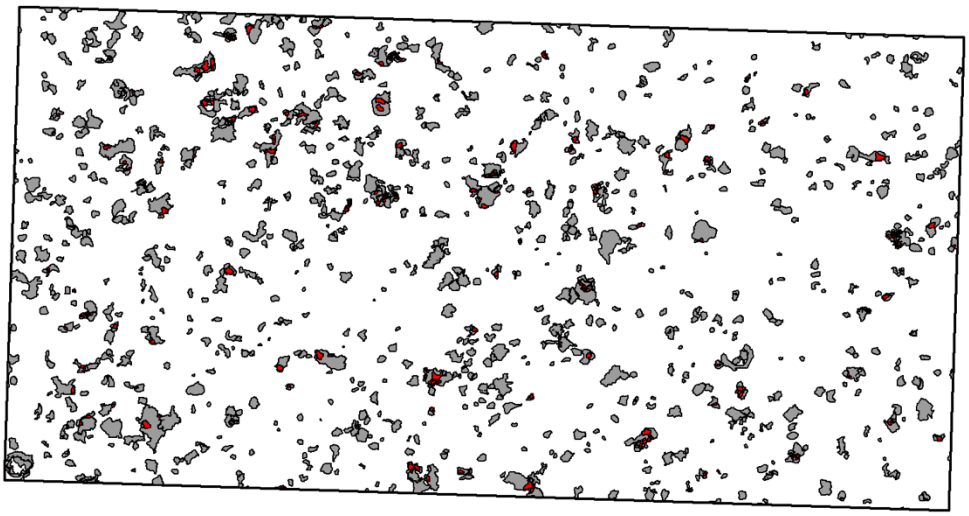

Figure S4. Map of canopy disturbances on the 50 ha plot (black rectangle, 1000 x 500 m) on Barro Colorado Island, Panama, from 2 October 2014 to 28 November 2019. Areas that were disturbed a single time are shown in grey, those disturbed more than once in red.

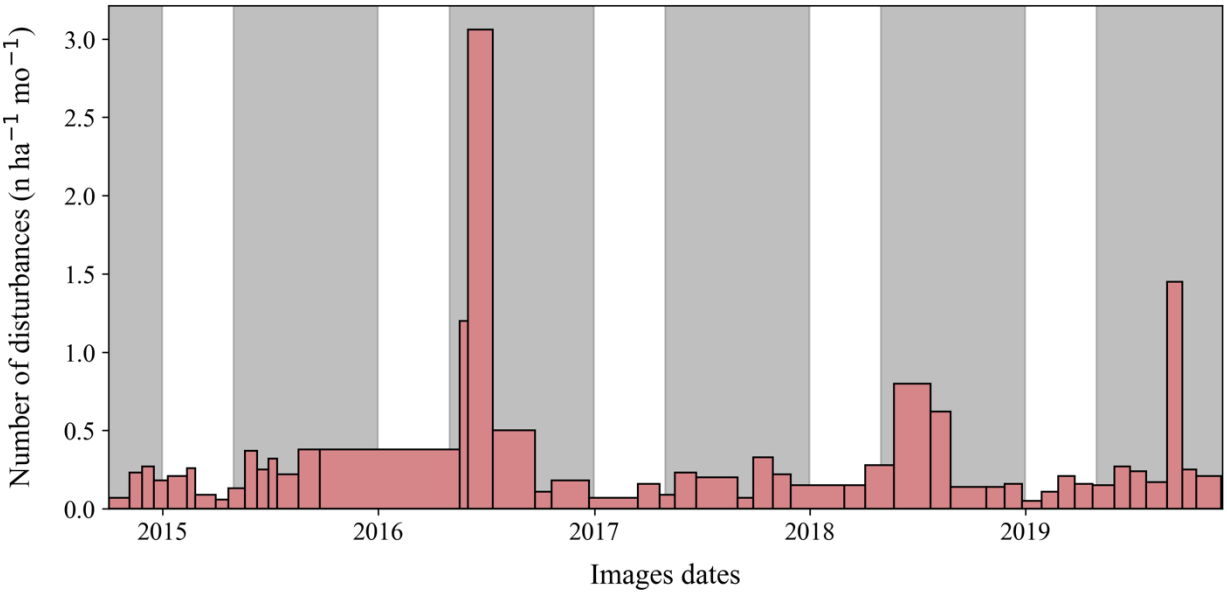

Figure S5. Temporal variation in canopy disturbance rates in the 50 ha plot on Barro Colorado Island, Panama, quantified as number of disturbances per area per time (compare with Fig. 3, which shows variation in unites of proportion of area per time). Gray shading indicates the wet seasons (May to December) of each year and ticks on the x axis indicate the first day of each year. Rates are shown in units of number of gaps per hectare per month (i.e., per 30 days). Note that the total area of each rectangle is proportional to the total number of canopy disturbances during that measurement interval.

