Ecological variability prediction based on functional characteristics of an urban rainforest

ABSTRACT

The relation among basal area, light and functional characteristics variation is still an unexplored issue, especially in rainforests with different disturbance regimes. The following hypotheses were tested: 1) basal area of arboreal plants and light availability is a good predictor of the functional characteristics, once it is believed that in forest environments with a lower basal area and much light, functional characteristics values linked to the fast light resources utilization are found in leaves, stem and roots; 2) environments where there is greater light availability, the standard deviation values of the leaf characteristics will be greater. The functional characteristics values were not influenced by the geographic distance (spatial autocorrelation) neither by the species phylogeny. The prediction that in the areas with the lower basal area, values of characteristics associated with the rapid use of the light resource were confirmed for five characteristics: dry leaf matter (LMDC), stem (SDMC) and root (RDMC), the density of wood stem (WDC) and root (WDR). Significant investment was not found in structural carbon (greater dry matter values of leaf and wood) in environments with the greater basal area. It is considered that in urban fragments the disturbances are frequent, it is possible to suppose that plants with lower values of LDMC, DWC, DWR, SDMC, and RDMC have also "established" in the two areas with a greater basal area. It is concluded that in fragments in urban rainforest studied, perturbations may change the succession path due to population dynamics, especially in the area with more abundant light availability and lesser basal area (A4<AB). the study suggests that this greater light input in the A4<AB environment, due to the greater perturbations, would lead plants with the strategy of using a slow resource, favoring those with fast use of the resource, and as a result, there would be less variability of the leaf characteristics in A4<AB. The basal area and light intensity are not good predictors of variations of functional characteristics in the urban fragments studied.

1. INTRODUCTION

In forest ecosystems, the basal area is one of the first parameters to recover after disturbances in the community [1-3], then there is a change in the functional characteristics of the species [4]. It is also known that these functional characteristics are good indicators of species ecology, helping to understand the responses to different environments or disturbance regimes [5,6]. However, the existing relation among basal area, light and the variation of functional characteristics is still an unexplored issue, especially in rainforests with different disturbance regimes, such as urban fragments [7].

It is known that values of functional characteristics of plants respond in different ways to the availability of resources (water, light, etc.) [8-10]. These responses are observed in distinct

27 survival patterns as a result of their potential acquisition and use of the resource [11-13].
28 Therefore, the values of the functional characteristics of the species of the community help
29 to understand the responses of the plants to the changes in the availability of the resource
30 [14-15].

31 In the case of rainforests, where light is the main resource, at the beginning of the ecological
32 succession there is greater luminosity and lower values of basal area [16,10]. In this
33 environment, species with a high leaf area, specific leaf area and chlorophyll content [11],
34 low wood density of stem and root, high water content in the stem and root tend to occur.
35 This points to strategies linked to the acquisition of resources [17,18,10]. As the succession
36 progresses the canopies are closed, what changes the amount of light that reaches the
37 forest floor, leading to greater survival of plants more adapted to the capture of light [19,20].

38 The evaluation of functional characteristics in forests can be used to understand vegetation
39 changes under different environmental pressures [21-22], mainly along the process of
40 ecological succession and selection pressure, in which the species deal with luminosity
41 variations, an important resource for the regeneration and growth of plants in rainforests [23-
42 26].

43 Therefore, this research seeks to understand the influence of light availability and basal area
44 variation on the values of the functional characteristics of an urban rainforest. It was
45 assumed that the increase of the basal area and the decrease of the light intensity are
46 measures indicative of the succession in an urban rainforest. It was hypothesized that the
47 basal area of arboreal plants is a good predictor of functional characteristics.

