

# Structure and Function in Degraded Forests in the Amazon from Multi-source Remote Sensing

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the degree of

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# Certificate of Original Authorship

I, Ekena Rangel Pinagé, declare that this thesis is submitted in fulfilment of the requirements for the award of the degree of Doctor of Philosophy, in the Faculty of Science at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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# Table of Contents

Title page.....	1
Certificate of Original Authorship .....	i
Acknowledgements .....	ii
Table of Contents .....	iv
List of Figures .....	vii
List of Tables.....	xii
Abstract .....	xiii
Chapter 1. Introduction .....	1
1.1. Background .....	2
1.1.1. Forest structure .....	2
1.1.2. Ecosystem functioning.....	8
1.1.3. Anthropogenic disturbances and forest degradation.....	16
1.1.4. The Amazon forests.....	18
1.1.5. Remote sensing approaches to assess forest structure and functioning.....	23
1.2. Thesis objectives, knowledge gaps, and thesis structure .....	32
1.2.1. Thesis objectives.....	33
1.2.2. Knowledge gaps.....	33
1.2.3. Thesis structure .....	34
Chapter 2. Effects of tropical forest degradation on Amazon forest phenology.....	36
2.1. Introduction.....	36
2.2. Materials and methods .....	39
2.2.1. Study areas.....	39
2.2.2. Disturbance history assessment.....	42
2.2.3. Remotely sensed data .....	46
2.2.4. Extraction of phenology metrics.....	51
2.3. Results.....	53
2.3.1. EVI and NBR time-series .....	53
2.3.2. EVI and NBR seasonal profiles .....	58
2.3.3. Phenology metrics .....	63
2.4. Discussion .....	65
2.4.1. Mechanisms driving EVI and NBR responses to disturbance.....	65

2.4.2. Phenology responses to disturbance .....	68
2.4.3. Methodological implications and prospects of this study .....	73
Chapter 3. Relationship between structure and SIF-photosynthesis across intact and degraded forests in the Amazon .....	75
3.1. Introduction .....	75
3.2. Materials and methods .....	78
3.2.1. Site description .....	78
3.2.2. Disturbance history assessment .....	79
3.2.3. Remote sensing data .....	81
3.2.4. Modelling structure and SIF relationships .....	86
3.2.5. Statistical analysis .....	90
3.3. Results .....	91
3.3.1. Structural properties of intact and degraded forests .....	91
3.3.2. SIF variability at intact and degraded forests .....	95
3.3.3. Structural predictors of SIF .....	98
3.4. Discussion .....	101
3.4.1. Distinct responses of structure and functioning (SIF) to disturbance .....	101
3.4.2. SIF variability related to disturbance .....	102
3.4.3. Limitations and prospects of the study .....	106
Chapter 4. Interactions between surface energy dynamics and canopy structural properties in intact and disturbed forests in the Amazon .....	108
4.1. Introduction .....	108
4.2. Material and methods .....	113
4.2.1. Study area .....	113
4.2.2. Disturbance history assessment .....	114
4.2.3. Remote sensing data .....	115
4.2.4. Statistical analysis .....	121
4.3. Results .....	122
4.3.1. Seasonal water stress .....	122
4.3.2. ET-LST relationships .....	124
4.3.3. Structure-function relationships .....	127
4.4. Discussion .....	131
4.4.1. Water stress, ET and LST variability across a disturbance gradient .....	132

4.4.2. Forest structure controls on energy balance .....	134
4.4.3. Implications for vegetation modelling.....	136
4.4.4. Caveats of this study .....	137
Chapter 5. Conclusion.....	138
5.1. Summary of key findings.....	138
5.2. Contributions.....	139
5.3. Implications.....	141
5.3.1. Agreement among greenness, SIF and ET .....	141
5.3.2. Changes to leaf demography caused by disturbances.....	141
5.3.3. Ecological shifts in degraded forests .....	142
5.3.4. Forest structure as a mediator of recovery and repeated disturbances .....	142
Appendices.....	144
Appendix A. Relationships between Landsat and MODIS data, and between EVI and NBR .....	144
Appendix B. Preliminary analysis of the effects of recent fires on solar-induced fluorescence.....	148
Appendix C. Annual profiles of ET, LST, EVI and precipitation for FNA region .....	154
References .....	156