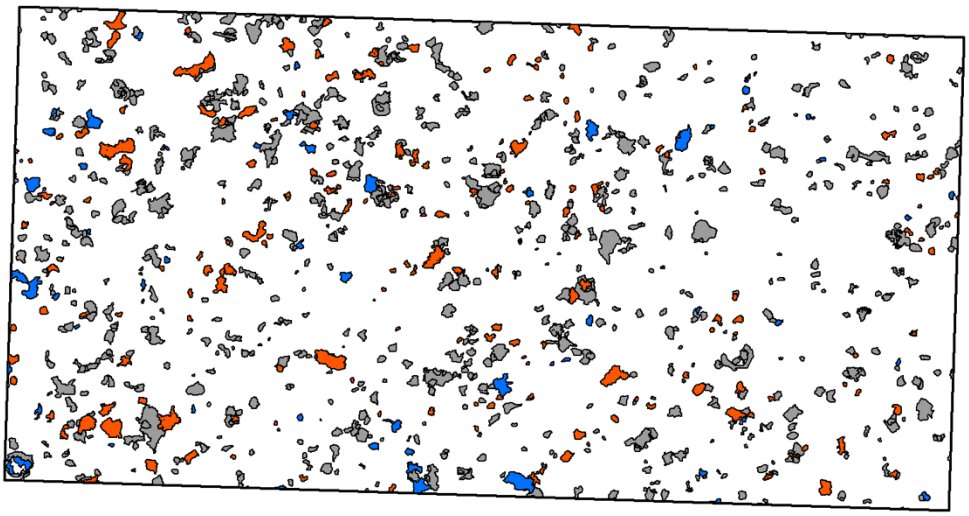

Figure S6. Map of canopy disturbances on the 50 ha plot (black rectangle, 1000 x 500 m) on Barro Colorado Island, Panama, from 2 October 2014 to 28 November 2019, with disturbance areas represented in gray. Canopy disturbances associated with the two periods having the highest disturbance rates, those between 1 June and 13 July, 2016 and between 28 August and 23 September, 2019, are shown in red and blue, respectively.

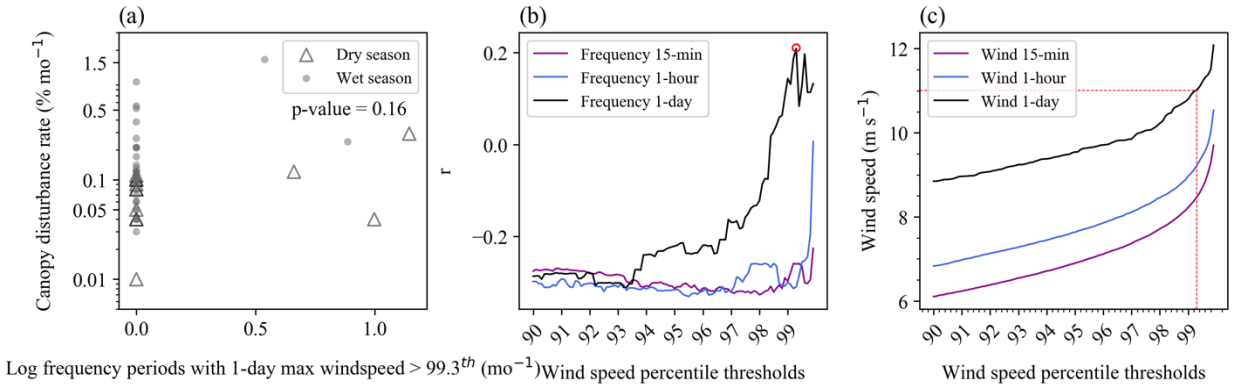

Figure S7. Relation of temporal variation in canopy disturbance rates to the frequency of extreme wind speed events. (a) The non-significant relationship for the best correlation of canopy disturbance rate: the frequency of periods with 1-day maxima wind speeds exceeding the 99.3th percentile. (b) Variation in Pearson correlation between canopy disturbance rate and frequency of extreme wind speed events depending on the temporal grain (colors) and percentile threshold (x axis) for defining extreme wind speed events, open red circle represents the best correlation. (c) The relationship of percentile threshold (x axis) and wind speed (y axis) for different temporal scales. Dashed red line indicates the wind speed of the 99.3th percentile.

