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VICTOR JUAN ULISES RODRIGUEZ CHUMA

PREVENDO PADROES ESPACIAIS DE QUEDA DE FRUTOS NA FLORESTA NACIONAL DO AMAPÁ

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Cada línea en este trabajo

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mucho más de lo que merezco.

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RESUMO

Rodriguez Chuma, Victor Juan Ulises. Prevendo padrões espaciais de queda de frutos na Floresta Nacional do Amapá. Macapá, 2017. Dissertação (Mestre em Biodiversidade Tropical) – Programa de Pós-graduação em Biodiversidade Tropical – Pró-Reitoria de Pesquisa e Pós-Graduação - Universidade Federal do Amapá

As interações fruto-frugívoros são um componente ecológico vital da biodiversidade amazônica e, dados de biomassa de frutos caídos proporciona compreensão da heterogeneidade espacial dos recursos para frugívoros terrestres e outros consumidores. Descrevemos, explicamos e prevemos padrões em mesoescala de queda de frutos dentro de uma floresta amazônica baixa. Dados de queda de frutos foram coletadas de Maio a Junho de 2016 com a avaliação do chão em 90 parcelas (4.42 ha) distribuídas numa grade de 25 Km^2. Modelos aditivos generalizados foram usados para explicar e prever os padrões espaciais de biomassa seca, riqueza e diversidade de frutos caídos. Seleção multimodal foi aplicada para determinar a importância relativa do espaço, topografia, hidrografia e cobertura da vegetação. Contamos um total de 21812 frutos caídos, distribuídos em 86 espécies, 28 famílias, e 51 gêneros. Considerando ambos meses, a média de biomassa de frutos foi de 44.84 Kg ha^{-1} mes^{-1} (±45.13 SD); o número médio de espécies frutificando de 4.3 (±2.6 SD) e a média do índice de diversidade de Shannon de 0.84 (±0.5 SD). Encontramos que o efeito do espaço explica fortemente a variação dos padrões de frutos caídos e que a contribuição das variáveis espaço, topografia, hidrografia e vegetação são diferentes para cada respostas. Embora foi possível explicar proporções importantes do desvio nas respostas, previsões espaciais explicitas utilizando variáveis preditivas obtidas por sensores remotos não obtiveram estimações exatas. Numa era de rápida adopção de dados de sensoramiento remoto, nossos resultados sugerem que padrões de frutos caídos é um dos vários componentes embaixo do dossel da diversidade da floresta amazônica que continuará requerendo dados coletados no campo. No entanto maior amostragem é necessário para definir associações espaço e tempo.

Palavras-chave: Amapá, Modelo digital de elevação (MDE), biomassa seca de frutos caídos, escudo da Guiana, Índice de Vegetação de Diferença Normalizada (NDVI), Índice de diversidade de Shannon, floresta de terra firme.

ABSTRACT

Rodriguez Chuma, Victor Juan Ulises. Patterns and predictions of fruit-fall biomass in a lowland Amazon forest. Macapá, 2017. Dissertação (Mestre em Biodiversidade Tropical) – Programa de Pós-graduação em Biodiversidade Tropical – Pró-Reitoria de Pesquisa e Pós-Graduação - Universidade Federal do Amapá

Fruit-frugivore interactions are a vital ecological component of Amazon forest biodiversity and fruit-fall biomass data provide insight into the spatial heterogeneity of resources for terrestrial frugivores and other consumers. Here we describe, explain and predict meso-scale fruit-fall patterns within a lowland Amazon forest. Fruit-fall data were collected from May and June of 2016 with a ground survey in 90 plots (total of 4.42 ha) distributed across a 25 Km^2 grid. Generalized additive models were used to explain and predict the spatial patterns of fruit-fall dry biomass, richness and diversity. Multi model selection was used to determine the relative importance of space, topographic, hydrographic and vegetation cover. We counted 21812 fallen fruits, this total included fruits of 86 species from 28 families and 51 genera. Considering combined totals from both months, the mean fruit-fall biomass was 44.84 Kg ha^{-1} month^{-1} (±45.13 SD); mean number of species fruiting 4.3 (±2.6 SD) and mean Shannon diversity index 0.84 (±0.5 SD). We found that spatial effects most strongly explained variation in fruit-fall patterns and that the contribution of spatial, topographic, hydrographic and vegetation variables differed between responses of the variables. Whilst it was possible to explain substantial proportions of deviance in the responses, spatially explicit predictions using remotely sensed variables did not return accurate estimates. In an age of rapid adoption of remotely sensed data, our findings suggest that fruit-fall patterns are one of the myriad below canopy components of Amazon forest diversity that will continue to require ground based data collection. More sampling for space-time association is required.

Keywords: Amapá, Digital Elevation Model (DEM), fruit-fall dry biomass, Guiana shield, Normalized Difference Vegetation Index (NDVI), Shannon diversity index, terra firme forest.

SUMÁRIO

1. INTRODUÇÃO GERAL

Quase 95% das espécies de plantas produzem frutos que podem ser dispersados por animais (Howe and Smallwood 1982). Sendo que a polpa dos frutos carnosos é aproveitada como alimento pelos mamíferos (Barlow and Peres 2006), aves (Blake et al. 1990), répteis (Castro and Galetti 2004) e insetos (Henderson et al. 2000), que representam os principais agentes dispersores das sementes (Castro et al. 2007). No entanto, a disponibilidade dos frutos não é constante ao longo do tempo e o espaço, o que afeta a dinâmica e as populações de animais que dependem desse recurso (Hanya et al. 2011). Essa variação influencia diretamente os consumidores que devem deslocar-se temporariamente entre os diferentes ambientes durante a época de escassez em busca de frutos (Castro et al. 2007, Caillaud et al. 2010). Assim a estrutura da floresta pode ser em parte determinada pela frutificação e dispersão de sementes (Boissier et al. 2014), que promove a presença de outras espécies associadas que usam esses recursos como nichos (Diaz martin et al. 2014).

A competição entre plantas, regeneração natural, sucessão e interação planta-animal são processos interconectados que dependem dos padrões espaciais e temporais da produção e queda de frutos (Crawley et al. 1986). Nesse sentido, a frutificação é um processo fundamental na manutenção da estrutura, e funcionamento das florestas tropicais (Howe and Smallwood 1982, Howe 1986, Jordano 1992). Especialmente no Neotrópico pela grande produtividade e diversidade das espécies que produzem, segundo Jordano (1992), entre 180 e 1000 Kg ha^{-1} de biomassa seca anual de frutos.

Devido ao custo de tempo e dificuldades para avaliar as copas das árvores no campo, a amostragem de frutos em áreas grandes são raras, assim os estudos para determinar produção e fenologia de frutos utilizaram contagens de frutos caídos (Blake et al. 1990, Ponce 2002, Schaefer et al. 2002, Arévalo et al. 2007, Norden et al. 2007, Caillaud et al. 2010, Schleuning et al. 2011, Boissier et al. 2014, Hawes and Peres 2014). Assim, a avaliação de frutos caídos fornece uma ferramenta poderosa para estimar rapidamente a atividade frugívora e identificar ameaças à regeneração da floresta (Boissier et al. 2014, Diaz martin et al. 2014), e existe uma variedade de técnicas de amostragem para avaliar a queda dos frutos (Malenky et al. 1993, Chapman et al. 1994, Zhang and Wang 1995).

Dentre esses, a avaliação de frutos em trilhas no chão permitem resultados mais comparáveis e tem a vantagem das amostras serem mais eficientes e rápidas numa área relativamente grande maximizando a variação espacial (Chapman et al. 1994, Barlow and Peres 2006). É importante considerar que tanto as armadilhas de sementes e avaliação do chão não amostrarem adequadamente a totalidade dos frutos dispersados, pois medem apenas uma quantidade residual dos frutos: produção de frutos total menos a quantidade de fruto predados por frugívoros nas copas, incluindo insetos, numa área menor (Blake et al. 1990).

A biomassa viva acima do solo tem sido o foco principal da modelagem de diversos estudos (Saatchi et al. 2007, Baccini et al. 2012, Avitabile et al. 2016), e os estudos de biomassa seca frutos caídos em florestas tropicais tem se focado na caracterização da fenologia das espécies, e na diferença entre ecossistemas e relação com frugivores (Charles-Dominique et al. 1981, Sabatier 1985, Blake et al. 1990, Arévalo et al. 2007, Hanya and Aiba 2010b, a, Hanya et al. 2011, Boissier et al. 2014, Freitas et al. 2016). No entanto pouco conhece sobre são os fatores ambientais que afetam a distribuição espacial da biomassa seca de frutos caídos produzida durante época de maior precipitação, que segundo Sabatier (1985) 88 % das espécies produzem frutos na nessa época.

Na atualidade os avanços em estatísticas permitirem a combinação de dados de áreas de amostragem maiores para gerar modelos de predição de distribuição potencial de recursos, utilizando uma combinação de imagens de satélite e dados de campo (Tuomisto et al. 2003, Platts et al. 2008, Caillaud et al. 2010, Figueiredo et al. 2015). Dessa maneira, a topografia e os solos tem demostrado ser os principais determinantes da distribuição das espécies e dos padrões das comunidades em escalas regionais (Costa et al. 2005, Martin-Garcia et al. 2013). Assim como a disponibilidade de água no solo que controla a distribuição e composição das espécies (Costa et al. 2009, Schietti et al. 2014).

Existem fatores derivados da topografia que podem ser úteis para prever distribuição espacial de espécies, como o índice topográfico de humidade (TWI) (Besnard et al. 2013), declividade (Besnard et al. 2013, Salm et al. 2015), distancia vertical e horizontal do drenagem mais próximo (Rennó et al. 2008, Schietti et al. 2014, Figueiredo et al. 2015) derivadas a partir do SRTM-DEM (Shuttle Radar Topographic Mission (Rabus et al. 2003)). Os padrões espectrais ou reflectância de imagens de satélite também podem ser usados para prever tipos de solos e padrões florísticos em florestas de terra firme. Figueiredo et al. (2015) e Pisek et al. (2015) utilizaram o índice de vegetação de diferença normalizada (NDVI) para estes fins.

Esse estudo seria o primeiro a pesquisar os fatores ambientais que afetam os padrões espaciais de frutos caídos numa área de 25 Km^2. Esse analisou a importância relativa e os efeitos do espaço, topografia, hidrografia e vegetação sobre a distribuição espacial da biomassa seca, riqueza e diversidade da queda de frutos. Utilizando dados de sensoramiento remoto previmos e elaboramos o mapa da distribuição de biomassa seca de frutos caídos da grade da FLONA

Nesse sentido esse trabalho pretende conhecer os padrões espaciais da produção dos frutos disponíveis para frugívoros terrestres na região norte do Brasil no final da época de chuva e, a partir disso, aplicar planos de manejo e aproveitamento dos recursos mais adequados (Boissier et al. 2014, Legendre and Gauthier 2014). Conhecendo a importância das variáveis sobre o processo de queda dos frutos se pode promover melhoras no planejamento de amostragem de outras espécies associadas a esses recursos, assim como monitoramento da estrutura e riqueza dos ecossistemas. Os resultados obtidos terão impactos significativos para a gestão e conservação dos recursos naturais e presentam um aporte para futuras pesquisas na grade da FLONA e para desenvolver uso potencial dos frutos pelas pessoas que moram as margens do rio Araguari e Falsino.

2. HIPÓTESES

PERGUNTA

Quais são os fatores ambientais que explicam os padrões espaciais de biomassa seca, riqueza e diversidade de frutos caídos, numa mesoescala?

HIPÓTESE 1

A distribuição espacial da biomassa seca, riqueza e diversidade de frutos caídos na época da chuva pode ser explicada somente pela distribuição espacial, descrito como coordenadas geográficas.

HIPÓTESE 2

A distribuição espacial da biomassa seca, riqueza e diversidade de frutos caídos na época da chuva está explicada principalmente pela topografia descrita por a altitude, declividade e aspecto.

HIPÓTESE 3

Os padrões espaciais de biomassa seca, riqueza e diversidade dos frutos caídos podem ser explicados por fatores hidrográficos definidos por distancia horizontal e vertical ao drenagem mais próximo e índice topográfico de humidade.

HIPÓTESE 4

Os padrões espaciais e da biomassa seca, riqueza e diversidade dos frutos caídos são explicados pela combinação do fatores descritivos da vegetação como o índice de vegetação de diferencia normalizada e a distribuição espacial da biomassa viva acima do solo.

HIPÓTESE 5

Os padrões espaciais da biomassa seca, riqueza e diversidade dos frutos caídos são explicados pela combinação dos fatores ambientais combinados de espaço, topografia, hidrografia e vegetação adquiridos por sensores remotos.

3. OBJETIVOS

3.1. Geral

Identificar os principais fatores ambientais que explicam a variação espacial da biomassa seca, riqueza e diversidade de frutos caídos numa área contínua de terra firme na Amazônia baixa.

3.2. Específicos

- Identificar as espécies e calcular a produção de biomassa seca, riqueza e diversidade de frutos caídos na Floresta Nacional do Amapá.
- Determinar as principais variáveis que explicam a variação espacial da biomassa seca, riqueza e diversidade de frutos caídos na Floresta Nacional do Amapá.
- Mapear as predições de biomassa seca, riqueza e diversidade de frutos caídos na grade de amostragem da Floresta Nacional do Amapá.

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5. CAPITULO 1.