48 In this way, it is believed that in forest environments with lower basal area and greater light
49 intensity, values of functional characteristics linked to the fast use of the light resource are
50 found in both leaves (larger leaf area, specific leaf area, chlorophyll concentrations, low
51 investment in dry matter) and in the stem and root (higher amount of saturated water, lower
52 wood density and lower contents of dry matter) [24-25]. From the perspective that the light
53 availability is a good indicator of the variation of leaf characteristics, it was hypothesized that
54 in the environment where there is greater light availability, the coefficient of variation of leaf
55 characteristics will be higher. If this is true, greater variation in leaf dry matter, specific leaf
56 area, leaf area and chlorophyll content in this environment are expected.
57
58 ## 2. MATERIAL AND METHODS
59
60 ### 2.1 Study Location
61
62 The study was carried out in a fragment of Ombrophylous Dense Lowland Forest [27], in the
63 State Park of Dois Irmãos (PEDI), in the municipality of Recife-PE, Brazil, between
64 coordinates 7° 57' 21"and 8° 00' 54" S; 34° 55' 53" and 34° 58' 38" W. In the area
65 predominate the geological formation Barreiras and soils of the podzólico type, with
66 subordinate latossolos, in general areno-clayey, ranging from deep to very deep [28]. The
67 soil acidity varies from medium to high, which is in line with that expected for regions with
68 high precipitation [29]. The local climate is As' type (tropical humid or tropical coastal), with
69 average monthly temperatures above 23ºC, annual mean rainfall of 2460 mm and rainy
70 season in the autumn-winter period [29].
71
72 ### 2.2 Assembly of plots, inclusion criterion and floristic list
73
74 In the PEDI area, a module of the Biodiversity Research Program (PPBio), Mata Atlântica
75 Network, was installed using the RAPELD method: this is a combination of rapid inventories

76   (RAP) with long-term ecological research (PELD) [30]. The method consists in the opening
77   of two straight tracks of 5000 m of extension, distant 1000 m. Along each trail, one-hectare
78   plots were installed [30].

79   Of the two tracks installed by researchers PPBio Atlantic Forest was selected PE2, which
80   analyzed four plots (250 × 40 m), 1000 m distant from each other, resulting in four areas. For
81   each plot, a 250 m corridor was installed following the ground level curve [31].

82   Within each hectare, 20 plots of 10 × 20 m without overlap were drawn, where botanical
83   samples and functional characteristics of the species with stem diameter at breast height
84   (DBH) ≥ 5 cm at 1.30 m were collected. The minimum number of individuals that had their
85   functional characteristics checked was five, and the maximum 20, when the species was
86   present in the four areas and had five or more individuals in each area.

87   In area 1 there is evidence of people entering to remove wood for construction of residences
88   and firewood, traces of hunting, tents on site; in areas (2 and 3) about 30 years ago
89   vegetation was removed and crops were planted; in area 4 there are reports of occasional
90   fires, as well as the removal of wood for firewood (personal communication).

91   The floristic classification was made through the APG IV [32] system. All material was
92   deposited in the Vasconcelos Sobrinho Herbarium of the Rural Federal University of
93   Pernambuco (UFRPE).

94   In order to verify if the basal area differed among the four areas studied (4000 m^2 each), we
95   calculated the total basal area [10]. As the baseline, the data in each plot did not present
96   normal distribution in the four areas, so Kruskal-Wallis non-parametric analysis of variance
97   was performed, complemented by the Student-Newman-Keuls mean comparison test.

98   In the environment with the highest basal area (A1> AB), species sampled for collection of
99   the characteristics accounted for 78% of the total of individuals present, in A2ABI and
100 A3ABI, environments with intermediate basal areas the species represented 89% and 77%
101 of the total density, respectively. In A4 <AB environment with lower basal area, the sampled
102 species accounted for 81% of total density.
103
104 **2.3 Functional characteristics**
105
106 The measurement of the functional characteristics followed the protocol of [11]. There were
107 measured 10 characteristics, four foliar and six linked to wood. As previously observed, to
108 collect the characteristics, were selected at least five individuals per species to set the four
109 areas for the collection of functional characteristics. Thus, the minimum number of
110 individuals that had their functional characteristics checked was five and the maximum 20 for
111 the four areas (250 × 40 m plot). From each individual, 10 mature leaves were collected at
112 the middle of the canopy (exposed to the sun), with no evident symptoms of pathogen or
113 herbivore attack. After being collected, the samples were wrapped in wet paper and placed
114 in closed plastic bags and stored in Styrofoam with ice. In the laboratory the leaves (without
115 petiole) were rehydrated and placed in deionized water in the dark for at least six hours.

116 Chlorophyll content was measured after collection at four points of each leaf, with the aid of
117 a SPAD chlorophyll meter (Minolta SPAD 502 D Sprectrum Technologies Inc., Plainfield, II,
118 USA). After rehydration, the leaves were weighed in an analytical scale to obtain the
119 saturated weight of water. Then, the leaves were scanned for leaf area measurement by the
120 Image-Tool software [33] and the fresh mass was determined and then placed in an oven at
121 60 °C for 72 hours to obtain of the leaves dry mass.