# List of Figures

Figure 1.1. Core biogeophysical processes of the energy and water fluxes. Adapted from Bonan (2015).....	15
Figure 1.2. Amazon biome in South America ( <i>sensu</i> WWF ecoregions; Olson et al. 2001), and the Brazilian arc of deforestation. ....	19
Figure 1.3. Schematic diagram representing the impacts of degradation in tropical forest structure and function. Rows are sorted by degradation intensity, with the top row representing nondegraded forests. Changes in forest structure are exemplified by expected changes in canopy height and the vertical distribution of returns from airborne lidar measurements. Functional changes are expressed by community-level allocation to growth and photosynthesis vs allocation to structure and physical defence. Figure from Longo & Keller (2019).....	23
Figure 1.4. Remote sensing provides insights to understand a range of processes that operate at varying spatial and temporal scales. Background colours of the boxes denote hyperspectral (white), multispectral (yellow) and lidar/radar (green) remote sensing. Adapted from Chambers et al. (2007) and Martínez et al. (2016). ....	24
Figure 1.5. Graphic representation of optical remote sensing process. Source: <a href="https://crisp.nus.edu.sg/~research/tutorial/optical.htm">https://crisp.nus.edu.sg/~research/tutorial/optical.htm</a> . ....	25
Figure 1.6. Illustration of the conceptual differences between waveform and discrete return lidar data models. At the left is the intersection of the laser illumination area (a parameter identified as the lidar footprint), with a portion of a simplified tree crown. In the centre of the figure is a hypothetical return signal (the lidar waveform) that would be collected by a waveform-recording sensor over the same area. To the right of the waveform, the heights recorded by three types of discrete-return lidar sensors: first-return and last-return lidar devices record the position of the first and last objects in the path of the laser illumination, respectively; whereas multiple-return lidar, the most common discrete return sensor nowadays, records the heights of a small number (generally five or fewer) of objects in the path of illumination (Lefsky et al. 2002). ....	28
Figure 1.7. GEDI beam pattern. Note that the along-track and across-track distances are not to scale (across-track distance is about 10x larger). At any one instant, four laser pulses from the 3 lasers hit the ground. These are then dithered across-track to produce a complement of 8 tracks, with a gap of one shot along-track. Adapted from Dubayah et al. (2020). ....	32
Figure 2.1. Location (panel A) and mean monthly precipitation (panel B) of the study areas. In B, the blue and brown line represents the 100mm and 50mm dry season precipitation thresholds. Source of precipitation data: <a href="http://climate-data.org">climate-data.org</a> .....	41
Figure 2.2. Example of spatio-temporal dynamics of fire and selective logging disturbances over the years 2005-2010 in FNA region as revealed by NBR images. From 2005 to 2007, the selectively logged area expanded, and in 2008, two areas burned. Over the years, it is possible to observe forest recovery from both types of disturbances. While	



selective logging has a diffuse pattern of small clearings and low magnitude canopy damage, fires cause higher magnitude and widespread canopy damage. ....	44
Figure 2.3. Distribution of the polygons of the disturbance classes over the study areas. ....	46
Figure 2.4. Example of cloud/shadow mask application in Landsat images. Original image (A), cloud mask based on QA band only (B), and additional cloud mask based on brightness thresholds (C). The background image is Landsat 8, R6G5B4. ....	47
Figure 2.5. Schematic diagram of the phenology metrics computed from a hypothetical growing season. ....	52
Figure 2.6. FNA site time-series of the pre-processed MODIS data for vegetation indices (panels) and disturbance class (facets). Dots represent the median VI value of all pixels in each disturbance polygon per image date, while the red line shows the median value across all polygons per image date. The red-shaded rectangles depict the approximate disturbance periods. ....	54
Figure 2.7. FNA site time-series of the pre-processed Landsat data for vegetation indices (panels) and disturbance class (facets). Dots represent the median VI value of all pixels in each disturbance polygon per image date, while the red line shows the median value across all polygons per image date. The red-shaded rectangles depict the approximate disturbance periods. ....	55
Figure 2.8. PRG site time-series of the pre-processed MODIS data for each vegetation index (panels) and disturbance class (facets). Dots represent the median VI value of all pixels in each disturbance polygon per image date, whereas the red line shows the median value across all polygons per image date. The red-shaded rectangles depict the approximate disturbance periods. ....	57
Figure 2.9. PRG site time-series of the pre-processed Landsat data for each vegetation index (panels) and disturbance class (facets). Dots represent the median VI value of all pixels in each disturbance polygon per image date, whereas the red line shows the median value across all polygons per image date. The red-shaded rectangles depict the approximate disturbance periods. ....	58
Figure 2.10. EVI (A-B) and NBR (C-D) seasonal profiles for all disturbance classes at FNA site. MODIS data are on the upper and Landsat data are on the lower panels. The beige shade depicts the dry season (months with < 100mm of rain), and the shades along the lines represent their 95% confidence intervals. ....	60
Figure 2.11. Normalization (each year of the post-disturbance period minus the pre-disturbance average) of MODIS VI at FNA site. SL = logged forests, B1 = once-burned forests, B2 = twice-burned forests. B2 plots show the normalized curves for years after the second fire events only. The beige shade depicts the dry season (months with < 100mm of rain). ....	61
Figure 2.12. EVI (A-B) and NBR (C-D) seasonal profiles for all disturbance classes at PRG site. MODIS data are on the upper and Landsat data are on the lower panels. The beige shade depicts the dry season (months with < 100mm of rain), and the shades along the lines represent their 95% confidence intervals. ....	62