Patterns and predictions of fruit-fall biomass in a lowland Amazon forest

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Patterns and predictions of fruit-fall biomass in a lowland Amazon forest

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ABSTRACT

Fruit-frugivore interactions are a vital ecological component of Amazon forest biodiversity and fruit-fall biomass data provide insight into the spatial heterogeneity of resources for terrestrial frugivores and other consumers. Here we describe, explain and predict meso-scale fruit-fall patterns within a lowland Amazon forest. Fruit-fall data were collected from May and June of 2016 with a ground survey in 90 plots (total of 4.42 ha) distributed across a 25 Km^2 grid. Generalized additive models were used to explain and predict the spatial patterns of fruit-fall dry biomass, richness and diversity. Multi model selection was used to determine the relative importance of space, topographic, hydrographic and vegetation cover. We counted 21812 fallen fruits. This total included fruits of 86 species from 28 families and 51 genera. Considering combined totals from both months, the mean fruit-fall biomass was 44.84 Kg ha^{-1} month^{-1} (±45.13 SD); mean number of species fruiting 4.3 (±2.6 SD) and mean Shannon diversity index 0.84 (±0.5 SD). We found that spatial effects most strongly explained variation in fruit-fall patterns and that the contribution of spatial, topographic, hydrographic and vegetation variables differed between responses. Whilst it was possible to explain substantial proportions of deviance in the responses, spatially explicit predictions using remotely sensed variables did not return accurate estimates. In an age of rapid adoption of remotely sensed data, our findings suggest that fruit-fall patterns are one of the myriad below canopy components of Amazon forest diversity that will continue to require ground based data collection.

Keywords: Amapá, Digital Elevation Model (DEM), fruit-fall dry biomass, Guiana shield, Normalized Difference Vegetation Index (NDVI), Shannon diversity index (H’), terra firme forest.

5.1. Introduction

Fruit-fall is a highly dynamic component of tropical forest biodiversity. The unpredictability of fruit-fall across space and time means that we currently lack surrogates or models to predict fruit-fall distribution across Amazon forests. Yet, it is these very same spatial and temporal differences in fruit-fall that are such a critical component in structuring tropical forest biodiversity [1-4]. Despite their importance, fruit-fall patterns are one of the myriad below canopy components of Amazon forest diversity that have yet to be adequately explained or predicted.

Fruits are an important forest resource for both humans and a wide variety of frugivorous animals [2, 5, 6] and the majority of fruits from Amazon forest tree species are dispersed by animals [7-9]. Fruit-fall is the part of tropical forest fruit production that is not used by canopy frugivores [10]. The availability of fallen fruit therefore reflects not only reproductive phenology but also weather (wind and rain) and the plant-animal interactions with both canopy and terrestrial frugivores [4, 10-12].

Patterns in tropical forest phenology and overall fruit production are dynamic and vary across space, time and communities within and between species. Although patterns in overall production have been relatively well studied in several locations e.g. Cocha Cashu [4] and Barro Colorado island [8], there remain few fruit-fall data from across the Amazon basin. Fruit-fall biomass is also part of the carbon biomass cycle that is poorly studied in spatial distribution level. Fruit-fall contribute with the carbon cycle as a fundamental part of forests dynamics and ecosystems services. Identifying factors that influence meso-scale fruit-fall patterns are also necessary to define habitats of vertebrates and invertebrates that use these resources.

Systematic on-the ground measurements of fruit-fall over large areas, such as the Amazon basin, are expensive and highly unlikely. Here, we used a GAM framework to examine the relative importance of topographic, hydrographic and other environmental factors on meso-scale fruit-fall patterns in a lowland Amazon forest. This framework was used to address two main questions: what are the environmental factors that explain meso-scale patterns of fruit-fall biomass and taxonomic diversity? And, is it possible to predict meso-scale fruit-fall using freely available remotely sensed data?

5.2. Materials and Methods

Ethics Statement

Fieldwork and data collection was conducted under research permit numbers IBAMA/SISBIO 40355–1 and 47859-2to DN, issued by the Brazilian Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio).

5.2.1. Study area

We sampled fallen fruits at a Brazilian Program for Biodiversity Research (“Programa de Pesquisa em Biodiversidade” – hereafter PPBio, [13]) research grid (25 km^2) in Amapá National Forest (Floresta Nacional do Amapá – hereafter ANF). ANF is a sustainable-use protected area of approximately of 412,000 ha, centered in the state of Amapá, in north-eastern Brazilian Amazon between the Falsino and Araguari rivers (0°55’29’’N, 51°35’45’’W, Figure 1).

The regional climate is classified by Köppen-Geiger as Am (Equatorial monsoon) [14], with an annual rainfall greater than 2000 mm [15]. The driest months are September to November (total monthly rainfall < 150 mm) and the wettest months from February to April (total monthly rainfall > 300 mm) [15] (Figure S1). The ANF consists of continuous tropical rainforest vegetation, predominantly never-flooded closed canopy ‘‘terra firme” forest [16]. Canopy trees within the ANF typically reach a height of 25–35 m interspersed with emergent trees reaching up to 50 m [16].

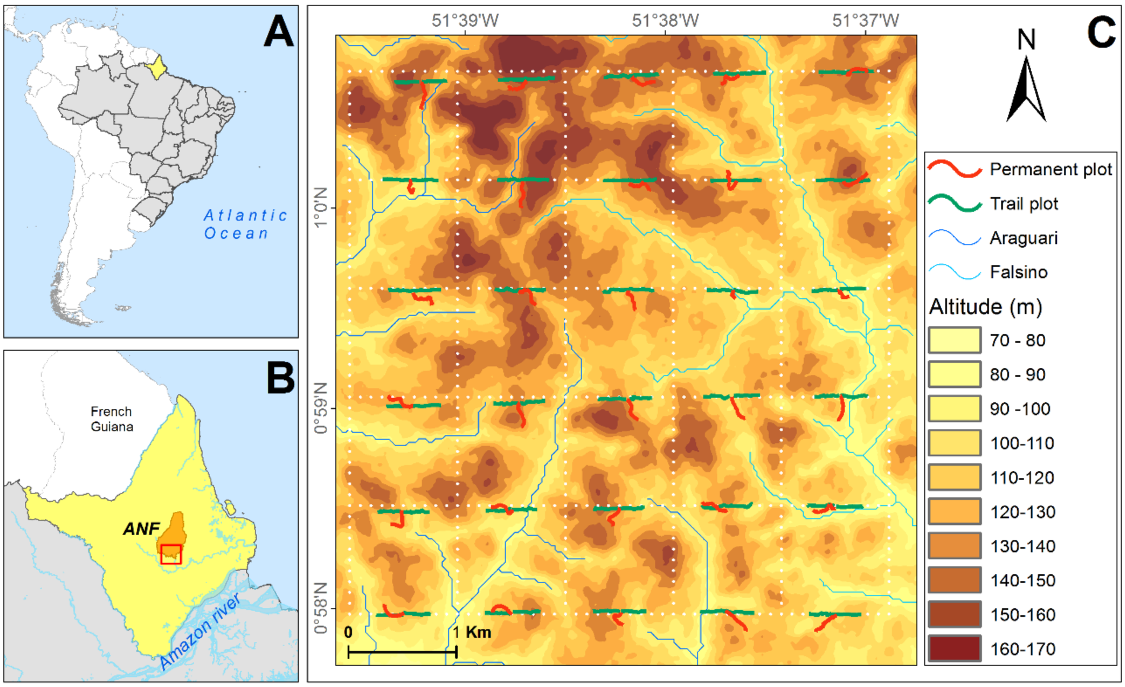

Figure 1. Location of the study site in Amapá National Forest (ANF), Amapá State, north-eastern Brazilian Amazon. (A) State of Amapá in Brazil. (B) Location of ANF in Amapá. (C) Elevation (10 m) across the grid system (white dotted lines); permanent and trail sampling plots (red and green solid lines respectively) where fruit-fall ground surveys were conducted.

5.2.2. Fruit-fall data collection

Fruit-fall ground surveys are a well-established, relatively efficient and straight forward method to assess fruit production in tropical forests and can reflect seasonal fruiting phenology well [10, 17]. Within the 25 km^2 PPBio grid, a total of 30 regularly spaced (1 Km intervals) points were sampled (Figure 1) [18]. This regular arrangement and sample size of 30, has been shown to be adequate for capturing variation in meso-scale species diversity responses across lowland Amazonia [19].

To coincide with the expected seasonal peak in fruit-fall for the region [20-22], two fruit-fall surveys were conducted in May and June 2016. Although fruit production (number and biomass) generally reaches a peak following the start of the rainy season [20, 22], in 2015 there was a six week delay to the expected increase in monthly rainfall (Figure S1) that coincided with a strong “El Niño” event. This delay in rainfall, also coincided with a delay in fruiting in the study area (D. Norris pers. obs.). At each of the 30 sample points, surveys were conducted along three plots (one permanent plot and two trail plots). The permanent plots (250 m long) are nonlinear and follow altitudinal contours to minimize the internal variation in both altitude and correlated covariates such as soil type [13, 18]. Additionally, we sampled two linear trail plots (250 m each), one before and the other after the start point of the permanent plots (Figure 1). Fallen fruit were sampled 1 m to each side of the plot centerlines i.e. covering a total area of 500 m^2 (2 × 250 m) for the linear trail plots. This effort provided a total sampled area of 4.42 ha (plot area m^2 mean ±SD = 490.7 ±46.9).

To obtain robust and reproducible estimates of fresh fallen fruit we established a number of inclusion and exclusion criteria (Figure 2). The counting and collection of fruits was carried out according to the following criteria [11]: all fresh (i.e. not rotten or desiccated) fallen fruits were counted. Fruits considered unlikely to change in appearance (i.e. *Vouacapoua americana*, *Apeiba sp*, *Hevea brasiliensis*) were removed in order to avoid counting the same fruit twice. Fresh fruits that had been partially eaten were also counted (Figure 2).

To obtain dry fruit biomass estimates the mean dry weight from a maximum of 30 mature fruits of all fallen fruit species was calculated (Table S1). Fruits with seeds beginning to germinate were not weighed [23]. The collected fruits were dried to constant weight in an oven at 50 °C [24] and then weighed with a precision balance (fruits < 10

g) or digital balance with error ±0.01 g (fruits > 10 g). The fruits sampled (Table S1) were identified to the lowest taxonomic level and named following APG III [25] by botanists from the Amapá State Scientific Research and Technology Institute (Instituto de Pesquisas Científicas e Tecnológicas do Estado do Amapá, IEPA).

Fruit-fall dry biomass (FFB) and taxonomic diversity (richness (S) and Shannon diversity (H')) were selected for this study in order to represent important responses in fruit biodiversity in the study area. Values of fruit-fall dry biomass were expressed as kg ha^{-1} $month^{-1}$ for each plot. S was calculated as the total number of observed species per plot.

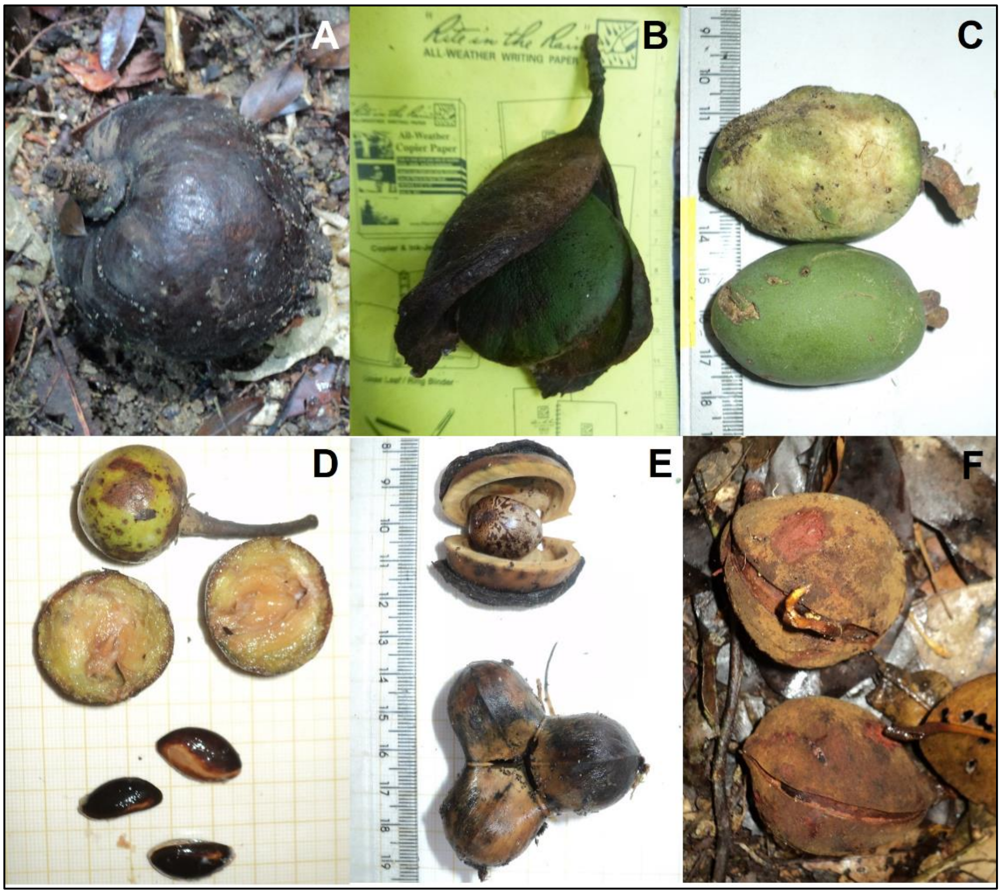

Figure 2. Examples of criteria of fruit-fall status survey. Not collected and not counted: (A) Fusaea longifolia (Annonaceae) rotten fruit; (B) Vatairea guianensis (Fabaceae) dried fruit. Counted: (C) Dipteryx odorata (Fabaceae) partially eaten and fresh counted not collected (partially eaten fruit was just counted); (D) Manilkara huberi (Sapotaceae)

collected and counted, fresh fruits and seed collected to weigh; (E) Hevea brasiliensis (Euphorbiaceae) counted and removed to avoid repetitive sampling; (F) Vouacapoua Americana (Fabaceae) counted and removed. Germinating fruits not collected for weighing and also not counted after second sampling.