122 The stem samples were collected at 1.30 m incremental soil auger (300 x 5.15 mm core
123 diameter). For the root samples, a shovel was used to facilitate the collection at 20-30 cm
124 depth in the soil in the region closest to the colon [34]. The samples were immersed in a
125 container with water for five days to rehydrate and reach the saturation point required for
126 measurement. Subsequently, each sample was kept standing out of the container for about
127 10 minutes to remove excess of water for weighing the stem mass (Msatc) from the root
128 (Msatr); After this, they were immersed in another container with water to obtain the volume,
129 based on the displacement of the liquid caused by the immersion of the part [35]. Then, each
130 sample was dried in oven at 103 °C until constant weight (MS); based on these data, DMC,
131 DMR; QAsatc; QAsatr; TMSC and TMSR were calculated.

2.4 Collection of light data

135 The total radiation (luminosity) was obtained in each of the 80 plots of 10 × 20 m drawn (20
136 per area). Initially hemispheric photos were taken in the center of each plot with a Nikon D50
137 camera with a hemispherical lens (Nikon DX 18-105 mm adapted fisheye 67-58 mm) on a
138 tripod adjustable to one meter above the ground, horizontally leveled, positioned with the
139 upper part aligned with magnetic north. The photographs were taken between August and
140 December 2015, between 8:30 and 11:00 hours [36]. The image processing was done with
141 the aid of GLA software (Gap Light Analyzer) version 2.0 [37] in order to obtain the total
142 radiation that crosses the canopy (luminosity).

2.5 Data analysis

146 In order to verify if the phylogenetically close species are similar in values of functional
147 characteristics, their phylogenetic signal was calculated in each of the four areas. Thus, a
148 matrix with the list of families, genus and species was constructed according to APG IV [32].
149 To obtain the phylogenetic trees of each area, we used the program Phylocom 4.0.1 [38].
150 With the trees constructed and the phylogenetic distances calculated the Blomberg K
151 statistic was applied [39]. K values closer to zero demonstrate that the phylogenetic signal is
152 less than expected at random, meaning that the phylogenetically close species are distinct in
153 relation to the analyzed characteristic, the greater values suggest the existence of a
154 phylogenetic signal. To determine if the phylogenetic signal was greater or lower than
155 expected at random, the values obtained from K with null models, obtained in 999
156 randomizations were compared. These analyzes were performed using the 'phytools'
157 package in Environment R version 3.3.1 [40].

158 The weighted average of the functional characteristics was calculated in the four areas to
159 obtain the Community-Weighted Mean (CWM) by the formula: CWM = $\sum_{i=1}^{S}$ Wi.Xi, where X is
160 the total number of species, Wi is the abundance of the *ith* species (obtained by the
161 quantitative survey of the plants in each area) and Xi is the characteristic value of the *ith*
162 species [41]. In order to analyze if there was variation of the functional characteristics in the
163 four areas and if this change influenced the functional structure of the community, the
164 Kruskal-Wallis mean comparison test was applied in the CWM values. The normality of the
165 data was tested by the Shapiro-Wilk test. As the data did not present normal distribution, so
166 the Kruskal-Wallis non-parametric test was applied, followed by Student-Newman-Keuls test
167 to test the differences among the areas.

168 To analyze whether geographic distances influenced CWM values, the Bray-Curtis index
169 was applied to the data matrix, followed by the Mantel test [42]. The significance of the
170 correlations was tested by means of 999 permutations [43].

171 Normality tests and Kruskal-Wallis non-parametric analysis were performed using the SPSS
172 program (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0,
173 Armonk, NY: IBM Corp.). The Mantel test was done with the help of the Vegan Package in
174 Environment R version 3.3.1 [40].

175 To analyze the effect of basal area and light on the functional characteristics, Mixed Linear
176 Models (LMMs) were constructed. The basal area and light were used as independent
177 variables (explanatory) and the functional characteristics of the species (average of each
178 characteristic per plot, by area) were used as independent variables. As a result of this
179 analysis, the minimum explanatory model was obtained by removing the fixed-effect
180 variables one by one, followed by deviation analysis [44]. All LMs were made using the lme4
181 package in Environment R version 3.3.1 [40].

182 From the 10 characteristics studied, the coefficients of variation of four foliar characteristics
183 was calculated: specific leaf area, leaf area, chlorophyll content and leaf dry matter content
184 [45,46].

