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Forest fragment grouping analysis under selective logging in Amazonian biome

Karen Janones da ROCHA[1]*, Édila Cristina de SOUZA[2], Cyro Matheus Cometti FAVALESSA[2], Sidney Fernando CALDEIRA[2], Silvo Alves RODRIGUES[3], Gilvano Ebling BRONDANI[4]*

[1]Federal University of Rondonia, Rolim de Moura, RO, Brazil.
[2]Federal University of Mato Grosso, Cuiabá, MT, Brazil.
[3]Independent consultant in Forestry, Cuiabá, MT, Brazil.
[4]Federal University of Lavras, Lavras, MG, Brazil.
E-mail: karenrocha@unir.br; gilvano.brondani@ufla.br
ORCID: (0000-0002-2165-3081; 0000-0001-5528-8804; 0000-0002-6630-1979; 0000-0001-6042-4313; 0000-0001-9734-4907; 0000-0001-8640-5719)

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ABSTRACT: The aim of this study was to analyse the existence of floristic groups in Seasonal Semi-deciduous Forest fragments under the effects of selective logging located in Tapurah-MT. The given clusters were allocated and measured, and each one had five subunits of 500 m². For each sampling unit, all of the arboreal and shrub species with a diameter at breast height (DBH) equal to or greater than 10 cm were considered. In the sampling subunits studied, the vegetation matrix was composed of the density of the 20 species in the fragment with the greatest importance. The presence of floristic groups was verified by a grouping analysis through the species association method. Euclidean distance with Hellinger's transformation was used as a similarity measure between the groupings, and Ward's linking method was used for the dendrogram elaboration. The number of groups was established by Kendall's coefficient, and correlations between the groups and the species were assessed. Once the concordance was determined, the number of groups in which the species were correlated was chosen. The species' auto-ecological characteristics, mainly the propagating material dispersion type and average DBH, were the main factors responsible for the species association and similarity inside each floristic group.
Keywords: similarity between species groups; species association; floristic group; environmental disturbance.

Análise de agrupamento de fragmento florestal sob efeitos da extração seletiva no bioma amazônico

RESUMO: O objetivo deste estudo foi analisar a existência de grupos florísticos em fragmentos de Floresta Estacional Semidecidual sob os efeitos da exploração madeireira seletiva localizada em Tapurah-MT. Os transectos foram subdivididos em cinco subunidades de 500 m². Para cada unidade amostral, foram consideradas todas as árvores com DAP maior ou igual a 10 cm. Nas subunidades amostrais estudadas, a matriz de vegetação foi composta pela densidade das 20 espécies de maior importância no fragmento. A presença de grupos florísticos foi verificada por meio de uma análise de agrupamento pelo método de associação de espécies. A distância euclidiana com a transformação de Hellinger foi usada como uma medida de similaridade entre os agrupamentos, e o método de ligação de Ward foi usado para a elaboração do dendrograma. O número de grupos foi estabelecido pelo coeficiente de Kendall e as correlações entre os grupos e as espécies foram avaliadas. Uma vez determinada a concordância, optou-se pelo número de grupos em que as espécies estavam correlacionadas. Foi verificado que as características auto-ecológicas das espécies, principalmente o tipo de dispersão do material propagado e o DAP médio, foram os principais responsáveis pela associação e similaridade das espécies dentro de cada grupo florístico.
Palavras-chave: similaridade entre grupos florísticos; associação de espécies; agrupamentos florísticos; perturbação ambiental.

1. INTRODUCTION

Although there are laws that authorize logging in specific areas, illegal logging is widespread in Brazil and in several Amazonian countries. And despite selective logging only targeting trees with commercial value, when not carried out through instruments such as the Sustainable Forest Management Plan (Plano de Manejo Florestal Sustentável – PMFS), the logging methods cause environmental damage.

Areas that were the object of selective logging are more likely to be occupied by new residents and to suffer clear cuts for the cultivation of pasture or grain, promoting the process of forest fragmentation. And the consequences are serious, fragmentation affects the organization of natural communities, reduces biodiversity, increases the risk of extinction of wild animals and compromises the ecological services provided by the forest. Furthermore, the mere presence of these fragments does not guarantee their maintenance (ROCHA et al., 2017).