5.2.3. Environmental explanatory variables

Remote sensing data represent continuous measurements of environmental variables that can be applied in ecological studies [26-29]. To explain and predict patterns in fallen fruit we used a total of nine remotely sensed variables (Table 1). These remotely sensed variables were selected to represent meso-scale patterns in topography, hydrography and vegetation cover. To ensure consistency in projections and analysis with the different data sources all raster variables were projected to a Mercator equal area projection, then clipped using a 500 m buffer around the ANF survey grid (downloaded from: https://ppbio.inpa.gov.br/mapas).

Table 1. Summary statistics of explanatory variables data used for models (90 plots) and of ANF survey grid in 92 and 250 m spatial resolution (4422 and 625 pixels respectively)

	Variable (units)	Source[a]	Grid[b]	Plots values[c]		Study area values 92 m		Study area values 250 m		Correlates	Ecological Relevance
				Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range		
Topography	**Altitude** (m)	DEM	92	120 (12.6)	94 - 154.7	117.2 (14.5)	67.0 – 182.0	117.1 (13.4)	75.0- 164.8	HAND (**0,78**) SWI(-0,627)	Altitude above sea level/floristic structure and composition
	Slope (%)	DEM	92	7.6 (2.6)	1.9 - 16.7	7.7 (3.1)	1.3- 19.1	3.4 (1.9)	0.01 – 11.1		Topographic morphometry
	Aspect (Degree)	DEM	92	181.8 (65.3)	53.1 - 337.6	186.9 (69.2)	21.1 - 347.1	183.2 (59.6)	27.3 - 332.2		Symmetric wetness/radiation index
Hydrography	**TWI** (None)	DEM	92	13.5 (2.0)	8.3 - 18.7	13.7 (4)	2.3 - 23.6	13.7 (1.7)	9.4- 20.2		Topographic wetness index/floristic structure and composition
	SWI (None)	DEM	92	7.5 (0.8)	5.3 - 9.2	7.5 (0.8)	5.2 – 9.2	7.6 (0.9)	5.1 – 9.7	Slope (-0,629)	
	HAND (m)	DEM	92	15.4 (8.9)	0.4 - 39.4	14.9 (11.1)	0.0 - 62.5	15.0 (9.3)	0.1 – 48.8	HDND (0,64)	Distance to de nearest channel/ soil properties
	HDND (m)	DEM	92	453.2 (297.9)	44.3 - 1593.3	445.0 (322.7)	0.0 – 2608.0	454.3 (314.1)	52.8- 2459.9		
Vegetation	**AGLB**[d] **(Mgha^{-1})**		30	281.8 (25.8)	203.0 - 322.5	277.1 (30.3)	31.0 - 328.8	276.9 (23.1)	157.3 - 314.3		Above ground live biomass
	NDVI (-1 to 1)	MODIS	250	0.57 (0.06)	0.37 - 0.71	0.57 (0.06)	0.37 - 0.74	0.57 (0.06)	0.37 - 0.74		Vegetation cover

a Remote sensed data source.

b Native cell resolution (meters) of raster grid.

c Values calculated with rasters resampled at 92 m spatial resolution.

d Derived from MODIS, imagery using GLAS (Geoscience Laser Altimeter System) LiDAR data, see Baccini, Goetz (30) for technical details.

5.2.3.1.Topography

Topographic data were obtained from the Shuttle Radar Topography Mission, U.S. Geological Survey (http://srtm.usgs.gov/). The SRTM digital elevation model-DEM [31] was supplied at three arc-seconds (92 m approx.) pixel size and 1 m altitudinal resolution (downloaded from: http://earthexplorer.usgs.gov/). Two predictors were derived from elevation to represent the form and shape of the surface: slope (percent) and aspect (degrees) (Table 1). These variables were used to explain fruit-fall patterns based on previous studies in species distribution models [27, 28, 32-34] because species occurrence and spatial patterns could be influenced by adaptive characteristics and habitat preferences of topography.

5.2.3.2.Hydrography

Hydrographic variables represented the spatial distribution of water bodies and associated features important for plant-soil interactions such as Topographic Wetness Index (TWI), height above nearest drainage (HAND) and horizontal distance to the nearest drainage (HDND).

Topographic Wetness Index (TWI) calculates the capacity of water accumulation of each pixel in a watershed using a DEM [35] considering topography as the dominant factor that controls water flow. TWI is calculated for each pixel (with D8 algorithm proposed by Beven and Kirkby (35)) using slope and drainage area as follows: TWI = ln (AS/tan b) where AS is the drainage area (in m^2) and b is the local slope gradient (in %). SRTM-DEM was used to calculate AS and b values. There are other methods derived from the D8 index [36], but for all algorithms, pixels with higher TWI values have higher capacity of water accumulation.

Height above the nearest drainage (HAND) algorithm was developed by Rennó, Nobre (37) and calculates the vertical distance between points on the terrain and their nearest drainage, based on the SRTM-DEM. HAND indicates the water gravitational potential, that is, a component of the soil water potential, which reflects the difficulty for plants to extract soil water or to avoid excess water [38]. High values are high vertical draining potential and low values indicate proximity to the water table, where the lack of drainage leads to waterlogging [39]. The most important step in the calculation of HAND is the definition of the drainage network density because this is the base for the calculations of terrain vertical distances from drainage [39]. This step needs field calibration for the establishment of the headwaters, which is defined by the minimum-contributing-area threshold. We used a minimum contribution area of 0.25 km^2 and validated several small streams and headwaters along the trail system in the field using a handheld GPS.

Horizontal distance from nearest drainage (HDND) is a proximity attribute that provides information on the relative position of cells to the bottoms and are usually related to soil drainage [40]. Areas horizontally close to streams are also more likely to waterlog and to receive sediment deposits from streams [38].

5.2.3.3.Vegetation

We used two variables to represent patterns in vegetation cover in the study area: normalized Difference Vegetation Index (NDVI) and aboveground live woody biomass density (ALGB). NDVI is an indicator of vegetation greenness is defined as the difference between the Near-Infrared (NIR) and Visible (VIS, generally red) bands divided by their sum of satellite images [41]. The NDVI plays an important role in vegetation monitoring and others like extraction of phenological parameters. We used the monthly L3 Global (MOD13Q1) NDVI dataset [42] from the Moderate Resolution Imaging Spectroradiometer - MODIS satellites (250 m pixel size, available in: https://reverb.echo.nasa.gov). To characterize the vegetation conditions more reliably, we averaged NDVI values for six months (from January to June of 2016, total of 10 images). This step improved the quality of the data by filtering out cloud cover and reducing noise in the NDVI data. ALGB values were obtained from a medium (30 m) resolution pan-tropical data product [43], available from http://data.globalforestwatch.org.

5.2.4. Processing explanatory variables

All explanatory rasters were processed in SAGA 2.1.2 (System for Automated Geoscientific Analyses) (http://www.saga-gis.org/en/index.html), with help of R packages: *RSAGA* version 0.94-5 [44], *raster* [45], *maptools* [46], *sp* [47] and *ggplot2* [48]. NDVI originally in 250 m was resampled to 92 m spatial resolution using bilinear interpolation in order to stack with other variables and obtain mean plot values. AGLB was also resampled to the DEM resolution (from 30 to 92 m pixel resolution) using a cell area weighted interpolation method. Two indices with different algorithms were calculated with ‘Terrain Analysis – Hydrology’ module: Topographic wetness index-(TWI) with multiple flow algorithm FD8 [49] and the SAGA wetness index (SWI) [50]. The multiple flow direction algorithm (FD8) allows a split of flow according to the slope gradient of each eight directions corresponding to the neighboring cells. SWI is an algorithm based on a multiple flow direction method, weighing the catchment area value by a function of the slope angle and the maximum values of neighboring pixels in the catchment area smoothing the index value in flat areas. Then, SAGA module “Overland flow distance to channel network” was used to calculate HAND and HDND. “Grid statistics for polygons” tool was used to transform rasters derived explanatory variables from DEM and AGLB in polygons with the mean values to 250 m pixel. Then polygons were rasterized to the final explanatory rasters of 250 m pixel to maintain consistency with NDVI layer for predictions. We extracted all environmental predictive values from the raster of 92 m (with bilinear interpolation, 4422 pixels in total study area) (Figure S2) for 25 locations along the permanent and trail plots survey centre lines and calculated de mean of this values for the 90 plots (Table 1) and used the data for subsequent GAMs.

5.2.5. Spatial model development

To examine the environmental factors affecting fruit-fall spatial patterns of dry biomass (FFB), richness (S) and diversity (H’), Generalized Additive Models (GAMs) were employed [51, 52]. GAMs are a nonparametric extension of general linear models that provide the flexibility to model non-parametric and nonlinear relationships that are typical of many ecological patterns. Response variables were tested for spatial autocorrelation with Moran’s I test (Table 2). Moran’s I values normally range from -1.0 (regular distribution) to +1.0 (aggregated distribution) [53]. We also calculated species accumulation curves, which present the number of species accumulated for each additional plot.

Table 2. Summary statistics of fruit-fall biomass and taxonomic diversity.

Response variable		Units	Range	Mean (±SD)	Moran's I Index	Z (p)
Fruit-fall dry biomass	FFB	Kg ha^{-1} Month^{-1}	0.0 - 194.6	44.84 (±45.1)	0.35	2.91 (0.003)
Richness	S	N° Species plot^{-1}	0.0 – 12.0	4.3 (±2.6)	-0.04	-0.21 (0.834)†
Shannon Diversity Index	H'	None	0.0 - 1.9	0.84 (±0.5)	0.21	1.74 (0.082)

Significance values: †not significant, $p < 0.10$, $p < 0.01$.

Response variables were modelled with the Tweedie error distribution family and a log link function [54]. GAMs were generated using the "mgcv" package [52] using R 3.10 software [55]. Penalized cubic regression splines determined the shape of nonparametric functions, with the degree of smoothing selected automatically via maximum likelihood using the mgcv package defaults for all models.

To avoid subjective bias in model development we did not examine correlation among variables until after formulation of our a priori models. We applied a two stage approach to examine patterns and obtain predictions for the three fruit-fall responses. Firstly, separate models were developed to examine the effects of space (latitude and longitude with a two-dimensional interaction smoother), topography, hydrography and vegetation (Table 3).

Table 3. A priori models and formulas applied for each response variable: Fruit-fall dry biomass (FFB), richness (S) and Shannon diversity index (H').

Model	**Model**	**Formula**
1	Space only	Response ~ s(Latitude, Longitude)
2	Topography	Response ~ s(Altitude) + s(Slope) + s(Aspect)
3	Hydrography	Response ~ s(HAND) + s(HDND) + s(TWI) + (SWI)
4	Vegetation	Response ~ s(AGLB) + s(NDVI)
5	Full	Response ~ s(Latitude, Longitude) + s(Altitude) + s(Slope) + s(Aspect) + s(HAND) + s(HDND) + s(TWI) + s(SWI) + s(AGLB) + s(NDVI)

Within each of our four models, explanatory variables were tested for collinearity. The explanatory power of the models was tested and compared within a maximum likelihood framework using a combination of model deviance explained and information criteria (AIC and BIC) [52, 56].

Secondly, we predicted the meso-scale patterns (250 m spatial resolution, a total of 625 pixels in the study area) in the three responses across the study area. Predictions were obtained using the most parsimonious ("best") model, with the most important predictors selected using a manual backward stepwise selection based on minimizing AIC values. Manual selection started from the full model without correlated variables, with stepwise exclusion of variables if they did not make a statistically significant ($p \geq 0.05$) contribution [57]. Finally, to compare the accuracy of model predictions, the predicted values for each model were extracted and the root mean square error (RMSE) calculated.

5.3. Results

We counted 21812 fallen fruits with a diameter ≥ 1 cm in the ANF survey grid between May and June 2016. This total included fruits of 86 species from 28 families and 51 genera. It was possible to identify 81 (94.1%) to species and 95.3% to genus and family level (Table S1). Fabaceae was the most species rich family with 24.4% of collected species, followed by Sapotaceae (12.7%) and Lecythidaceae (8.1%). Fabaceae presented also the most genus, 12 in total, followed by Sapotaceae, Lecythidaceae, Euphorbiaceae, all with three genus each (Figure 3.A). Excluding unidentified species, 14 (50 %) families were represented by just one genus (Caryocaraceae, Elaeocarpaceae, Chrysobalanaceae, Passifloraceae, Sterculiaceae, Sapindaceae, Logaginaceae, Bombacaceae, Melastomataceae, Polygalaceae, Meliaceae, Vochysiaceae, Clusiaceae, Tiliaceae, Ebenaceae, Ochnaceae and Humiriaceae).