185 The coefficients of variation of leaf characteristics in the four areas were submitted to the
186 Shapiro-Wilk test to evaluate the data normality. As the data did not present a normal
187 distribution, the Kruskal-Wallis non-parametric variance test was performed, complemented
188 by the Student-Newman-Keuls mean comparison test to verify if there were differences
189 between the coefficients of variation of the characteristics in the areas (IBM Corp. Released
190 2011. IBM SPSS Statistics for Windows, Version 20.0, Armonk, NY: IBM Corp.).

191 In order to analyze if the geographical distances influence the coefficient of variation of leaf
192 characteristics in each area, the Bray-Curtis index was applied in the data matrix, followed
193 by the Mantel test [42]. The significance of the correlations was tested using 999
194 permutations [43], using the vegan package in Environment R version 3.3.1 [40]

195 To test the hypothesis that, where there is greater light availability the coefficients of
196 variation of leaf characteristics would be greater, Linear Models (LM) were constructed. Light
197 was used as an independent variable and the values of the coefficients of variation for the
198 leaf characteristics of the species (coefficients of variation values for each characteristic by
199 area) were used as dependent variables. As a result of this analysis, the minimum
200 explanatory model was obtained by removing the fixed-effect variables one by one, followed
201 by deviation analysis [44]. All LMs were made using the lme4 package in Environment R
202 version 3.3.1 [40].
203
204 **3. RESULTS AND DISCUSSION**
205
206 **3.1 Functional characteristics and basal area**
207
208 Almost all functional characteristics in all areas presented K values below that expected at
209 random, indicating the absence of phylogenetic signal, except for stem wood density in the
210 area A1> AB. The fact that there is no phylogenetic signal for nine of the 10 functional
211 characteristics indicates that the variation in values occurred due to changes in the
212 environment and not due to the degree of kinship (Table 1).

213 **Table 1.   Phylogenetic sign of the functional characteristics sampled in four areas**
214 **of a fragment of an urban rainforest.**

Characteristics	$A1_{>AB}$		$A2_{ABI}$		$A3_{ABI}$		$A4_{<AB}$	
	K	p	K	p	K	P	K	P

Characteristics								
AF (cm^2)	0.22	0.82	0.38	0.42	0.39	0.52	0.99	0.50
AFE (cm^2.mg^{-1})	0.31	0.54	0.34	0.58	0.37	0.67	0.00	0.50
Cc_mass (micromol.g^{-1})	0.31	0.59	0.35	0.51	0.35	0.77	0.99	0.50
TMSF (mg.g^{-1})	0.34	0.45	0.26	0.89	0.43	0.37	0.00	0.50
DMC (mg.mm^{-3})	0.46*	0.04*	0.38	0.41	0.41	0.46	0.00	0.50
DMR (mg.mm^{-3})	0.52	0.06	0.30	0.75	0.53	0.31	0.99	0.50
QA$_{satc}$ (%)	0.50	0.08	0.42	0.35	0.40	0.56	0.00	0.50
QA$_{satr}$ (%)	0.48	0.16	0.42	0.32	0.48	0.37	0.99	0.50
TMSC (mg.g^{-1})	0.45	0.07	0.36	0.48	0.40	0.45	0.00	0.50
TMSR (mg.g^{-1})	0.47	0.09	0.31	0.69	0.46	0.44	0.00	0.50

*K - Bloomberg value; P - probability; AF - leaf area; AFE - specific leaf area; Cc_mass - chlorophyll concentration; TMSF - leaf dry matter content; DMC - wood stem density; DMR - root wood density; amount of saturated water from the stem; amount of saturated root water; TMSC - dry matter content of the stem; TMSR - dry matter content of the root; A1> AB (area with greater basal area); A2ABI (intermediate basal area); A3ABI (intermediate basal area) and A4 <AB (area with lower basal area). * represent statistical significance (p <.05).*

The CWM values of the functional characteristics and the geographic distances did not present spatial autocorrelation according to the Mantel test (r = -0.05848; p <.101). The change in the values of the functional characteristics in the community, evaluated through CWM, revealed differences among the areas (Table 2). In relation to the ten characteristics, five (TMSF, DMC, DMR, TMSC and TMSR) confirmed the prediction in A4 <AB, since in this area were found values of characteristics related to the fast use of the resource: DMC (3.27 mg.mm^{-3}); DMR (0.28 mg.mm^{-3}); TMSF (1.13 mg.g^{-1}); TMSC (0.42 mg.g^{-1}) and TMSR (0.35 mg.g^{-1}).