Biological diversity conservation strategies require studies that quantify the existing species and their distribution in the environment as well as provide knowledge on the relationships between floristic composition and ecosystem diversity (PRIMACK; RODRIGUES, 2001). Conservation initiatives, management and restoration of forest fragments require detailed studies, such as flora inventories and the ecology of plant communities (FARAH et al., 2017). Grouping analysis, which is frequently used in scientific projects, is a useful tool for understanding natural forest by helping to detect specific floristic associations (SÜHS; BUDKE, 2011; CHAI; WANG, 2016). The search for species associations is often based on the non-tested suppositions that species have nonrandom patterns of association due to environmental control or biotic interactions (LEGENDRE; LEGENDRE, 2012).

Under the hypothesis of environmental control, once associations are verified, it is possible to focus on finding the mutual ecological demands of most or even all species of an association instead of having to describe the biology and habitat of each species individually. Associations can be better predictors of the environmental quality than the individual species because associations are less affected by sampling errors (LEGENDRE, 2005; LEGENDRE; LEGENDRE, 2012).

In this context, the aim of the present study was to analyse the existence of floristic groups and to evaluate which are the main factors responsible for the association and similarity of species within each floristic group in a fragment of the Seasonal Semi-deciduous Forest under the effects of selective logging.

2. MATERIALS AND E METHODS

A floristic and structural survey on a 32.98 ha fragment was conducted in the municipality of Tapurah, Mato Grosso, Brazil (12°28'5.67" S; 56°33'32.14" W) (Figure 1). The fragment is located in the field of the Submontane Seasonal Semi-deciduous Forest from Amazon Biome (INPE, 2010) and suffers the effects of selective logging that occurred in the 1990s. The climate in the region is Am type according to Köppen's classification, with a short dry winter, high annual rainfall of approximately 3,000 mm year^{-1}, and an average annual temperature of 25°C (ALVARES et al., 2013).

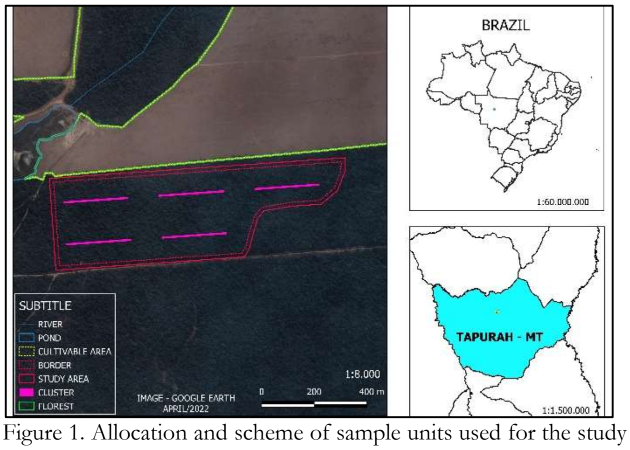

Figure 1. Allocation and scheme of sample units used for the study of the Seasonal Semideciduous Forest fragment under the influence of selective logging, Amazonian Biome, 2022.

Figura 1. Localização e esquema das unidades amostrais utilizadas para o estudo do fragmento de Floresta Estacional Semidecidual sob influência da extração seletiva de madeira, Bioma Amazônico, 2022.

For systematic sampling, the fixed area method was applied to 10 m × 250 m clusters with five subunits of 10 m × 50 m each, and a minimum border of 15 m was considered. The allocation of the clusters respected the greatest variation gradient of the forest, West-East direction due to proximity to the river (1,010 m) and the slope of the terrain (13.6%) (Figure 1). All living individuals with a diameter at breast height (DBH) greater than or equal to 10 cm were measured. Botanical material of the species that could not be identified in the field by a parabotanist was collected for taxonomic analysis and identification in the herbarium of the Federal University of Mato Grosso (UFMT).

To update and confirm the nomenclature of species, Brazil's Flora Species List (BFG, 2022 – reflora.jbrj.gov.br) was used. The delimitation of families followed the APG IV classification system (THE ANGIOSPERM PHYLOGENY GROUP, 2016).

The vegetation matrix was composed of the density of 20 species with the greatest importance (VI) in the fragment (Table 1) in the 25 sampling subunits that were studied, more details in Rocha (2015). Based on field observations and literature reviews (CARVALHO, 2006; LORENZI, 2009; PERES, 2016), the species were classified in ecological groups and dispersion syndrome types. The succession classification was based on the terminology by Gandolfi et al. (1995), and the species were categorized as pioneers, early secondary, late secondary and due to a lack of information, non-classified (NC). The dispersion syndromes were based on the terminology by Van der Pijl (1982) and included anemochorous, zoochorous, autochorous and, due to a lack of information, non-classified (NC).