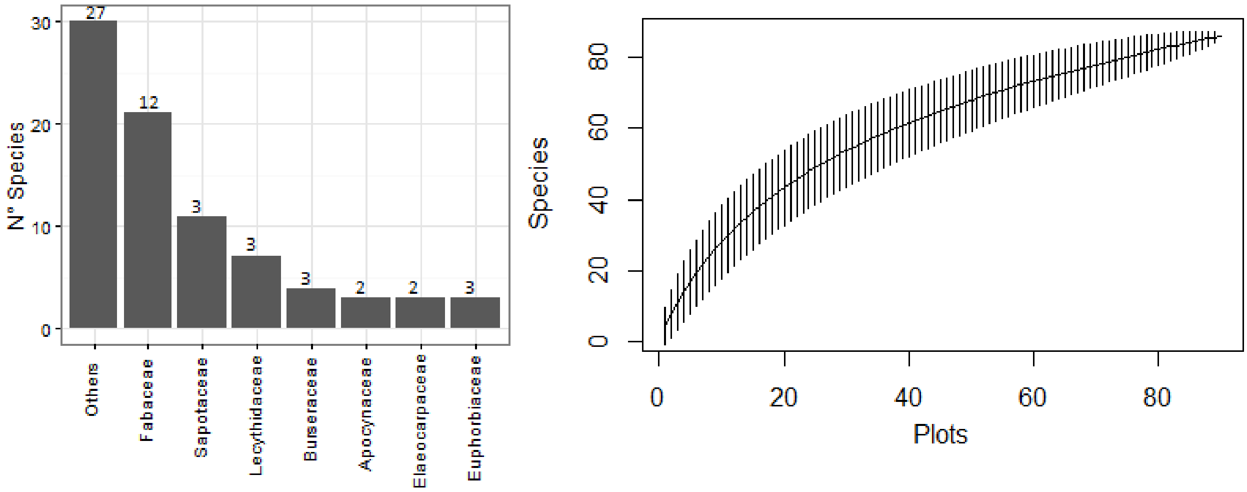

Figure 3. (A) Number of species and genus (number above of bar) of main families with fallen fruits collected in wet season in ANF. (B) Species accumulation curve of fruit-fall in ANF grid sampling.

The species accumulation curve did not reach an asymptote (Figure 3.B) and there was substantial variation in the number, taxonomic diversity and biomass of fallen fruit between the 90 sampled plots (Table 2, Table S1). No fallen fruits were recorded in three plots considering both months, whereas approximately 30% of plots had no fallen fruit each month (10 plots in May and 11 in June, Table S2). Considering combined totals from both months, the mean fruit-fall biomass was 44.84 Kg ha^{-1} month^{-1} (±45.13 SD); mean number of species fruiting per plot (S) 4.3 (±2.6 SD) and mean Shannon diversity index (H') 0.84 (±0.5 SD). *Vouacapoua americana* (Fabaceae) was the most commonly recorded species (detected in 62 of the 90 plots), accounting for 43% of the 21812 counted fruits (Table 4). In contrast, the sum of three next most abundant species accounted for less than 20% of the fruits counted (*Euterpe oleracea* (8.2%), *Geissospermum sericeum* (4.7%), *Manilkara huberi* (4.6%)). The four species most widely recorded in plots were *V. americana, M. huberi, Licania sp1* and *Inga capitata* (62, 17, 14 and 13 plots respectively). A total of 33 species were recorded in only a single plot (Table S1).

Overall fruit-fall biomass was dominated by *V. americana* (64%) followed by *Caryocar villosum* (5%) and *Clusia grandiflora* (3%). The mean fruit-fall dry biomass more than doubled from May to June (25.8 Kg ha^{-1} (±35.2 SD), 63.8 Kg ha^{-1} (±75.3 SD), May and June respectively, Figure S3.A).

Table 4. Distribution analysis of main fruit-fall species collected. B = Biomass in Kg ha^{-1}; N = Number of fruits; P=Number of plots; RA= Relative abundance; RF= Relative Frequency; RD= Relative dominance calculated with biomass; IVI = Importance Value.

Species	**B**	**N**	**P**	**RA**	**RF**	**RD**	**IVI**
Vouacapoua americana	57.8	9425	62	43.2	15.9	64.1	123.2
Manilkara huberi	0.8	1008	17	4.6	4.4	0.9	9.9
Euterpe oleracea	0.5	1786	3	8.2	0.8	0.6	9.5
Geissospermum sericeum	0.7	1027	11	4.7	2.8	0.8	8.3
Inga capitata	1.8	407	13	1.9	3.3	2.0	7.2
Clusia grandiflora	2.7	282	11	1.3	2.8	3.0	7.1
Caryocar villosum	4.5	151	4	0.7	1.0	5.0	6.7
Licania sp1	1.4	263	14	1.2	3.6	1.5	6.3
Vochysia rufescens	0.1	834	7	3.8	1.8	0.2	5.8

Moran’s I test for spatial autocorrelation showed statistically significant p-values for Fruit-fall biomass (FFB) and Shannon Diversity Index (H’) which describe a cluster pattern whereas Richness (S) was random distributed features in study area (Table 2; Figure S3.B).

Most of the explanatory variables were weakly correlated (Pearson r ≤ 0.69) (Table 1). The highest correlations were observed for the relationship between Altitude and HAND (0.78), but these were retained in different models (topography and hydrography) as they represent distinct ecological components. Interestingly the correlation between altitude and the derived variables was low (< 0.37) indicating the potential importance of altitude as an explanatory and predictor variable independent of aspect, TWI or slope.

Space was the most important model for explaining patterns in biomass and taxonomic diversity of fallen fruits (Table 5). Hydrography was the second most important model for explaining patterns in biomass (16.9 %) and H’ (7.23 %) and S (8.1 %).

Table 5. Summary of GAMs results for each model and for each response and parameters used for model selection.

Response	Model	ML[a]	Var[b]	R2	DE (%)[c]	AIC[d]	BIC[e]	RMSE[f]
Fruit-fall Biomass	Space only	429.7	2	0.28	29.2	867.4	907.8	36.3
	Topography	432.6	3	0.08	10.2	875.6	893.9	46.2
	Hydrography	431.9	4	0.13	16.9	869.2	890.5	42.4
	Vegetation	434.2	2	0.09	12.8	877.0	901.1	50.7
	Full	426.3	11	0.25	33.1	857.4	893.2	37.4
	Best	**426.1**	**7**	**0.31**	**40.0**	**856.9**	**906.4**	**38.4**
Best Formula: FFB ~ s(Lat. Long) + s(HAND) + s(HDND) + s(Slope) + s(Aspect) + (NDVI)								
Richness	Space only	145.0	2	0.18	23.3	584.9	614.4	2.3
	Topography	150.3	3	0.04	6.3	663.3	680.0	2.7
	Hydrography	149.3	4	0.06	8.1	650.1	666.1	2.5
	Vegetation	150.5	2	0.04	6.2	664.2	680.8	2.6
	Full	143.8	11	0.21	26.4	568.2	601.5	2.4
	Best	**143.4**	**5**	**0.23**	**28.5**	**550.3**	**592.0**	**2.4**
Best Formula: S ~ s(Lat. Long) + s(Slope) + s(HDND) + s(AGLB) + (NDVI)								
Shannon Diversity Index	Space only	80.7	2	0.08	8.73	171.8	193.1	0.49
	Topography	80.6	3	0.04	4.14	169.2	180.6	0.52
	Hydrography	80.1	4	0.07	7.23	168.5	183.4	0.49
	Vegetation	81.2	2	0.03	2.62	171.0	182.7	0.51
	Full	79.9	11	0.11	12.8	169.7	194.6	0.51
	Best	**79.9**	**5**	**0.11**	**12.8**	**169.7**	**194.6**	**0.50**
Best Formula: H’ ~ s(Lat. Long) + s(Slope) + s(TWI) + s(AGLB)								

The relationship with individual predictors also differed between descriptors of fruitfall. Results from the best models indicated a significant positive linear relationship between fruit-fall biomass and HAND (Figure S4). In addition, response plots also showed a significant nonlinear (U shaped) relationship between biomass and horizontal distance from the channel network (Figure S4). The number of fallen fruit species tended to increase linearly with NDVI but tended to decline with AGLB (Figure S4). Finally, diversity tended to increase linearly with slope and decreased with increasing AGLB.

A combination of spatial, topographic, hydrographic and vegetation covariates were retained as important predictors of fruit fall biomass and diversity (Table 5). Richness predictions were correlated with both diversity and biomass values (Pearson's r = 0.69; 0.52 respectively), whereas biomass was only weakly correlated with diversity (Pearson's r = 0.26). While there were visible differences in the spatial patterns of the three responses, predictions of all three tended to increase along a geographic (east-west) gradient (Figure 4). The mean RMSE of model predictions (Table 5) were similar to the observed SD values (Table 2) for all three responses.

5.4. Discussion

Here we describe, explain and predict meso-scale fruit-fall patterns across 25km^2 of lowland Amazon forest. We found that spatial effect, which are probably a reflection of soil patterns associated to drainage, most strongly explained variation in fruit-fall patterns and that the contribution of spatial, topographic, hydrographic and vegetation variables differed between responses. Whilst it was possible to explain substantial proportions of deviance in the responses, spatially explicit predictions using remotely sensed variables did not return accurate estimates. We discuss these findings in relation to what is known regarding fruit-fall patterns across lowland Amazonia and then consider the implications for understanding patterns in diversity below the forest canopy.

5.4.1. Fruit-fall patterns

Even though the species accumulation curve did not reach an asymptote, our sample provides a representative snapshot of fruit-fall patterns across the 25km^2 study area. The composition of families and species follows the general pattern found in nearby forest sites and across the Guiana shield [20, 24, 58-61]. We found fallen fruits from four (*Crhysophyllum*. *Licania*. *Protium* and *Eschweilera*) of the five most abundant genus that Pereira, Sena (60) found in 1.9 ha of nearby (32 km distant) lowland terrra-firme forest. Fabaceae was also the dominant family in a recent inventory of large (> 40cm DBH) trees. close (<30 km) to our study area [58]. These authors found at total 201 species distributed in 37 families from a 80 ha sample area, which is only 9 more families than our much smaller (4.2 ha) sample area. This could be explained by the short of time of sampling, that clearly not cover all phenology patter of tropical forest, but represent a midterm in the transition of the most and less productive months according the observations of the locals with live in the zone for more than 40 years.

Knight (62) indicates that Shannon diversity Index in tropical forest range from 3.84 to 5.85. Our results show low values for diversity [60, 61], as was expected because we have to consider that this was calculated with only fruit-fall abundances (See Table S1). Hence, the estimates of fruit-fall response represent only a subsample of the overall tree diversity.

Fruit-fall biomass was similar to values reported by studies from the Guianan Shield. In the most productive month in the rainy season, Sabatier (20) reported a mean of 50 Kg ha^{-1} of fruit-fall production, and 86 % of species producing fruits during this season. The less productive soils of the Guianan Shield result in lower values of arboreal species richness [63, 64]. This pattern also appears to be reflected in fruit production [65], with values from French Guyana (292 Kg ha^{-1} annual fruit-fall dry biomass) less than half those reported from western Amazonia (e.g. 796 Kg ha^{-1} of annual fruit-fall dry biomass, Cocha Cashu, Peru) [65]. Furthermore. Rodrigues, Furch (12) compared the litter fall in primary and secondary terra firme forest in the central Amazon, and report 291 Kg $ha^{-1}yr^{-1}$ and 439 kg $ha^{-1}yr^{-1}$ of fruit-fall production, respectively. Previous studies provide live tree aboveground dry biomass estimates of 434 Mg ha^{-1} (95% CI: 293.9–763.4 Mg ha^{-1} 1) from 45 permanent tropical forest plots in the Guianan Shield [66]. Based on our plotwise monthly mean estimate, we can obtain a maximum value of 538.1 kg ha^{-1} yr^{-1} (44.84 Kg ha^{-1} $month^{-1}$ x 12). Therefore, annual fruit-fall represents a maximum of 0.18% of the aboveground biomass of ANF (0.538 / 292.9).

We found that fruit-fall can be dominated by few species. whose reproductive phenology responds to climatic drivers. Clearly a single species *V. americana* was the main source of fruit-fall. with 9425 fruits counted. Fruiting in this species has been characterized as 'mast-fruiting' triggered by distinct climate events [67]. Similarly, the abundant Lecythidaceae (including Eschweilera spp) have been shown to present synchronous fruiting, which is precluded by increased flowering during prolonged dry spells [20, 22]. Such hyperdominance in meso-scale fruit production may contribute disproportionately to the spatial and temporal variation that is characteristic of tropical forest-fruit fall.

5.4.2. Predicting fruit-fall patterns

Several studies have used remote sensing data to create accurate models of predictions of tropical forest carbon or biomass in diverse scales [68-75], but such approaches have not been applied to fruit-fall biomass. Predictive variables for fruit-fall biomass present similar patterns to models used for predicting AGLB and carbon even using different methods. NDVI presented a positive linear relationship with fruit-fall, which follows patterns from modelled estimates of carbon stock [68] and biomass [75]. Additionally, fruit-fall biomass increased with vertical distance to channel network but was not affected by slope (Figure S3) similar of de Castilho, Magnusson (76). Furthermore, the remotely sensed explanatory variables appear unsuitable to predict fruit-fall richness and diversity. Other environmental drivers such as climatic, soil fertility and/or additional vegetation variables may be required.

There are a number of (not mutually exclusive) alternative factors that may affect the strength of the relationship between predictor and fruit-fall response variables. For instance, the selection of Algorithm for derivate variables and DEM resolution might influence the explanatory power of the predictor [77-79]. It is also known that models (including GAMs) will not always extrapolate well [80]. The important issue is that predicting to unsampled regions of the environmental space is inherently risky, and model uncertainty as well as predictions should be mapped and carefully assessed [81]. The maps presented (Figure 4) are a useful base for visualizing the environmental space in more than one dimension and for understanding the predicted responses in the 25 Km^2

study area. However, comparison with fruit-fall patterns in other lowland sites is necessary to enable more rigorous model testing and evaluation.