Table 2. Weighted mean values of the characteristics in the community (CWM) in four environments of a fragment of an urban rainforest.

Characteristics	A1$_{>AB}$	A2$_{ABI}$	A3$_{ABI}$	A4$_{<AB}$
AF (cm^2)	943.07a	996.87a	404.17b	37.09c
AFE (cm^2.mg^{-1})	1214.84a	1293.34a	509.14b	165.04c
Cc_mass (micromol.g^{-1})	6.13a	5.76a	2.44b	0.75c
TMSF (mg.g^{-1})	5.98a	4.86a	2.71b	1.13c
DMC (mg.mm^{-3})	0.59a	0.55a	0.59a	0.37b
DMR (mg.mm^{-3})	0.60a	0.58a	0.62a	0.28b
QA$_{satc}$ (%)	99.67a	95.63a	70.57a	45.71b
QA$_{satr}$ (%)	95.30a	94.41a	86.50a	42.38b
TMSC (mg.g^{-1})	0.59a	0.68a	0.88a	0.42b
TMSR (mg.g^{-1})	0.60a	0.59a	0.58a	0.35b

Data presented as mean: AF - leaf area; AFE - specific leaf area; Cc_mass - chlorophyll concentration; TMSF - leaf dry matter content; DMC - wood stem density; DMR - root wood density; QAsatc - amount of saturated stem water; QAsatr - amount of saturated root water; TMSC - dry matter content of the stem; TMSC - dry matter content of the root. A1AB (area with greater basal area), A2ABI (intermediate basal area), A3ABI (basal intermediate area) and A4 <AB (area with lower basal area); CWM - weighted average of the community. Means followed by equal letters do not differ by the Student-Newman-Keuls test (p <.05).

The results obtained in this study were partially corroborated in the predictions, since only the environment with lower basal area (A4 <AB) presented lower values of TMSF, DMC, DMR, TMSC and TMSR as predicted for these environments [47,48,11]. It is known that

plants of this environment invest in fast growth and present a shorter life cycle than those of older areas, confirming that in this environment less investment in aerial biomass occurs, which would cause to the plants of these environments to not invest in structural carbon [34,49,50].

Unlike expected, environments with higher basal area (A1> AB and A2ABI) do not differ on the following characteristics: TMSF, DMC, DMR, TMSC and TMSR. The contrary was reported by [10] who found greater investment in structural carbon (dry matter of leaf and wood) in environments with greater basal areas; this study did not reveal this pattern, since there was no increase in the values of these characteristics in the two areas with greater basal areas (A1> AB and A2ABI). It is assumed that in urban fragments the disturbances are more frequent, so it is possible to suggest that plants with lower values of these characteristics have also been "established" in the two environments of greater basal area.

Regarding the characteristics: AF, AFE, Cc_mass, Qasatc and Qasatr, there was no variation among the areas, as expected by the predictions; as suggested by [51] it is expected that in the environment A4<AB the plants would have more saturated water in the stem. Some authors observed that in environments closer to the end of the succession, such as those with greater basal area (A1>AB and A2ABI), would be lower values of FA, AFE and CC_mass, which did not occur in the present study; It can be assumed that this behavior was not due to the fact that it is a fragment of a city and undergoes frequent alterations [52-53].

In relation to changes in the values of functional characteristics in environments with different degrees of perturbation, there are reports in the literature that mention that functional characteristics may behave differently from what happens according to the classic succession paradigm [10,54,55,56].

In order to verify the influence of the basal area and light on the values of the 10 functional characteristics was performed analysis of mixed linear models (LMMs). Only AFE and Cc_mass had effects, but not as expected (Table 3), since smaller values of those characteristics were found in the environment with lower basal area and greater incidence of light (A4 <AB) revealing that the basal area and light are not adequate predictors of functional characteristics.

Table 3. Mixed linear models of functional characteristics as a function of basal area and light in a fragment of an urban rainforest.