Figure 2.13. Normalization of post-disturbance VI per year after disturbance according to pre-disturbance average at PRG site. B2 plots show the normalized curves for years after the second fire events only. The beige shade depicts the dry season (months with < 100mm of rain).....63

Figure 2.14. Phenology metrics derived from MODIS EVI data for both sites. Disturbance stages are classified as pre-disturbance (from 2002 to 2006 and 2002 to 2004), early-post disturbance (from 2007 to 2012 and 2005 to 2008) and late post-disturbance (from 2013 to 2014 and from 2009 to 2014 for FNA and PRG, respectively). The x-axis on the PGS metric plots was adjusted for the sake of clarity. ....64

Figure 2.15. Phenology metrics derived from MODIS EVI data for both sites. These metrics describe key EVI statistics during the greening season for each disturbance stage. ....65

Figure 2.16. Three different forest conditions in Pará and Mato Grosso States: unburned, twice-burned, and burned more than three times. Source: Alencar et al. (2015)..... 69

Figure 3.1. Location, land cover and monthly precipitation of the study area. Source of precipitation data: climate-data.org..... 79

Figure 3.2. Lidar pulses from the airborne sensor penetrate the forest canopy and either bounce off leaf or woody material, or hit the ground, and return to the plane (1). These height measurements are then voxelized at the desired spatial resolution (2). The MacArthur-Horn method is then applied to voxelized columns of LiDAR returns (3), returning a LAD profile of the given area (4). The sum of LAD values in a column of voxels with a ground return is equal to the LAI of that vertical column. Adapted from Kamoske et al. (2019). .... 84

Figure 3.3. Graphical representation of a height metric (95<sup>th</sup> height percentile) derived from lidar data. .... 85

Figure 3.4. Example of SIF pixel selection (intact at green, logged at blue and burned forests at orange inset) according to pixel mixture and availability of lidar transect. Background images are NBR annual composites from 2019 (main map and intact forest inset), 2016 (logged forest inset) and 2010 (burned forest inset). Lighter areas represent dense canopy cover, while darker areas represent low or no canopy cover. Degradation by fire or logging appears in intermediate grey tones..... 87

Figure 3.5. Canopy height models and associated density plots for 8-ha samples for each disturbance class..... 92

Figure 3.6. Height metrics for the disturbance classes (P10, P25, P50, P75, P95, TCH and sdTCH stand for 10<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup>, 95<sup>th</sup> height percentiles, top-of-canopy height and standard deviation of top-of-canopy height). The symbols indicate statistical significance (p-values) as computed from the multiple pairwise test against a reference group (IN, intact forests). ns =  $p > 0.05$ ; \* =  $p \leq 0.05$ ; \*\*  $p \leq 0.01$ ; \*\*\* =  $p \leq 0.001$ . .... 93

Figure 3.7. Panel A: Vertical Foliage Profile (VFP) for the disturbance classes. Intact forest's LAD is plotted over logged and burned forests' plots as a reference. Bands along the lines represent the standard error. Panel B: distribution of total leaf area index (LAI) above 4.5m for the disturbance classes. The violin plots summarize LAI distributions as a function of disturbance class and show the kernel probability density of the data at

different values. All violins have the same area. The median of each group is indicated by the white dots. The symbols indicate statistical significance (p-values) as computed from the multiple pairwise tests against a reference group (IN, intact forests). Each grey dot represents one lidar transect, and together, they represent the sample size for each disturbance class..... 94

Figure 3.8. Vertical profile of incident (panel A) and absorbed light (panel B) for the disturbance classes. Intact forest's profile is plotted over logged and burned forests' plots as a reference. The bands along the lines represent the standard error. .... 95