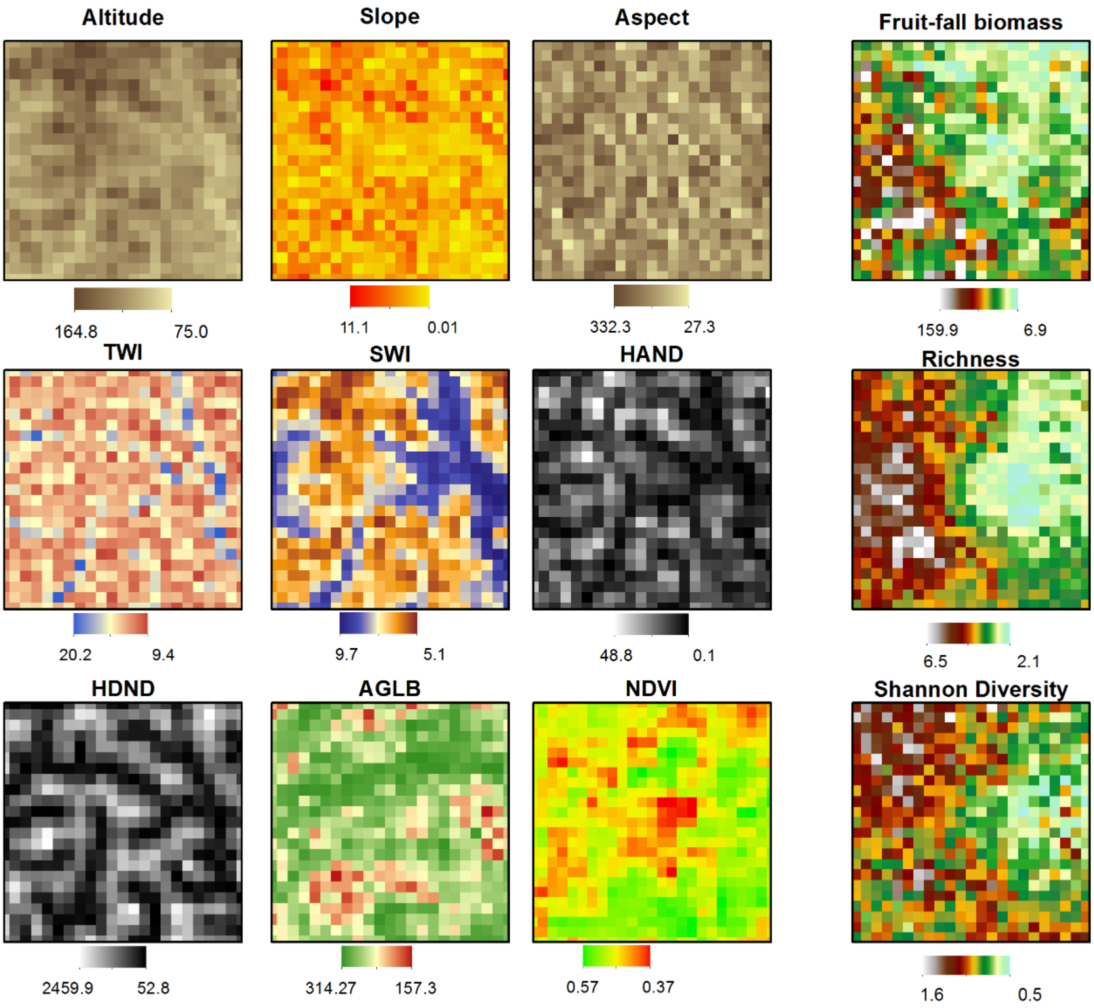

Figure 4. Explanatory variables and GAMs interpolations predictions for each response variables at 250 m pixel resolution for ANF grid sampling.

Fruit-fall patterns are an important ecosystem service that have been not considered in general projections of biomass and carbon models [30, 69, 75, 82]. Fruit-fall is fundamental for local and meso scales processes that involve frugivores and seed dispersal to maintain ecological processes and forest diversity [83, 84]. As remark by Stevenson (2001), fruit availability, estimated by fruit-fall, positively affected the biomass and the number of species among frugivorous primates. It is therefore important to monitor fruit-fall along at least a complete year to provide robust estimates of biomass in all seasons. Our model predictions show that field data collection will be necessary to generate these robust estimates. These estimates will improve our knowledge about what is being actually conserved and where we can find it within the protected area.

5.5. Conclusion

We found that HAND. HDND and NDVI proved to be useful environmental explanatory variables for modelling the distribution of fruit-fall dry biomass. More generally this study shows remotely sensed variables have potential for predicting meso-scale fruit-fall biomass. More studies with spatial distribution of species with suitability habitat approaches based on fruit-fall record on other habitats are required to assess the potential distribution and status of conservation of the principal plant and frugivores species conserved in ANF.

Conflict of interest

The authors declare that they have no conflict of interest.

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5.8. Supporting information captions

Figure S1. Study area rainfall.

Figure S2. Raster and distribution of 92 m spatial resolution of explanatory variables used to get the mean values for each plot.

Figure S3. (A) Distribution of fruit-fall dry biomass per type of plot. per month and per basin.). (B) Spatial distribution of response variables.

Figure S4. Response plots of explanatory covariates on fruit-fall patterns as analysed with generalized additive models (GAM). Shaded areas on each plot indicate 95% c.i. of smoothed response curves. The isopleths on the contour plot indicate the additive effects of the interaction between latitude and longitude position.

Figure S5. Field guide of fruits found in Amapá National Forest between September-November of 2015. and from Abril to July of 2016. Complete version available for free download in: https://www.researchgate.net/publication/312318151_Fruits_of_Amapa_National_Forest.

Table S1. Biomass. abundance and frequency of fallen fruits species found in May and June at ANF. Abundance defined as the number total of records. Frequency defined as number of plots where species were recorded.

Table S2. Environmental variables and response variables per plot. Area was calculated in ha with the longitude of the plot.

Fallen fruits were collected during the end of the wet season (May – June 2016. Fig. S1). During the survey period total monthly rainfall was 310 and 219 mm (monthly totals for May and June respectively).

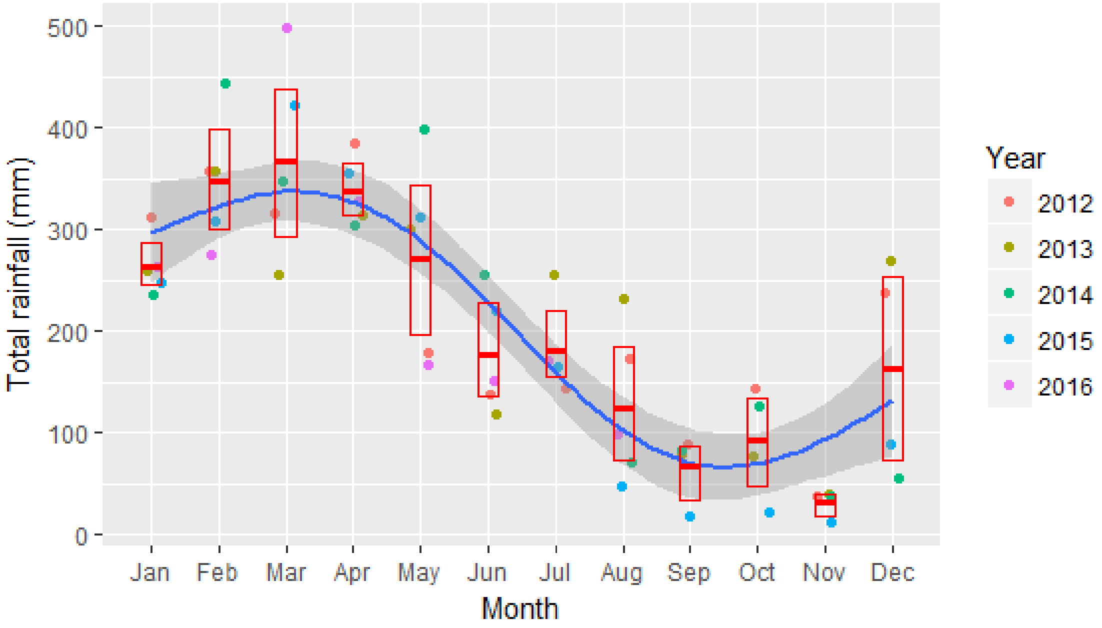

Figure S1. Monthly rainfall recorded close (36 Km) to the Amapá National Forest study site. Weather station data available from the Brazilian National Water Agency (station ID: 8052000. ANA 2016). Monthly totals are presented from five years (2012. 2013. 2014. 2015 and 2016). Boxplots show means and 95% confidence limits estimated via nonparametric bootstrap. The blue line and shaded areas are the mean value and 95% confidence intervals from a GAM model illustrating the trend in rainfall.