Characteristics	AB					Luz				
	D	Df	P	E	EP	D	Df	P	E	EP
AF (cm^2)										
AFE (cm^2.mg^{-1})	224.65	1	0.90	-	-	300.75	1	0.80	-	-
Cc_mass (micromol.g^{-1})	150.32	1	0.00**	-1.20^{e-01}	5.25^{e-02}	189.32	1	0.00**	-1.3^{e-01}	4.25^{e-02}
TMSF (mg.g^{-1})	114.24	1	0.00**	-0.13^{e-01}	4.00^{e-01}	224.44	1	0.00**	-0.2^{e-01}	5.03^{e-01}
DMC (mg.mm^{-3})	202.46	1	0.57	-	-	302.48	1	0.67	-	-
DMR (mg.mm^{-3})	207.14	1	0.75	-	-	210.15	1	0.85	-	-
QA$_{satc}$ (%)	219.44	1	0.86	-	-	239.55	1	0.76	-	-
QA$_{satr}$ (%)	134.63	1	0.25	-	-	234.73	1	0.35	-	-
TMSC (mg.g^{-1})	182.89	1	0.36	-	-	282.99	1	0.46	-	-
TMSR (mg.g^{-1})	225.00	1	0.91	-	-	146.00	1	0.81	-	-

AB - basal area; D - difference residue after removal of the variable; df - Degrees of freedom; P - associated p value; E - estimate; EP - standard error of the mean. AF - leaf area; AFE - specific leaf

279 *area; Cc_mass - chlorophyll concentration; TMSF - leaf dry matter content; DMC - wood stem density;*
280 *DMR - root wood density; amount of saturated water from the stem; amount of saturated root water;*
281 *TMSC - dry matter content of the stem; TMSC - dry matter content of the root. (Area with greater basal*
282 *area), A2ABI (intermediate basal area), A3ABI (intermediate basal area) and A4 <AB (area with lower*
283 *basal area). (** = p <.01).*

285 Thus, the lower values of AFE and Cc_mass in A4 <AB, occurred due to these
286 characteristics present high variability in more open areas [45,46]. The literature reports that
287 of the organs of the plant, the leaf is the most variable because its morphology and
288 physiology are strongly influenced by environmental factors [56,57]. It is worth mentioning
289 that the value of CWM of leaf dry matter, one of the components of AFE, is lower in the open
290 area (A4 <AB), confirming that this environment would present plants with lower investment
291 in structural carbon [9,58].

293 **3.1 Variation of leaf characteristics in function of light availability**

295 The analysis of the coefficient of variation of the characteristics by environment revealed that
296 areas with less light availability (A1> AB and A2ABI) did not differ among them; on the other
297 hand, A3ABI and A4 <AB differed from each other and presented lower coefficient in the
298 characteristics (Table 4).

300 **Table 4. Coefficient of variation (CV) of leaf characteristics, basal area and**
301 **light intensity in the four areas of a fragment of an urban rainforest.**

Areas	AF	TMSF	AFE	Cc_mass	AB ($4000\ m^2$)	Light (%)
			CV			
$A1_{>AB}$	0.91 a	0.33 a	0.81 a	0.87 a	9.43 a	6.09 c
$A2_{ABI}$	0.83 a	0.34 a	0.92 a	0.82 a	4.14 b	12.94 c
$A3_{ABI}$	0.52 b	0.18 b	0.50 b	0.61 b	1.95 b	31.75 b
$A4_{<AB}$	0.13 c	0.07 c	0.17 c	0.10 c	1.00 c	46.97 a

302 *AF - leaf area (cm^2), TMSF - leaf dry matter content ($mg.g^{-1}$), AFE - specific leaf area ($cm^2.mg^{-1}$),*
303 *Cc_mass - chlorophyll content ($micromol.g^{-1}$). A1AB (area with greater basal area), A2ABI*
304 *(intermediate basal area), A3ABI (intermediate basal area) and A4 <AB (area with lower basal area);*
305 *Averages followed by the same letters do not differ by the Student-Newman-Keuls test (p <.05).*

307 The prediction that there would be a greater coefficient of variation of the four characteristics
308 (AF, TMSF, AFE and Cc_mass) in the environment with greater light availability (A4 <AB)
309 was not confirmed, since all the characteristics exhibited lower CV values: 0.13); TMSF
310 (0.07); AFE (0.17) and Cc_mass (0.10) (Table 5).