Figure 3.9. SIF time-series (daily data averaged to 16-days) for the disturbed classes with intact forests time-series as reference in all panels. The included period is March 1<sup>st</sup> 2018 to September 30<sup>th</sup> 2019. Beige shades indicate the dry season (months with <100mm precipitation) in the study area. Lines represent the median value of the 16-days average, and the bands represent the 95% confidence interval for the median..... 96

Figure 3.10. Distribution of 16-day SIF data. The violin plots summarize SIF distributions as a function of disturbance class, and also show the kernel probability density of the data at different values. The tails of the violins are trimmed to the range of data, and all violins have the same area before trimming the tails. The median and interquartile range of each group are indicated by the white mini-boxplots. Grey dots represent 16-days SIF values and are shape-coded according to season. P-values computed from the multiple pairwise tests against a reference group (IN, intact forests) are shown, as well as the global p-value for the ANOVA test. N= 36. .... 97

Figure 3.11. Comparison of averaged SIF values between intact and disturbed forests across wet and dry seasons. Coloured lines represent the best fit, black dashed line indicates the 1:1 line, and grey bands represent 95% confidence intervals. .... 98

Figure 3.12. Observed versus predicted values of SIF as estimated by the models. The dashed line is the 1:1 line, and r values are the Pearson correlation coefficient between observed and predicted values. .... 100

Figure 3.13. Relationship between SIF and sdP25, sdP95 and sdVFP metrics. The black line represents the best fit line..... 104

Figure 4.1. Location, forest cover and monthly precipitation (inset) of the study area. Source of precipitation data: climate-data.org. .... 114

Figure 4.2. GEDI waveform. A near-infrared pulse of laser energy is fired towards the surface where it is reflected by leaves and branches within a nominal 25 m diameter footprint (shown on right). The returned waveform (shown on left) is processed to find ground topography, canopy height, and various relative height (RH) metrics. Source: Dubayah et al. (2020). .... 118

Figure 4.3. Disturbance classification at FNA region and post-filtering GEDI shots over the focal area (yellow outline polygon). Insets are zooms from red outline polygon in the main map and show GEDI variables (PAI, canopy cover and top-of-canopy height). Inset background images are LST and ET from Sep-2019. Higher values of LST and ET are brighter. Unclassified areas (over alluvial vegetation or savannas, or due to mismatch among input datasets) are shown in white in the disturbance classification. .... 121

Figure 4.4. Annual profile of the MODIS Evaporative Stress Index for the disturbance classes (A) for FNA region. The grey rectangles in A indicate the dates that the Landsat-based ESI for a subset of the study area was extracted (B). A sample of 100 Landsat pixels was included for each class. The red error bars in B represent 95% confidence interval of the mean. Labels in the x-axis in B represent the disturbance classes and are in the same order and colour of the legend. .... 123

Figure 4.5. Disturbance classification (A), evapotranspiration in wet and dry seasons (B-C), a false-colour RGB composite (D), and land surface temperature in wet and dry seasons (E-F) over a subset of the study area. RGB composite image info: path/row 225/069, date 28-Sep-2019, R6G4B5. .... 124

Figure 4.6. Distribution of ET (A) and LST (B) in the wet and dry seasons across the disturbance classes. Only 1/500 pixels were included, and observations falling below the 2.5<sup>th</sup> and above the 97.5<sup>th</sup> percentiles were excluded. Violin plots show the kernel probability density of the data at different values. All violins have the same width, and the median of each group is indicated by the white dots. Groups labelled with the same letter are not significantly different at a confidence level of 95% (Tukey's HSD test). The wet season image date is January 31<sup>st</sup>, 2019, and the dry season image date is September 28<sup>th</sup>, 2019. .... 125

Figure 4.7. Relationship between ET and LST across wet and dry seasons for all classes (A), and for the broad disturbance classes separately (B). Only 1/500 pixels were included, and observations falling below the 2.5<sup>th</sup> and above the 97.5<sup>th</sup> percentiles were excluded. Black lines represent the best fit line. .... 126

Figure 4.8. Structural variables derived from GEDI data for the disturbance classes. Groups labelled with the same letter are not significantly different at a confidence level of 95% (Tukey's HSD test). Observations falling below the 2.5<sup>th</sup> and above the 97.5<sup>th</sup> percentiles were excluded, and in this plot, only 20% of the observations were included. .... 128