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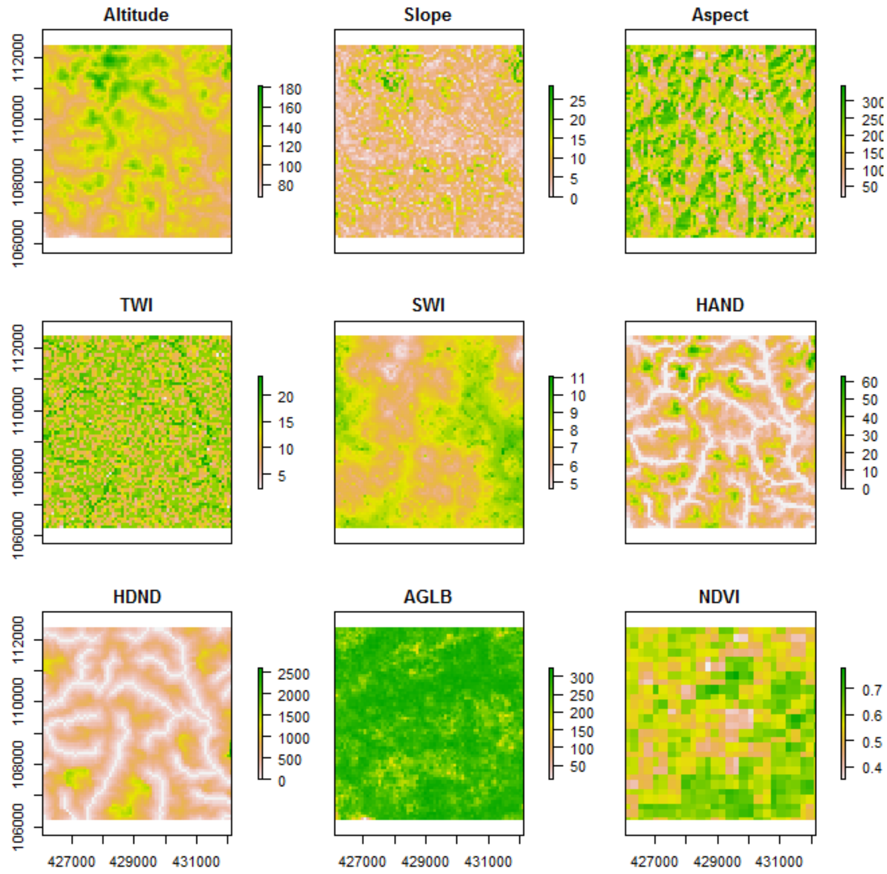
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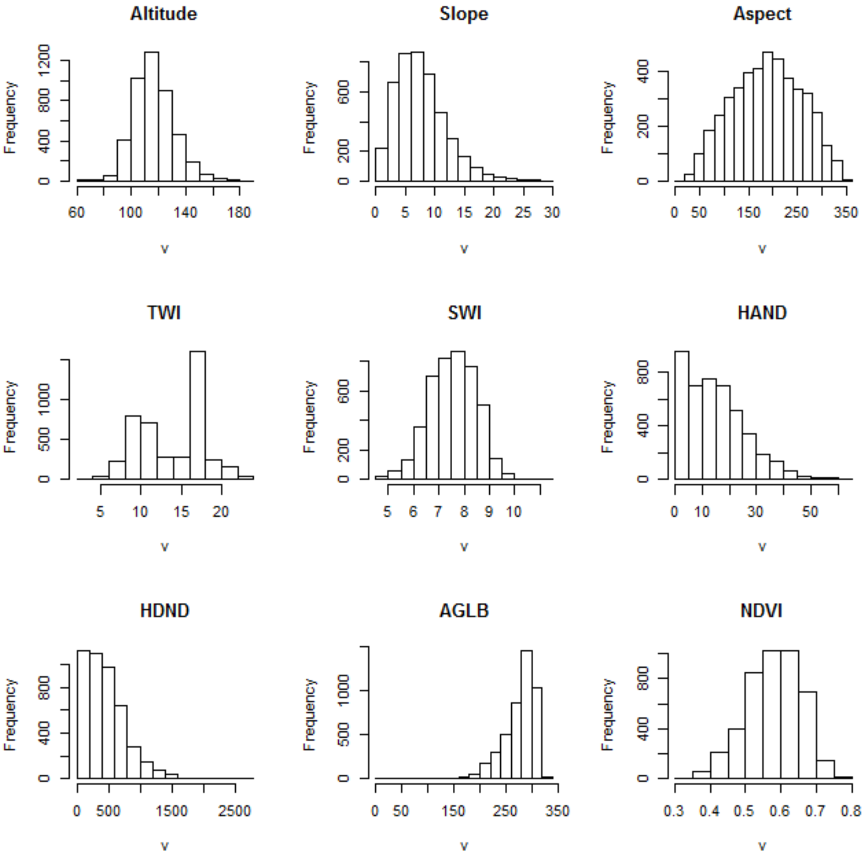
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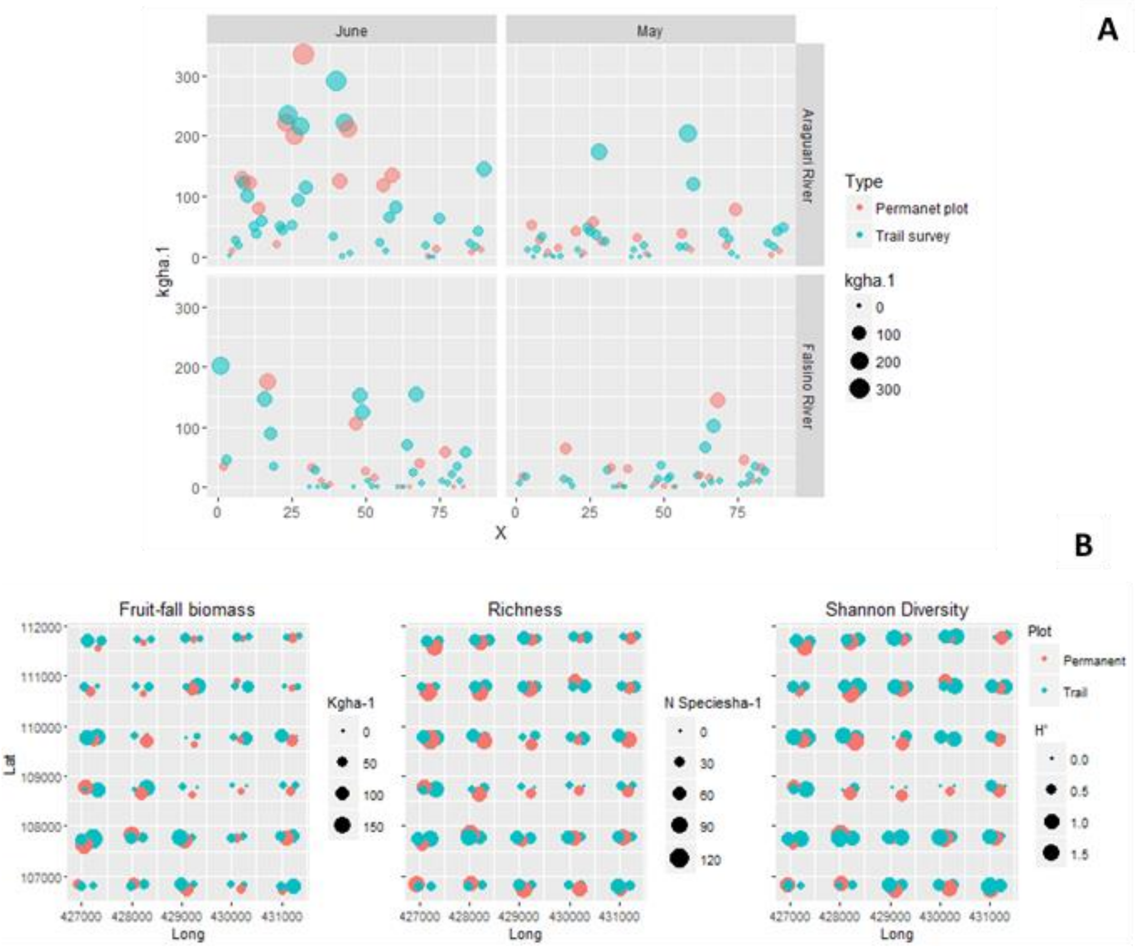
A
June
May
Araguari River
Falsino River
kgha.1
X
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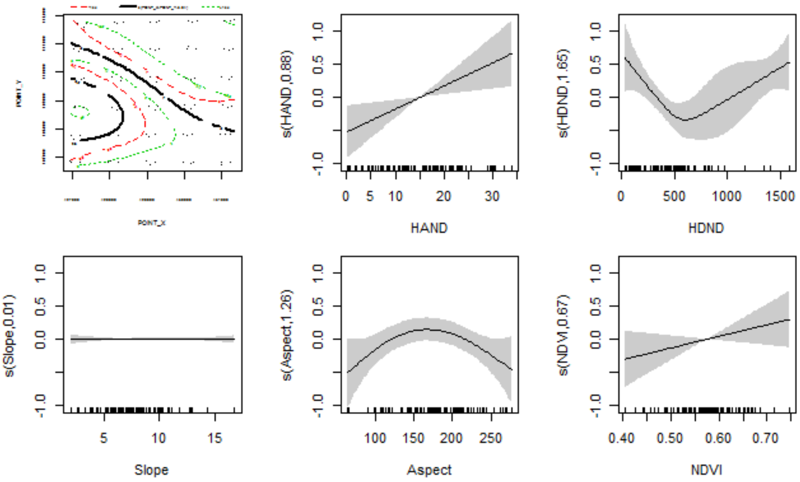
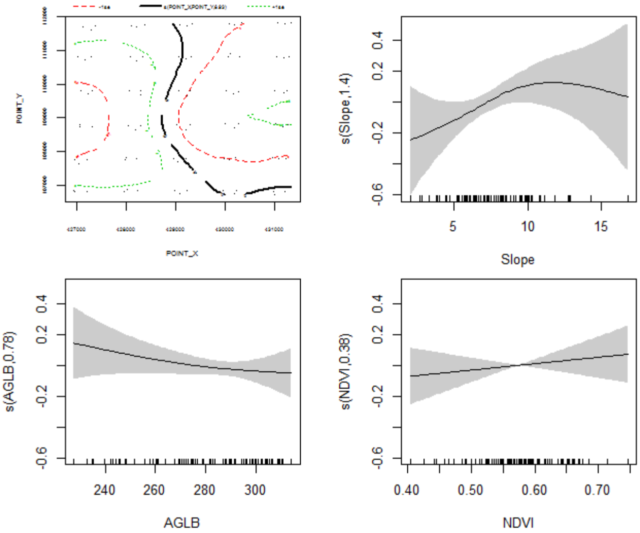
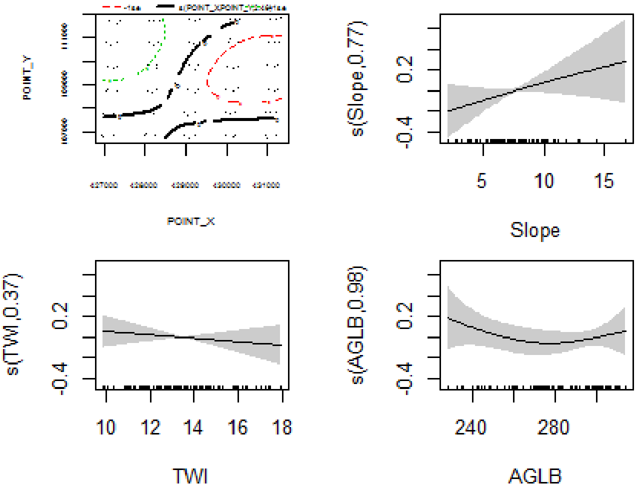
25
50
75
0
100
200
300
Type
Permanet plot
Trail survey
kgha.1
0
100
200
300
B
Fruit-fall biomass
Richness
Shannon Diversity
Lat
Long
112000
111000
110000
109000
108000
107000
427000
428000
429000
430000
431000
Kgha-1
0
50
100
150
N Speciesha-1
0
30
60
90
120
Plot
Permanent
Trail
H'
0.0
0.5
1.0
1.5

Fruit-fall dry biomass (FFB)





Shannon Diversity Index (H')



Floresta Nacional do Amapá - Amapá, BRASIL

FRUITS of **AMAPA NATIONAL FOREST**

1

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Fotos: Rodriguez-Chuma, V. (Exceto 97 e 134 por A. Arévalo-Sandi). Produzido por: Laboratório de Ecologia e Conservação de Vertebrados (LECoV) com apoio do CAPES, CNPq, IBAMA, ICMBio.

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1 Caju ANACARDIACEAE
Anacardium occidentale

2 - ANNONACEAE
Duguetia cadaverica

3 - ANNONACEAE
Duguetia cadaverica

4 - ANNONACEAE
Duguetia cadaverica

5 **Araticum-do-mato** ANNONACEAE
Duguetia sp

6 **Araticum-do-mato** ANNONACEAE
Fusaea longifolia

7 **Araticum-do-mato** ANNONACEAE
Fusaea longifolia a

8 - ANNONACEAE
Duguetia cadaverica

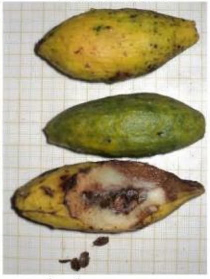
9 - ANNONACEAE
Duguetia cadaverica

10 - ANNONACEAE
Xylopia sp

11 - APOCYNACEAE
Allamanda cathartica

12 - APOCYNACEAE
Allamanda cathartica

13 Pepino-do-mato APOCYNACEAE
Ambelania acida



14 Pepino-do-mato APOCYNACEAE
Ambelania acida

15 Quinarana APOCYNACEAE
Geissospermum sericeum

16 Quinarana APOCYNACEAE
Geissospermum sericeum

17 Quina APOCYNACEAE
Geissospermum laeve

18 Quina APOCYNACEAE
Geissospermum laeve

19 Quina APOCYNACEAE
Geissospermum laeve

20 - APOCYNACEAE
Tabernaemontana undulata

Floresta Nacional do Amapá - Amapá, BRASIL

FRUITS of AMAPA NATIONAL FOREST

2

Victor J.U. Rodriguez-Chuma[1], Darren Norris[1], Omar S. Landázuri[1], Yuri B. Silva e Silva[1] & Patrick Cantuária[2]
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21 Mumbaca ARECACEAE
Astrocaryum gynacanthum

22 Mumbaca ARECACEAE
Astrocaryum gynacanthum

23 Murumuru ARECACEAE
Astrocaryum farinosum

24 Palha-preta ARECACEAE
Attalea attaleoides

25 Pupunha ARECACEAE
Bactris gassipaes

26 Pupunha ARECACEAE
Bactris gassipaes

27 Marajá ARECACEAE
Bactris sp

28 Marajá ARECACEAE
Bactris sp

29 Marajá ARECACEAE
Bactris sp

30 Açaí ARECACEAE
Euterpe oleracea

31 Açaí ARECACEAE
Euterpe oleracea

32 Marajá-do-igapó ARECACEAE
Bactris bidentula

33 Marajá-do-igapó ARECACEAE
Bactris bidentula

34 Marajá-do-igapó ARECACEAE
Bactris bidentula

35 Para-pará BIGNONIACEAE
Jacaranda copaia

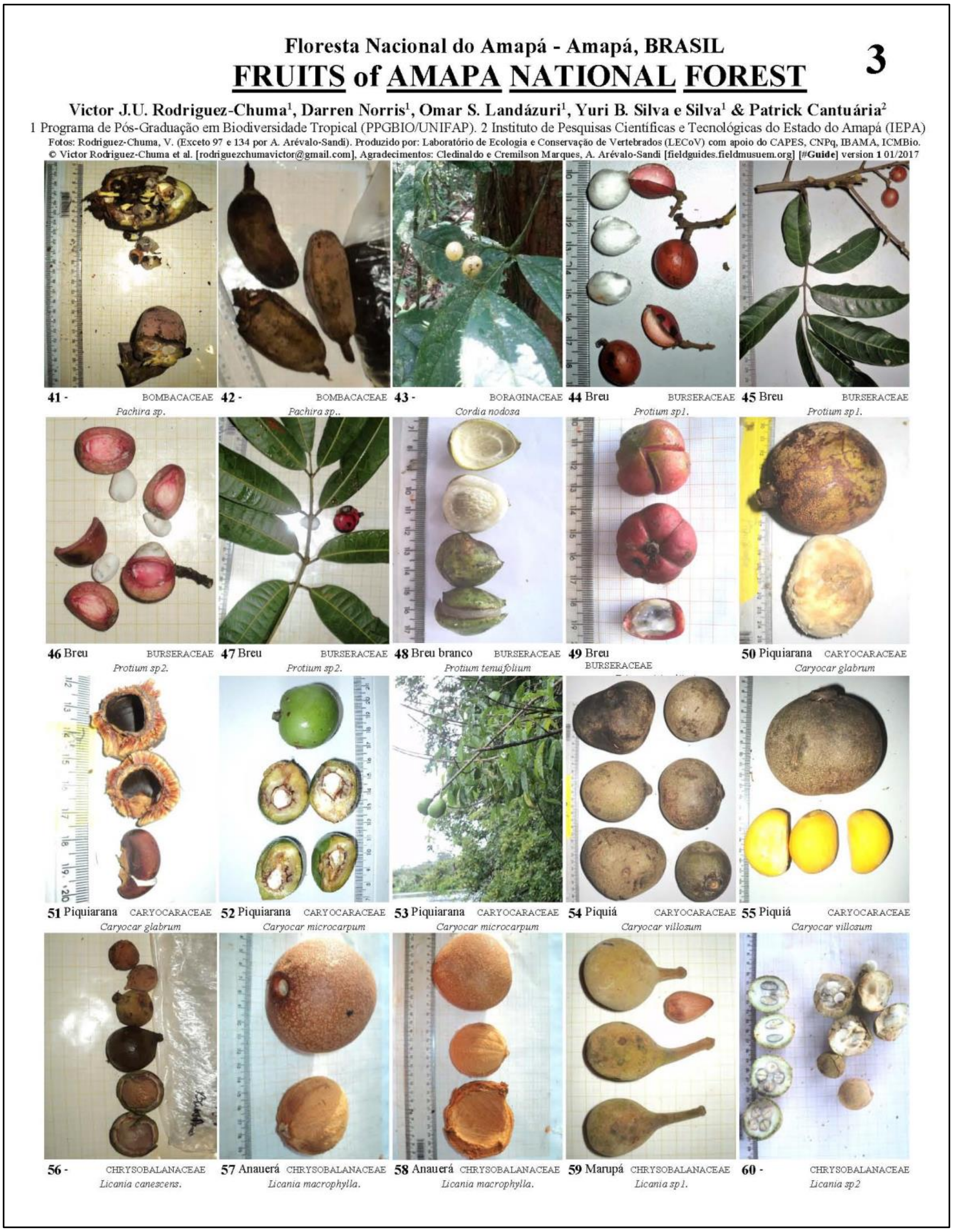
36 Para-pará BIGNONIACEAE
Jacaranda copaia

37 - BIGNONIACEAE
Fridericia mollis

38 - BIGNONIACEAE
Fridericia mollis

39 Urucum BIXACEAE
Bixa orellana

40 Samauma BOMBACACEAE
Ceiba pentandra



Floresta Nacional do Amapá - Amapá, BRASIL

FRUITS of AMAPA NATIONAL FOREST

3

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41 - BOMBACACEAE
Pachira sp.