312 **Table 5. Linear models of the coefficient of variation of the functional**
313 **characteristics as a function of light intensity in a fragment of an urban rain**
314 **forest.**

Características	Intensidade de luz (%)				
	D	Df	P	E	EP
CV_AF (cm^2)	244.65	1	0.00**	-1.74^{e-02}	2.71^{e-02}
CV_AFE ($cm^2.mg^{-1}$)	255.32	1	0.00**	-1.32^{e-01}	3.25^{e-02}
CV_Cc_mass (micro $mol.g^{-1}$)	179.24	1	0.00**	-0.23^{e-01}	0.33^{e-01}
CV_TMSF ($mg.g^{-1}$)	310.46	1	0.00**	-2.86^{e-01}	1.34^{e-02}

315 *CV - Coefficient of variation; D - difference residue after removal of the variable; Df - Degrees of freedom; P -*
316 *associated p value; E - estimate; EP - standard error of the mean. DP_AF - leaf area; AFE - specific leaf area;*
317 *Cc_mass - chlorophyll concentration; TMSF - leaf dry matter content; (Area with lower basal area), A2ABI*

318 *(intermediate basal area), A3ABI (intermediate basal area) and A4 <AB (area with lower basal area). (** = p*
319 *<.01).*
320
321 Contrary to the expectations, the environments with greater light availability did not present
322 higher coefficient of variation of leaf characteristics. According to table 4, it was observed
323 that the area A4<AB, where there was greater light availability, the values of the coefficient
324 of variation were smaller.

325 To test the hypothesis that greater light availability will cause greater variation in the value of
326 the coefficient of variation of leaf characteristics, linear models (LM) were constructed (Table
327 5). All the analyzed characteristics (AF, TMSF, AFE and Cc_mass) had an effect of light
328 intensity, but not as expected, since in the environment with greater light availability (A4
329 <AB, table 1) had smaller values of standard deviation (Table 5).

330 It is worth noting that when we observed the effect of the geographic distance on the
331 coefficient of variation of the characteristics, the results showed that the space had no effect
332 on the standard deviation (r = -0.0567; p> .001).

333 It was expected that in the area A4<AB, where there was greater light intensity (Table 4), the
334 leaf characteristics would be more variable [59], especially the physiological ones, such as
335 the chlorophyll content [56], but showed lower values of coefficient of variation of the
336 characteristics of AF, TMSF, AFE and Cc_mass (Table 5). This greater variability of the
337 characteristics of the plants in environments with more light can be due to the high
338 heterogeneity of light reception, due to plants to grow rapidly and thus change the availability
339 of light inside the forest [60-62].

340 It is known that the succession in urban and peri-urban landscapes is remarkably unique,
341 since the proximity of the urban environment increases the probability of continuous
342 anthropic disturbances, being able to alter the variability of the characteristics in the
343 environment with more light and consequently alteration in the classic path of the succession
344 [8,63,64,65]. Similar to that was found in this study, [52] also observed that more open and
345 disturbed areas showed less variation of characteristics.

346 This pattern is distinct from that reported in the literature for the area with more light, due to
347 the fact that the dynamics of this environment is strongly altered as a result of increased
348 mortality. According to the classical succession paradigm [54], it would be expected that in
349 environments with greater light availability, plants with characteristics related to the rapid use
350 of the resource would be more abundant, although plants with characteristics related to the
351 slow use are less abundant [19,67]; as succession advances the roles would reverse [9],
352 thus, it can be assumed that this greater light input in the environment A4<AB, is due to the
353 greater perturbations, what could led to a higher mortality of plants with slow use of
354 resources, favoring even more those of quick use of the resource, or perhaps those have not
355 even been established; as a result, the variability of the leaf characteristics of A4<AB would
356 be reduced.

357 The LM analyzes revealed that light is not a good predictor of leaf variability of tree plants in
358 urban fragments, since as light availability increased in A4 <AB, there was a reduction in the
359 coefficient of variation of all leaf characteristics (FA, TMSF, AFE and Cc_mass).
360
361 **4. CONCLUSIONS**
362
363 Frequent disturbances can alter the classical succession path due to population dynamics,
364 especially in the area with greater light availability, which may cause higher mortality of

plants with slow use of the resource, favoring those that are quick to use or that perhaps use have not even been established, resulting in reduced variability of leaf characteristics.

The variation of functional characteristics as a function of the basal area and the availability of light in an urban rainforest fragment is different from what occurs in the classic succession commonly reported, pointing out that possible disturbances caused by the surroundings are the main agents of the functional structure of the community. In this way, it is suggested that in the next researches the intraspecific variation of the tree species in these areas should be more focused and add more functional characteristics to analyze, especially the physiological ones, such as nitrogen, phosphorus and potassium foliar, because these reflect better the behavior of the species.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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