When looking for species associations, Legendre (2005) suggested transforming the species abundance to control for differences in total abundance among places, producing more monotonic correlations between species. Before the concordance analysis among species, the data were transformed using Hellinger's transformation (Equation 1) (LEGENDRE; GALLAGHER, 2001). The presence of floristic groups was verified through grouping analysis with the species association method (LEGENDRE; LEGENDRE, 2012). Euclidean distance with Hellinger's transformation was used as a similarity measure between the groupings (Equation 2).

$$y'_{ij} = \sqrt{\frac{y_{ij}}{\sum_{j=1}^{k} y_{ij}}} \qquad (01)$$

$$D(y_1, y_2) = \sqrt{\sum_{j=1}^{p} \left(y'_{1j} - y'_{2j}\right)^2} \qquad (02)$$

where: y'_{ij} = the abundance of j species in the sampling x_i subunit transformed; y_{1j} = the abundance of j species in the sampling x_1 subunit; y_{2j} = the abundance of j species in the sampling x_2 subunit; k = total of species in the sampling x_i subunit.

The Ward's linking method was used for the dendrogram elaboration. Ward's method is a procedure in which the similarity measure used to unite groupings is calculated as the sum of the squares between both groupings that present the lowest increase in the global sum of the squares inside the groupings (HAIR et al., 2009). According to Dutra et al. (2004), Ward's method forms groups based on the minimum standard deviation among the data of each group.

The data were organized in a data matrix with 20 columns, representing the 20 species with greatest importance values, and 25 lines, representing the observations formed by the 25 sampling subunits. The grouping analysis was processed through R software 2.2-0 (2014) version, mvpart package (DE'ATH, 2007).

Table 1. Species with the greatest importance found in the Seasonal Semideciduous Forest fragment under the influence of selective logging in Amazonian Biome, with their number of individuals, basal area, phytosociological parameters, succession ecological group and propagating material dispersion type.
Tabela 1. Espécies de maior importância encontradas no fragmento de Floresta Estacional Semidecidual sob influência do corte seletivo no bioma Amazônia, com número de indivíduos, área basal, parâmetros fitossociológicos, grupo ecológico de sucessão e tipo de dispersão do material de propagação.

Yi	Species	N	G	FR	DoR	DR	VI	EG	Disp.
Y1	*Qualea paraensis* Ducke	42	8.4011	5.36	14.46	7.32	9.05	ST	AUTO
Y2	*Aspidosperma discolor* A.DC.	25	6.2954	3.83	10.84	4.36	6.34	ST	ANE
Y3	*Matayba arborescens* (Aubl.) Radlk.	48	3.2019	4.82	5.53	8.35	6.23	P	ZOO
Y4	*Vochysia vismiifolia* Spruce ex Warm.	39	3.7899	4.08	6.52	6.79	5.80	ST	AUTO
Y5	*Pouteria guianensis* Aubl.	30	3.5305	3.83	6.08	5.23	5.04	ST	ZOO
Y6	*Pseudolmedia laevigata* Trécul	20	1.4975	3.57	2.58	3.48	3.21	SI	ZOO
Y7	*Xylopia* spp.	22	1.1054	3.83	1.90	3.83	3.19	NC	ZOO
Y8	*Nectandra cuspidata* Nees	25	0.9396	3.57	1.62	4.36	3.18	P	ZOO
Y9	*Ocotea acutangula* (Miq.) Mez	19	1.3459	2.55	2.32	3.31	2.73	ST	ZOO
Y10	*Tachigali vulgaris* L. G. Silva & H. C. Lima	18	0.9537	3.06	1.64	3.14	2.61	NC	ANE
Y11	*Sterigmapetalum obovatum* Kuhlm.	13	1.2410	2.81	2.14	2.26	2.40	NC	NC
Y12	*Inga* spp.	10	1.5222	2.03	2.63	1.74	2.13	NC	ZOO
Y13	*Erisma uncinatum* Warm.	11	1.2546	2.30	2.16	1.92	2.12	ST	ANE
Y14	*Toulicia guianensis* Aubl.	12	0.8503	2.04	1.46	2.09	1.87	SI	ZOO
Y15	*Tapirira guianensis* Aubl.	10	0.8480	2.30	1.46	1.74	1.83	SI	ZOO
Y16	*Diplotropis purpurea* (Rich.) Amshoff	11	0.9957	1.79	1.71	1.92	1.81	ST	ANE
Y17	*Bellucia grossularioides* (L.) Triana	10	1.2088	1.53	2.08	1.74	1.78	P	ZOO
Y18	*Licania blackii* Prance	8	0.9868	1.78	1.70	1.39	1.62	NC	NC
Y19	*Helicostylis tomentosa* (Poepp. & Endl.) Rusby	8	0.8850	1.79	1.52	1.39	1.57	SI	ZOO
Y20	*Cheiloclinium cognatum* (Miers) A.C.Sm.	9	0.5248	2.03	0.91	1.57	1.50	SI	ZOO