42 - BOMBACACEAE
Pachira sp..

43 - BORAGINACEAE
Cordia nodosa

44 Breu BURSERACEAE
Protium sp1.

45 Breu BURSERACEAE
Protium sp1.

46 Breu BURSERACEAE
Protium sp2.

47 Breu BURSERACEAE
Protium sp2.

48 Breu branco BURSERACEAE
Protium tenuifolium

49 Breu
BURSERACEAE

50 Piquiarana CARYOCARACEAE
Caryocar glabrum

51 Piquiarana CARYOCARACEAE
Caryocar glabrum

52 Piquiarana CARYOCARACEAE
Caryocar microcarpum

53 Piquiarana CARYOCARACEAE
Caryocar microcarpum

54 Piquiá CARYOCARACEAE
Caryocar villosum

55 Piquiá CARYOCARACEAE
Caryocar villosum

56 - CHRYSOBALANACEAE
Licania canescens.

57 Anauerá CHRYSOBALANACEAE
Licania macrophylla.

58 Anauerá CHRYSOBALANACEAE
Licania macrophylla.

59 Marupá CHRYSOBALANACEAE
Licania sp1.

60 - CHRYSOBALANACEAE
Licania sp2

Family/Species	Dry mass (g)	Dry mass fruit (%)	Abundance	Frequency
ANNONACEAE				
Duguetia cadaverica Huber.	26.5	0.007	2	1
Fusaea longifolia (Aubl.) Saff.	468.7	0.118	11	6
APOCYNACEAE				
Ambelania acida Aubl.	35.6	0.009	10	1
Geissospermum laeve (Vell.) Miers	229.5	0.058	9	2
Geissospermum sericeum Miers.	3205.3	0.805	1027	11
ARECACEAE				
Astrocaryum gynacanthum Mart.	4.2	0.001	1	1
Euterpe oleracea Mart.	2339.7	0.587	1786	3
BIGNONIACEAE				
Fridericia mollis (Vahl) L.G.Lohmann	30.8	0.008	1	1
Jacaranda copaia (Aubl.) D.Don.	7619.7	1.913	109	4
BOMBACACEAE				
Pachira sp.	30.2	0.008	3	1
BURSERACEAE				
Protium sp1	420.5	0.106	378	11
Protium sp2	321.7	0.081	383	12
Protium tenuifolium (Engl.) Engl.	180.9	0.045	86	4
Tetragastris altissima (Aubl.) Swart	201.7	0.051	80	4
CARYOCARACEAE				
Caryocar glabrum (Aubl.) Pers.	2100.7	0.527	33	5
Caryocar villosum (Aubl.) Pres.	19972.7	5.015	151	4
CHRYSOBALANACEAE				
Licania canescens	470.9	0.118	75	2
Licania macrophylla Benth.	139.5	0.035	3	1
Licania sp1	6069.9	1.524	263	14
Licania sp2	44.3	0.011	7	2
CLUSIACEAE				
Clusia grandiflora Splitg.	11969.8	3.005	282	11
EBENACEAE				
Diospyros dichroa Sandwith	2994.3	0.752	177	8
ELAEOCARPACEAE				
Sloanea garckeana K.Schum.	525.3	0.132	270	3

Family/Species	**Dry mass (g)**	**Dry mass fruit (%)**	**Abundance**	**Frequency**
Sloanea grandiflora Sm.	697.22	0.175	126	1
Sloanea sp	16.3	0.004	2	1
EUPHORBIACEAE				
Glycidendron sp	5040.0	1.265	280	1
Hevea brasiliensis (Willd. ex A. Juss.) Müll. Arg.	4019.9	1.009	407	6
Mabea caudata Pax & K.Hoffm.	37.3	0.009	44	1
FABACEAE				
Batesia floribunda Benth.	32.1	0.008	7	1
Cassia fastuosa Willd. ex Benth.	157.2	0.039	3	1
Dinizia excelsa Ducke	181.3	0.046	35	2
Dipteryx odorata (Aubl.) Willd.	955.3	0.240	77	8
Hymenaea courbaril L.	1558.5	0.391	56	1
Indet. 2	615.0	0.154	249	2
Inga alba (Sw.) Willd.	3878.5	0.974	109	4
Inga capitata Desv.	8069.4	2.026	407	13
Inga heterophylla Willd.	7.9	0.002	1	1
Inga sp1	1373.0	0.345	102	4
Inga sp2	191.2	0.048	15	1
Inga sp3	937.2	0.235	208	2
Inga sp4	475.0	0.119	32	1
Inga sp5	186.3	0.047	17	3
Inga sp6	17.8	0.004	2	1
Inga sp7	39.3	0.010	8	1
Mucuna sp	2826.8	0.710	22	3
Parkia pendula (Willd.) Walp.	29.0	0.007	7	1
Pseudopiptadenia psilostachya (DC.) G.P.Lewis & M.P.Lima	6050.6	1.519	193	3
Vatairea guianensis Aubl.	3831.6	0.962	255	11
Vouacapoua americana Aubl.	255488.5	64.146	9425	62
HUMIRIACEAE				
Vantanea sp	1138.0	0.286	26	1
UNIDENTIFIED				
Indet 1	85.3	0.021	1	1
Indet 3	50.4	0.013	13	1

Family/Species	Dry mass (g)	Dry mass fruit (%)	Abundance	Frequency
Indet 4	155.2	0.039	40	1
Indet 5	211.6	0.053	65	1
LECYTHIDACEAE				
Couratari guianensis Aubl.	3948.7	0.991	84	5
Couratari multiflora (Sm.) Eyma	117.8	0.030	104	3
Eschweilera alata A.C.Sm.	2153.1	0.541	95	5
Eschweilera pedicellata (Rich.) S.A.Mori.	4752.4	1.193	228	8
Eschweilera sp1	1742.7	0.438	53	2
Eschweilera sp2	1287.0	0.323	76	3
Lecythis corrugata Poit.	1003.7	0.252	211	9
LOGAGINACEAE				
Strychnos sp	176.3	0.044	2	1
MELASTOMATACEAE				
Bellucia grossularioides (L.) Triana	10.5	0.003	16	1
MELIACEAE				
Carapa guianensis Aubl.	118.8	0.030	2	1
MORACEAE				
Ficus sp	49.4	0.012	12	1
Helicostylis pedunculata Benoist	17.0	0.004	19	3
MYRTACEAE				
Eugenia sp	557.7	0.140	303	8
Psidium sartorianum (O.Berg) Nied.	24.0	0.006	68	2
OCHNACEAE				
Ouratea sp	15.7	0.004	12	1
PASSIFLORACEAE				
Passiflora sp	86.8	0.022	30	3
POLYGALACEAE				
Moutabea guianensis	850.0	0.213	50	1
SAPINDACEAE				
Paullinia sp	16.7	0.004	100	1
SAPOTACEAE				
Chrysophyllum durifructum (W.A.Rodrigues) T.D.Penn.	1048.3	0.263	18	2
Manilkara huberi (Ducke) Chevalier.	3494.0	0.877	1008	17

Family/Species	**Dry mass (g)**	**Dry mass fruit (%)**	**Abundance**	**Frequency**
Manilkara sp1	10.4	0.003	15	1
Manilkara sp2	188.0	0.047	94	3
Pouteria heterosepala	23.6	0.006	2	1
Pouteria hispida Eyma	320.5	0.080	157	6
Pouteria jariensis Pires & T.D.Penn.	27.3	0.007	11	2
Pouteria macrophylla (Lam.) Eyma.	5958.2	1.496	82	9
Pouteria sp1	2746.5	0.690	146	5
Pouteria sp2	943.8	0.237	46	2
Pouteria torta	386.4	0.097	23	2
STERCULIACEAE				
Sterculia excelsa Mart.	4105.7	1.031	226	13
TILIACEAE				
Apeiba macropetala Ducke.	3734.0	0.938	310	9
VOCHYSIACEAE				
Vochysia rufescens W.A.Rodrigues	619.4	0.156	834	7

N	Plot ID	Altitude	Slope	Aspect	TWI	SWI	HAND	HDND	AGLB	NDVI	Latitude	Longitude	Area	FFB	S	H'
1	LO1_0.25-0.5	112.0	6.7	242.8	11.0	8.3	12.3	278.6	309.3	0.6	431227.0	106795.4	0.05	104.18	30	0.808
2	LO1_0.5	109.1	6.1	276.6	12.8	8.2	8.5	442.8	306.1	0.7	431019.4	106722.8	0.05	26.70	50	1.491
3	LO1_0.5-0.75	103.7	5.9	212.4	17.4	8.2	3.4	312.1	287.9	0.7	430985.8	106798.9	0.05	32.32	70	1.699
4	LO1_1.25-1.5	105.8	7.4	197.3	14.3	7.2	5.4	471.2	278.6	0.5	430236.5	106819.2	0.05	5.36	20	0.622
5	LO1_1.5	112.9	8.2	114.3	11.3	7.1	12.4	549.8	289.6	0.6	430197.1	106742.5	0.05	31.33	70	1.469
6	LO1_1.5-1.75	101.4	8.8	261.1	13.6	7.4	3.0	166.4	263.9	0.7	429981.3	106822.2	0.05	13.57	20	0.632
7	LO1_2.25-2.5	111.9	6.5	155.0	16.8	7.4	16.4	908.5	299.5	0.7	429244.0	106824.1	0.05	16.10	20	0.611
8	LO1_2.5	119.3	8.4	91.1	12.8	7.4	23.4	973.2	303.8	0.7	429097.6	106727.4	0.05	78.83	90	1.212
9	LO1_2.5-2.75	126.9	5.2	163.9	11.9	7.6	30.5	1158.9	309.0	0.6	428991.1	106832.0	0.05	76.68	40	1.062
10	LO1_3.25-3.5	127.8	8.2	205.5	11.8	7.2	30.0	784.8	281.8	0.7	428251.4	106820.5	0.05	49.75	20	0.242
11	LO1_3.5	115.3	5.8	261.8	12.3	8.1	17.7	425.3	244.4	0.6	428026.9	106862.4	0.05	63.97	70	1.180
12	LO1_3.5-3.75	114.9	5.8	261.6	12.5	8.3	17.8	419.1	245.6	0.6	427982.3	106808.2	0.05	25.07	20	0.206
13	LO1_4.25-4.5	112.8	7.7	143.9	11.7	7.9	22.9	535.4	287.1	0.6	427233.5	106803.2	0.05	19.26	20	0.143
14	LO1_4.5	114.9	7.3	219.2	12.9	7.7	24.5	430.1	278.6	0.6	426948.1	106835.3	0.05	47.37	90	1.226
15	LO1_4.5-4.75	112.5	7.4	221.2	13.4	7.7	22.0	383.8	275.7	0.6	426980.8	106791.0	0.05	30.07	20	0.462
16	LO2_0.25-0.5	102.0	7.9	168.7	16.2	8.4	7.6	78.3	281.5	0.6	431244.0	107788.6	0.05	80.59	20	0.169
17	LO2_0.5	105.6	9.8	169.0	13.9	8.1	8.7	111.1	272.1	0.6	431093.0	107773.3	0.05	119.29	80	1.174
18	LO2_0.5-0.75	109.0	8.2	172.0	11.5	8.2	12.0	161.2	283.4	0.6	430981.0	107795.9	0.05	49.90	40	1.102
19	LO2_1.25-1.5	115.2	9.6	141.9	11.2	6.8	14.1	380.1	281.6	0.6	430226.7	107793.1	0.05	19.11	20	0.690
20	LO2_1.5	120.1	6.6	224.3	9.8	7.2	18.3	436.1	257.6	0.7	430094.9	107755.2	0.05	31.24	70	1.790
21	LO2_1.5-1.75	120.4	6.0	218.8	11.6	7.3	18.6	427.9	251.7	0.7	429990.0	107775.2	0.05	30.41	50	1.304
22	LO2_2.25-2.5	113.4	7.5	110.8	14.0	6.8	8.2	373.7	232.7	0.5	429224.5	107772.7	0.05	22.24	40	1.292
23	LO2_2.5	125.0	7.5	118.0	14.4	6.7	20.4	849.0	271.4	0.6	429059.7	107699.4	0.05	114.17	40	0.222