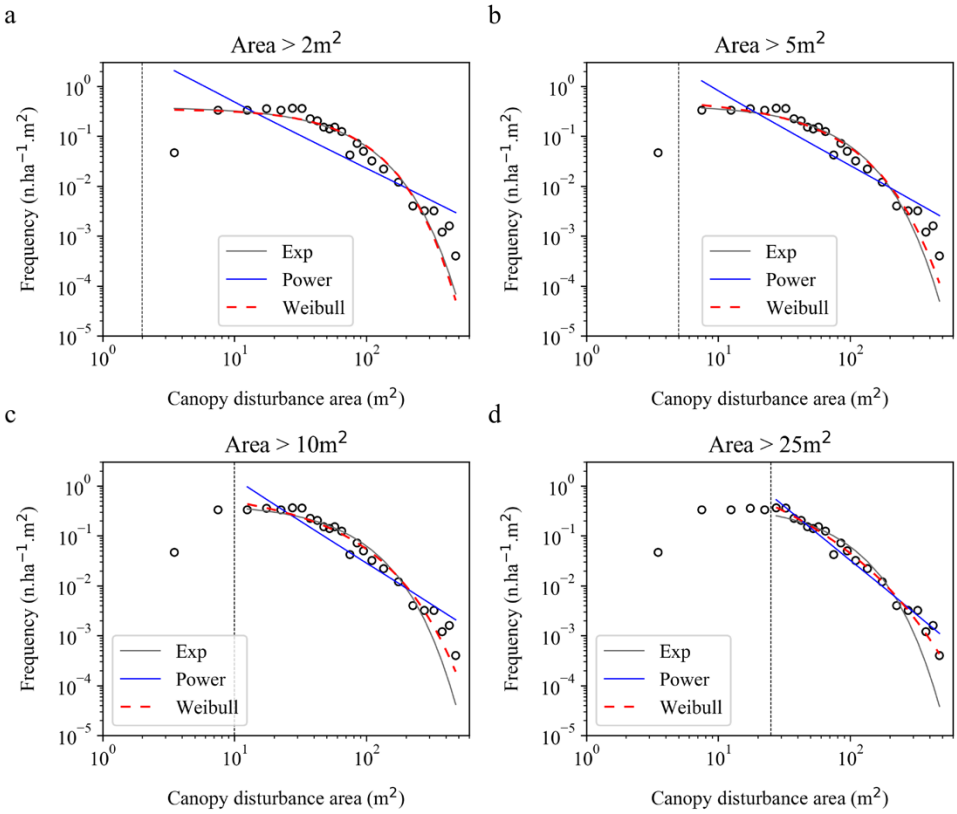

Figure S8. Observed size distributions of canopy disturbances, together with maximum likelihood fits under three alternative functional forms (exponential, power and Weibull functions). Each panel presents results for a particular minimum canopy disturbance area. Vertical dashed gray line indicates area thresholds.

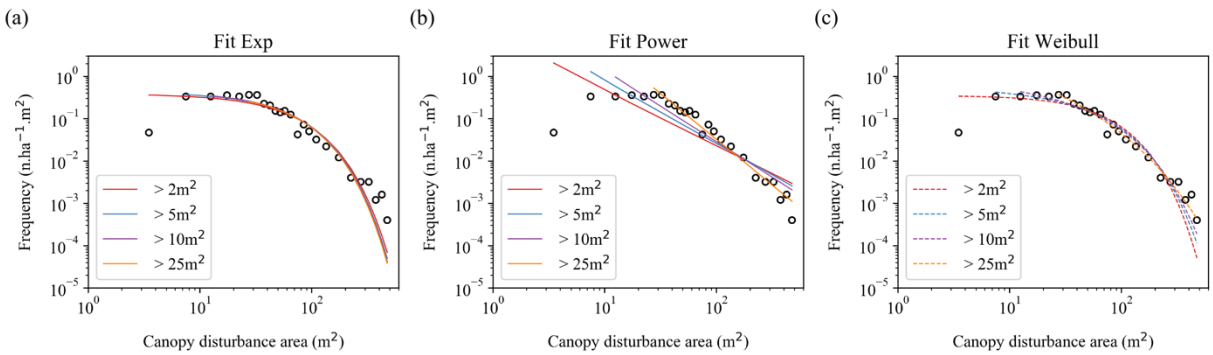

Figure S9. Observed size distributions of canopy disturbances, together with maximum likelihood fits, compared for different minimum canopy disturbance areas. Each panel presents results for a particular type of fitted function: exponential (a), power (b) and Weibull (c).