Figure 4.9. Stacked histograms of GEDI variables per broad forest classes, colour-coded by individual disturbance class. Observations falling below the 2.5<sup>th</sup> and above the 97.5<sup>th</sup> percentiles were excluded. To assess the relationships between structural variables and ET and LST, I collapsed the disturbance classes into four broad categories (intact, logged, burned and secondary forests). Croplands and pastures were excluded from this section, because the structure in these classes might be ephemeral (i.e., crops get harvested), making the examination of relationships of structure to ET&LST less meaningful. Structural variables showed moderate to high correlations with ET (positively correlated, coefficients from 0.51 to 0.77) and LST (negatively correlated, coefficients from -0.48 to -0.82) (Table 4.3). .... 129

Figure 4.10. Scatterplots showing the relationships between GEDI structural variables and evapotranspiration (A) and land surface temperature (B) for the broad forest classes. Lines represent the best fit from the linear regression models. .... 130

Figure 4.11. Scatterplots showing the relationships between GEDI structural variables and evapotranspiration in burned and secondary forest classes. Lines represent the best fit from the linear regression models. .... 131

## List of Tables

Table 1.1. Components of forest structure (adapted from Spies (1998)).	3
Table 2.1. Data sources and temporal domain of the disturbance characterization.	43
Table 2.2. Summary statistics of the disturbance classes.	45
Table 2.3. Description of the images.	48
Table 3.1. Characteristics of lidar samples.	80
Table 3.2. Characteristics of SIF samples.	81
Table 3.3. Characteristics of the lidar data acquisitions.	82
Table 3.4. Lidar-derived metrics included as predictors of SIF.	88
Table 3.5. Correlation matrix of SIF and the structural predictors after accounting for collinearity. All correlations are significant at 99% confidence. Positive coefficients are shown in blue and negative coefficients are shown in red. Predictors included in the models after the stepwise selection are highlighted in yellow. For a description of metrics, see Table 3.4.	98
Table 3.6. Equations, adjusted $R^2$ , root mean square error (RMSE), and F-statistic p-value of the tested models. For a description of metrics, see Table 3.4.	99
Table 3.8. Equations, adjusted $R^2$ , root mean square error (RMSE), and F-statistic p-value of canopy height and foliar distribution including interactions.	100
Table 4.1. Hypotheses and datasets for the research questions.	113
Table 4.2. Estimates of slope differences between wet and dry season in ET and LST relationship for the broad disturbance classes. P-values of pair-wise comparisons $> 0.05$ (highlighted in grey) indicate non-statistically significant differences in slope at 95% confidence level.	127
Table 4.3. Correlation matrix of structural properties, ET and LST. All correlations are significant at 99% confidence. Positive coefficients are shown in blue and negative coefficients are shown in red.	129

## Abstract

Tropical forests provide critical ecosystem services for global climate and biodiversity, and sustain the livelihoods of millions of people. Yet, they have become hotspots of land-use change. The Southern border of the Brazilian Amazon has been a focus of land development with large swaths of tropical forests converted to agriculture. Degradation of forests by selective logging and fires has accompanied the advance of the frontier and has resulted in significant impacts on Amazonian ecosystems. While the agricultural use in the region is well quantified, forest degradation is more challenging to study. Given that changes in tree cover and structure have large impacts on forest function, there is an urgent need to quantify these properties for degraded forests.

The overarching goal of this thesis is to investigate the functional and structural linkages in degraded forests in the Amazon and assess whether forest structure mediates forest responses to disturbance. To achieve this goal, I (1) compared phenological patterns of intact and degraded forests using time-series of spectral indices; (2) examined the relationship between forest structure and photosynthesis across a gradient of forest degradation, by integrating structural variables and solar-induced fluorescence (SIF) data; and finally, (3) investigated the influence of forest structure on evapotranspiration and land surface temperature. These broad thesis objectives were accomplished using multi-source remote sensing (MODIS, Landsat and TROPOMI SIF satellite data combined with airborne and orbital lidar observations) and statistical methods.

My results showed that fires had a stronger effect than selective logging on ecosystem functioning (e.g., stronger phenological shifts and alterations in evapotranspiration and land surface temperature) and caused more dramatic changes in forest structure (e.g., lower forest canopy and leaf area index, more abundant understory). I also found that shifts in ecosystem functioning related to forest degradation were exacerbated by the dry season in the study region. Finally, I found that the most heavily disturbed forests presented strong structure-function relationships that do not hold in the least disturbed forests, suggesting that forest structure acts as a mediator of forest recovery.

My findings help to elucidate the effects of human-induced disturbances in ecosystem fluxes and can inform public policy related to forest management and land use planning. Besides, my results provide inputs regarding the role of phenology and forest structure in

degraded forests for ecosystem demography models. The importance of this research is underscored by the recent surge in deforestation in the Brazilian Amazon and associated forest fires.