Where: Yi = variable that represents the species *i*; N = number of sampled individuals; G = basal area (m^2 per ha); FR = relative frequency (%); DoR = relative dominance (%); DR = relative density (%); VI = importance value (%); EG = ecological group; P = pioneer; SI = early secondary; ST = late secondary; NC = non-classified; Disp. = propagating material dispersion type; ZOO = zoochorous; ANE = anemochorous; AUTO = autochorous.
Onde: Yi = variável que representa a espécie *i*; N = número de indivíduos amostrados; G = área basal por hectare (m^2 por ha); FR = frequência relativa (%); DoR = dominância relativa (%); DR = densidade relativa (%); VI = valor de importância (%); EG = grupo ecológico; P = pioneira; SI = sencundária inicial; ST = secundária tardia; NC = não classificada; Disp. = tipo de dispersão de propágulos; ZOO = zoocórica; ANE = anemocórica; AUTO = autocórica.

Concordance analysis, which is based on Kendall's concordance coefficient, is used to outline groups of species that form statistically significant associations. The number of groupings was established using Kendall's concordance coefficient (W – Equation 3), together with the permutation test – paired average of Spearman's correlation, which was suggested by Legendre (2005). Spearman's correlations between the groups and the species were analysed, and a concordance global test was applied among the species of each group. With a concordance occurrence, the number of groups was chosen when the species were correlated.

$$W = \frac{(p-1)\bar{r}+1}{p} \qquad (03)$$

where: W = Kendall's concordance coefficient; p = the number of variables (judges), among which Spearman's correlation coefficients are calculated; $\bar{r}$ = the paired average of Spearman's correlation.

First, a general all-species independence test is performed. If the null hypothesis is rejected, groups of correlated species are searched and, within each group, the contribution of each species to the global statistics is tested, using the paired average of Spearman's correlation. The method aims at finding the most encompassing assemblages, i.e. the smallest number of groups containing the largest number of positively and significantly associated species (BOCARD et al., 2011).

When two sets of species are specified, the default correlation analysis includes descriptive statistics for each specie ($\bar{r}$) and pairwise Pearson correlation statistics between the two sets of variables. For a Spearman correlation, the Fisher's z transformation is used to derive its confidence limits and a *p*-value under a specified null hypothesis.

The null hypothesis (H0) from Kendall's concordance test (W) states that all species are independent, whereas the alternative hypothesis states that at least one of the species is concordant with one or some of the other species. The test was performed for four possibilities: with 3 groups, with 4 groups, with 5 groups and with 6 groups, which guarantees a minimum of two species per group.

3. RESULTS

Through the Euclidean distance with the Hellinger transformation, it is possible to verify the similarity between species and, consequently, between clusters (Table 2). But in general, the Spearman correlation between the species studied was low, $r \leq |0.60|$ (Table 3).

Six floristic groups were determined by Kendall's concordance test (W). Although groups 1 and 2 accepted the null hypothesis (H0) (Table 4), the groups did not have species with the paired average of Spearman's negative correlation (Table 5).

An a posteriori analysis was calculated to determine which individual species were concordant with one or some of the other species of the group. By analysing Spearman's paired average of each species, six floristic groups were established (Table 5).

The dendrogram elaborated by Ward's linking method is presented in Figure 2 in which the red dashed line represents the cut-off point cutting for the determination of the number of groups. None of the groups occurred in all sampling subunits, and as a Ward's method characteristic (HAIR et al., 2009), they presented similar dimensions (Table 6).

Table 2. Euclidean distance with Hellinger's transformation among the species with the greatest importance values in a Seasonal Semideciduous Forest fragment under the influence of selective logging, Amazonian Biome, 2014. ^{ns} – not significant at the level of 5% error probability; * – significant at the level of 5% error probability.
Tabela 2. Distância euclidiana com a transformação de Hellinger entre as espécies com maior valor de importância em um fragmento de Floresta Estacional Semidecidual sob influência da exploração seletiva, Bioma Amazônico, 2014. ^{ns} – não significativo ao nível de 5% de probabilidade de erro; * – significativo ao nível de 5% de probabilidade de erro.