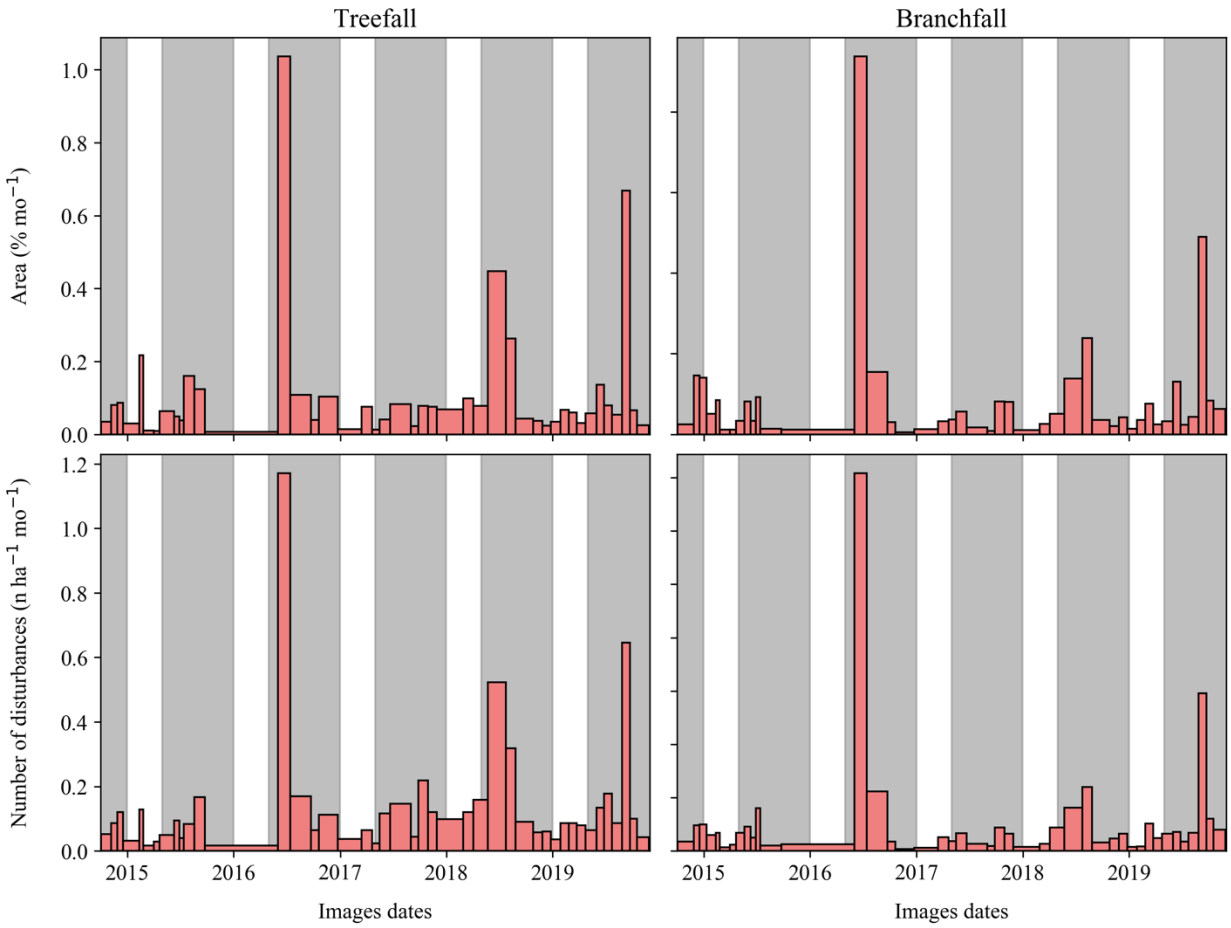

Figure S10. Temporal variation in treefall (left) and branchfall (right) rates in the 50 ha plot on Barro Colorado Island, Panama, evaluated in terms of area disturbed (upper panels) and the number of disturbances (bottom panels) across intervals. Gray shading indicates the wet seasons (May 1 to December 31) of each year.