N	Plot ID	Altitude	Slope	Aspect	TWI	SWI	HAND	HDND	AGLB	NDVI	Latitude	Longitude	Area	FFB	S	H'
24	LO2_2.5-2.75	133.9	8.0	171.1	11.1	6.6	29.5	814.9	274.1	0.6	428978.4	107770.3	0.05	141.49	60	0.936
25	LO2_3.25-3.5	103.9	5.7	171.1	17.5	7.8	3.3	99.7	239.8	0.6	428230.1	107764.5	0.05	46.89	60	1.224
26	LO2_3.5	110.0	8.6	159.9	13.2	7.4	10.6	353.2	227.6	0.5	428017.0	107805.6	0.05	128.52	120	1.913
27	LO2_3.5-3.75	109.1	8.3	159.8	13.5	7.3	9.9	380.3	234.9	0.5	427990.1	107750.6	0.05	65.78	80	1.571
28	LO2_4.25-4.5	112.1	10.2	159.2	12.5	6.7	15.8	1344.4	234.8	0.4	427230.9	107747.4	0.05	194.58	90	1.485
29	LO2_4.5	116.1	8.5	154.0	10.9	6.8	19.8	1398.5	270.6	0.6	427050.5	107622.8	0.05	179.97	50	0.342
30	LO2_4.5-4.75	126.1	9.9	163.7	11.9	6.5	29.7	1576.3	272.9	0.4	426980.1	107746.2	0.05	69.25	50	0.957
31	LO3_0.25-0.5	97.3	9.6	176.9	13.3	8.8	3.2	84.6	260.1	0.6	431282.7	108796.9	0.05	13.91	10	0.000
32	LO3_0.5	98.5	10.9	98.5	14.8	8.7	3.0	152.4	269.8	0.7	431181.4	108711.0	0.05	32.39	40	0.864
33	LO3_0.5-0.75	115.9	10.1	153.8	14.6	8.4	19.6	440.0	269.1	0.5	431032.6	108807.7	0.05	14.51	20	0.691
34	LO3_1.25-1.5	121.1	6.5	240.2	14.6	8.0	17.2	693.9	306.6	0.6	430290.0	108812.9	0.05	0.00	0	0.000
35	LO3_1.5	111.2	7.0	234.6	14.8	7.6	5.3	462.4	291.7	0.6	430198.5	108690.6	0.05	6.91	30	0.277
36	LO3_1.5-1.75	110.2	4.7	117.0	14.5	7.6	3.1	325.7	294.3	0.7	430009.5	108807.3	0.05	1.03	10	0.000
37	LO3_2.25-2.5	113.0	5.8	99.9	13.8	7.3	5.3	187.0	305.5	0.4	429308.2	108784.5	0.05	0.00	0	0.000
38	LO3_2.5	120.7	11.2	64.9	11.5	6.7	12.4	311.4	310.1	0.5	429231.9	108629.9	0.05	18.25	30	0.567
39	LO3_2.5-2.75	124.9	10.0	213.8	13.0	6.7	17.0	445.3	291.3	0.5	429042.0	108781.2	0.05	16.69	10	0.000
40	LO3_3.25-3.5	121.5	4.5	133.1	11.9	7.9	16.9	345.5	302.3	0.5	428306.0	108753.3	0.05	151.79	30	0.381
41	LO3_3.5	125.4	9.2	133.4	15.9	7.2	21.2	423.1	296.3	0.6	428199.6	108634.8	0.05	78.60	70	0.948
42	LO3_3.5-3.75	122.7	6.5	268.3	15.3	7.4	13.9	437.2	295.8	0.6	428059.9	108738.7	0.05	0.80	10	0.000
43	LO3_4.25-4.5	119.7	3.9	210.8	14.3	7.9	18.8	521.7	298.2	0.6	427328.5	108720.2	0.05	121.47	90	1.335
44	LO3_4.5	119.3	2.0	179.4	10.1	8.9	19.2	604.2	309.1	0.5	427085.9	108780.6	0.05	108.32	70	0.771
45	LO3_4.5-4.75	118.9	2.7	180.6	10.3	8.7	18.7	526.5	305.4	0.5	427075.7	108714.6	0.05	2.93	20	0.515
46	LO4_0.25-0.5	96.3	5.3	190.6	17.5	8.4	0.6	129.8	260.8	0.6	431273.7	109794.7	0.05	0.00	0	0.000

N	Plot ID	Altitude	Slope	Aspect	TWI	SWI	HAND	HDND	AGLB	NDVI	Latitude	Longitude	Area	FFB	S	H'
47	LO4_0.5	95.0	5.6	106.7	16.4	8.4	0.2	39.3	245.8	0.5	431196.7	109720.1	0.026	56.30	96	0.823
48	LO4_0.5-0.75	105.6	6.8	154.0	12.9	8.8	6.4	171.9	248.4	0.7	431016.2	109787.9	0.05	83.50	60	0.659
49	LO4_1.25-1.5	108.5	9.5	191.8	14.1	8.4	5.9	164.5	295.2	0.5	430282.7	109757.9	0.05	80.70	50	1.131
50	LO4_1.5	99.0	6.5	108.7	18.0	8.2	0.4	53.2	283.5	0.5	430179.9	109708.7	0.016	14.71	31	0.000
51	LO4_1.5-1.75	103.2	7.1	101.1	13.3	8.2	1.9	174.8	255.7	0.4	430042.5	109777.9	0.05	13.14	30	0.913
52	LO4_2.25-2.5	118.1	5.3	252.7	12.8	7.9	12.2	547.9	289.5	0.4	429311.0	109791.9	0.05	10.75	30	0.652
53	LO4_2.5	118.8	4.4	231.7	12.4	8.0	12.2	685.6	295.9	0.4	429248.5	109644.2	0.044	8.83	34	0.808
54	LO4_2.5-2.75	117.7	5.2	107.2	16.2	7.8	11.5	631.1	298.6	0.5	429076.1	109786.3	0.05	0.05	10	0.000
55	LO4_3.25-3.5	124.5	7.3	158.6	13.2	6.7	11.7	457.6	302.4	0.6	428314.7	109786.4	0.05	20.21	40	1.105
56	LO4_3.5	126.4	10.3	116.6	12.3	6.5	13.3	461.3	304.5	0.6	428306.7	109678.8	0.05	77.60	90	1.588
57	LO4_3.5-3.75	137.3	6.3	192.1	11.9	6.9	23.1	574.7	305.2	0.6	428076.6	109795.6	0.05	12.36	60	1.557
58	LO4_4.25-4.5	124.1	9.1	202.9	16.0	7.0	18.1	341.5	276.5	0.5	427334.5	109780.0	0.05	133.70	70	1.634
59	LO4_4.5	115.7	8.5	183.9	17.1	7.1	9.6	222.4	270.6	0.5	427239.3	109705.7	0.05	72.82	120	0.994
60	LO4_4.5-4.75	116.9	5.7	121.7	14.1	7.6	12.6	407.8	271.3	0.6	427090.5	109781.4	0.05	100.60	50	1.309
61	LO5_0.25-0.5	132.4	12.8	151.3	13.7	6.7	30.1	512.6	297.7	0.7	431307.9	110790.5	0.05	10.64	40	1.201
62	LO5_0.5	132.6	12.9	152.0	13.3	6.7	30.4	521.3	298.4	0.7	431195.1	110767.5	0.05	11.07	40	0.650
63	LO5_0.5-0.75	129.3	10.3	265.8	11.0	7.5	25.7	489.4	300.6	0.6	431057.5	110798.8	0.05	1.89	30	0.791
64	LO5_1.25-1.5	114.1	6.5	211.0	12.7	8.6	6.6	106.7	308.6	0.5	430310.8	110793.5	0.05	67.49	50	1.542
65	LO5_1.5	112.6	7.5	113.4	17.2	8.1	5.2	134.0	310.6	0.6	430111.1	110891.8	0.05	8.09	50	0.766
66	LO5_1.5-1.75	115.4	9.5	66.1	16.3	7.8	7.5	181.7	314.0	0.6	430075.1	110791.8	0.05	16.71	20	0.468
67	LO5_2.25-2.5	142.5	8.1	208.7	11.1	6.7	34.1	588.3	301.0	0.7	429336.6	110795.0	0.05	128.69	40	0.726
68	LO5_2.5	137.5	8.8	200.9	11.6	6.7	29.2	502.5	301.0	0.7	429218.9	110750.1	0.05	92.84	80	1.375
69	LO5_2.5-2.75	125.0	8.5	227.0	15.8	6.9	15.5	329.2	274.8	0.6	429086.2	110793.8	0.05	9.24	40	1.106

N	Plot ID	Altitude	Slope	Aspect	TWI	SWI	HAND	HDND	AGLB	NDVI	Latitude	Longitude	Area	FFB	S	H'
70	LO5_3.25-3.5	150.8	10.0	221.0	13.4	6.4	32.4	303.6	291.6	0.6	428338.7	110801.6	0.05	29.87	60	1.738
71	LO5_3.5	139.9	14.3	269.9	14.2	6.5	18.5	142.3	290.3	0.6	428224.1	110664.6	0.05	9.77	80	1.827
72	LO5_3.5-3.75	128.4	8.3	175.2	15.9	7.0	7.3	109.2	288.2	0.6	428098.5	110799.9	0.05	14.33	40	0.909
73	LO5_4.25-4.5	106.4	7.4	188.8	11.1	7.4	4.3	109.6	289.7	0.6	427309.9	110797.0	0.05	2.90	20	0.424
74	LO5_4.5	101.3	6.5	176.6	15.8	7.7	1.6	94.4	267.8	0.5	427184.1	110689.5	0.034	45.00	103	0.529
75	LO5_4.5-4.75	110.9	11.9	169.5	15.2	7.3	11.0	280.9	243.1	0.5	427044.7	110801.6	0.05	30.65	20	0.619
76	LO6_0.25-0.5	131.5	6.4	227.5	16.2	7.5	23.5	787.0	279.3	0.5	431340.4	111802.4	0.05	7.91	20	0.521
77	LO6_0.5	131.6	5.8	238.4	16.0	7.7	23.6	814.1	282.6	0.5	431232.7	111762.5	0.05	52.54	40	0.872
78	LO6_0.5-0.75	132.6	3.3	203.8	13.3	8.5	23.9	822.3	275.7	0.6	431084.0	111790.5	0.05	6.543	10	0.000
79	LO6_1.25-1.5	117.6	7.2	135.1	9.9	8.4	8.5	226.0	300.1	0.5	430344.8	111789.2	0.05	20.60	40	1.296
80	LO6_1.5	127.4	6.0	145.6	12.7	8.1	18.9	557.4	300.0	0.5	430203.2	111746.0	0.05	5.14	20	0.318
81	LO6_1.5-1.75	130.8	6.1	146.1	12.2	8.0	21.8	559.1	299.9	0.5	430099.0	111779.7	0.05	34.86	30	0.888
82	LO6_2.25-2.5	135.9	3.8	181.3	10.8	7.9	21.3	557.0	235.2	0.5	429348.6	111765.1	0.05	11.14	20	0.455
83	LO6_2.5	135.0	4.0	189.3	10.8	7.7	19.4	445.0	274.9	0.5	429247.6	111720.4	0.05	16.30	40	0.582
84	LO6_2.5-2.75	134.5	2.8	172.7	13.1	8.2	16.2	405.2	260.9	0.6	429093.8	111749.1	0.05	42.45	50	1.449
85	LO6_3.25-3.5	151.2	12.8	182.3	13.7	5.6	25.7	548.8	242.1	0.6	428384.6	111730.3	0.05	21.82	40	0.958
86	LO6_3.5	143.0	10.8	171.0	12.5	5.6	17.1	562.9	259.1	0.6	428220.1	111673.6	0.046	4.91	65	1.304
87	LO6_3.5-3.75	151.3	16.8	207.7	12.4	5.3	25.7	628.2	247.9	0.6	428122.5	111721.9	0.05	16.41	40	0.737
88	LO6_4.25-4.5	124.4	7.5	157.4	15.1	6.8	4.5	171.2	298.8	0.6	427395.2	111707.5	0.05	42.68	30	0.709
89	LO6_4.5	129.4	11.8	143.7	13.7	6.3	6.9	128.1	304.0	0.6	427312.2	111576.1	0.05	9.55	80	1.541
90	LO6_4.5-4.75	144.8	8.8	177.7	13.6	6.7	30.6	448.7	306.3	0.6	427140.5	111694.3	0.05	96.42	40	0.762

6. CONCLUSÕES

- Nosso trabalho reporta um total 21812 frutos contados distribuídos em 86 espécies, 28 famílias e 51 gêneros que seguem o padrão florístico presentada e Amazônia. A média de biomassa seca de frutos foi de 44.84 Kg ha^{-1} mes^{-1} (±45.13 SD); o número médio de espécies por hectare foi 44.55 (±27.31 SD) e a média do índice de diversidade de Shannon de 0.84 (±0.5 SD).

- Determino se que a distância horizontal e vertical ao drenagem mais próximo (HAND e HDND) e o índice de vegetação de diferencia normalizada (NDVI) são variáveis preditivas úteis para a modelagem da distribuição espacial da biomassa deca de frutos caídos.

- Nossos resultados sugerem que padrões de frutos caídos é um dos componentes embaixo do dossel útil para caracterizar a diversidade da floresta amazônica que não pode ser modelado com maior exactitude utilizando dados de sensoriamento remoto. Dados coletados em campo é recomendado para descrever padrões espaciais.

Anexo 1. Submission Confirmation for PLOS ONE

Subject: Submission Confirmation for PONE-D-17-07071 - [EMID:06619882e877a27c]
Date:21 Feb 2017 14:25:26 -0500
From:PLOS ONE <em@editorialmanager.com>
Reply-To:PLOS ONE <plosone@plos.org>
To: Darren Norris <dnorris75@gmail.com>

PONE-D-17-07071
Patterns and predictions of fruit-fall biomass in a lowland Amazon forest
PLOS ONE

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