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19
Y2	1.294																		
Y3	0.856	0.987																	
Y4	1.356	0.945	1.080																
Y5	1.104	1.011	0.531	1.173															
Y6	1.011	0.942	1.164	0.640	1.116														
Y7	1.224	0.989	0.921	0.996	0.795	1.097													
Y8	0.847	1.176	0.803	1.100	0.946	1.127	1.155												
Y9	1.340	1.073	0.848	0.511	0.933	0.767	0.629	0.972											
Y10	1.137	0.887	1.598	0.995	1.358	0.953	0.973	0.849	1.034										
Y11	0.932	1.095	1.004	1.481	1.027	1.480	0.924	1.012	1.192	0.941									
Y12	0.782	1.308	1.071	0.984	1.488	1.074	0.842	1.167	1.094	0.981	1.108								
Y13	0.853	0.868	0.950	1.235	0.815	0.955	1.270	1.297	1.509	1.324	1.217	1.028							
Y14	1.052	1.108	0.818	1.124	0.818	0.945	1.123	0.726	0.767	1.154	1.068	1.323	1.273						
Y15	1.019	1.184	1.183	1.397	1.097	1.201	0.888	0.864	1.134	0.826	0.564	0.729	1.327	0.880					
Y16	1.321	0.708	1.171	1.030	0.900	1.065	1.406	1.187	1.368	0.995	0.901	1.473	0.743	1.180	1.113				
Y17	1.290	1.099	1.067	1.003	1.144	0.843	0.975	1.186	1.118	1.265	0.880	1.069	0.925	1.050	0.965	0.631			
Y18	0.761	1.372	0.822	0.966	0.797	0.779	0.968	0.665	0.898	1.316	1.020	0.968	0.998	1.203	1.151	1.198	0.844		
Y19	1.061	1.019	1.460	1.204	1.060	1.469	1.107	1.073	1.242	0.860	0.943	1.094	0.678	0.914	1.111	0.932	1.119	1.367	
Y20	1.092	0.671	0.662	1.046	0.772	0.997	1.183	1.082	1.274	1.414	1.015	1.226	0.565	1.082	1.274	0.673	0.884	0.929	1.081

Table 3. Spearman's correlation matrix among the species with the greatest importance values in a Seasonal Semideciduous Forest fragment under the influence of selective logging, Amazonian Biome, 2014. (Underlined values are negative). ^{ns} – not significant at the level of 5% error probability; * – significant at the level of 5% error probability.
Tabela 3. Matriz de correlação de Spearman entre as espécies com os maiores valores de importância em um fragmento de Floresta Estacional Semidecidual sob influência da exploração seletiva, Bioma Amazônico, 2014. (Valores sublinhados são negativos). ^{ns} – não significativo ao nível de 5% de probabilidade de erro; * – significativo ao nível de 5% de probabilidade de erro.

	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
Y1	<u>0.29</u>^{ns}	0.14^{ns}	<u>0.36</u>^{ns}	<u>0.10</u>^{ns}	<u>0.01</u>^{ns}	<u>0.22</u>^{ns}	0.15^{ns}	<u>0.34</u>^{ns}	<u>0.14</u>^{ns}	0.07^{ns}	0.22^{ns}	0.15^{ns}	<u>0.05</u>^{ns}	<u>0.02</u>^{ns}	<u>0.32</u>^{ns}	<u>0.29</u>^{ns}	0.24^{ns}	<u>0.06</u>^{ns}	<u>0.09</u>^{ns}
Y2		0.01^{ns}	0.06^{ns}	<u>0.01</u>^{ns}	0.06^{ns}	0.01^{ns}	<u>0.18</u>^{ns}	<u>0.07</u>^{ns}	0.11^{ns}	<u>0.10</u>^{ns}	<u>0.31</u>^{ns}	0.13^{ns}	<u>0.11</u>^{ns}	<u>0.18</u>^{ns}	0.29^{ns}	<u>0.10</u>^{ns}	<u>0.37</u>^{ns}	<u>0.02</u>^{ns}	0.33^{ns}
Y3			<u>0.08</u>^{ns}	0.47*	<u>0.16</u>^{ns}	0.08^{ns}	0.20^{ns}	0.15^{ns}	<u>0.60*</u>	0.00^{ns}	<u>0.07</u>^{ns}	0.05^{ns}	0.18^{ns}	<u>0.18</u>^{ns}	<u>0.17</u>^{ns}	<u>0.07</u>^{ns}	0.18^{ns}	<u>0.46*</u>	0.34^{ns}
Y4				<u>0.17</u>^{ns}	0.36^{ns}	0.00^{ns}	<u>0.10</u>^{ns}	0.49^{ns}	0.00^{ns}	<u>0.48*</u>	0.02^{ns}	<u>0.23</u>^{ns}	<u>0.12</u>^{ns}	<u>0.40*</u>	<u>0.03</u>^{ns}	0.00^{ns}	0.03^{ns}	<u>0.20</u>^{ns}	<u>0.05</u>^{ns}
Y5					<u>0.12</u>^{ns}	0.20^{ns}	0.05^{ns}	0.07^{ns}	<u>0.36</u>^{ns}	<u>0.03</u>^{ns}	<u>0.49*</u>	0.19^{ns}	0.18^{ns}	<u>0.10</u>^{ns}	0.10^{ns}	<u>0.14</u>^{ns}	0.20^{ns}	<u>0.06</u>^{ns}	0.23^{ns}
Y6						<u>0.10</u>^{ns}	<u>0.13</u>^{ns}	0.23^{ns}	0.05^{ns}	<u>0.48*</u>	<u>0.07</u>^{ns}	0.05^{ns}	0.06^{ns}	<u>0.20</u>^{ns}	<u>0.06</u>^{ns}	0.16^{ns}	0.22^{ns}	<u>0.47*</u>	0.00^{ns}
Y7							<u>0.16</u>^{ns}	0.37^{ns}	0.03^{ns}	0.08^{ns}	0.16^{ns}	<u>0.27</u>^{ns}	<u>0.12</u>^{ns}	0.11^{ns}	<u>0.41*</u>	0.03^{ns}	0.03^{ns}	<u>0.11</u>^{ns}	<u>0.18</u>^{ns}
Y8								0.03^{ns}	0.15^{ns}	<u>0.01</u>^{ns}	<u>0.17</u>^{ns}	<u>0.30</u>^{ns}	0.27^{ns}	0.14^{ns}	<u>0.19</u>^{ns}	<u>0.19</u>^{ns}	0.33^{ns}	<u>0.07</u>^{ns}	<u>0.08</u>^{ns}
Y9									<u>0.03</u>^{ns}	<u>0.19</u>^{ns}	<u>0.09</u>^{ns}	<u>0.51*</u>	0.23^{ns}	<u>0.13</u>^{ns}	<u>0.37</u>^{ns}	<u>0.12</u>^{ns}	0.10^{ns}	<u>0.24</u>^{ns}	<u>0.27</u>^{ns}
Y10										0.06^{ns}	0.02^{ns}	<u>0.32</u>^{ns}	<u>0.15</u>^{ns}	0.17^{ns}	0.00^{ns}	<u>0.27</u>^{ns}	<u>0.32</u>^{ns}	0.14^{ns}	<u>0.41*</u>
Y11											<u>0.11</u>^{ns}	<u>0.22</u>^{ns}	<u>0.07</u>^{ns}	0.44*	0.10^{ns}	0.12^{ns}	<u>0.02</u>^{ns}	0.06^{ns}	<u>0.01</u>^{ns}
Y12												<u>0.03</u>^{ns}	<u>0.32</u>^{ns}	0.27^{ns}	<u>0.47*</u>	<u>0.07</u>^{ns}	0.03^{ns}	<u>0.09</u>^{ns}	<u>0.23</u>^{ns}
Y13													<u>0.27</u>^{ns}	<u>0.33</u>^{ns}	0.26^{ns}	0.07^{ns}	0.00^{ns}	0.32^{ns}	0.44*
Y14														0.12^{ns}	<u>0.18</u>^{ns}	<u>0.05</u>^{ns}	<u>0.20</u>^{ns}	0.09^{ns}	<u>0.08</u>^{ns}
Y15															<u>0.11</u>^{ns}	0.04^{ns}	<u>0.15</u>^{ns}	<u>0.11</u>^{ns}	<u>0.27</u>^{ns}
Y16																0.37^{ns}	<u>0.20</u>^{ns}	0.07^{ns}	0.33^{ns}
Y17																	0.16^{ns}	<u>0.12</u>^{ns}	0.12^{ns}
Y18																		<u>0.37</u>^{ns}	0.07^{ns}
Y19																			<u>0.08</u>^{ns}

Table 4. Results from the Ward concordance test regarding the species with the greatest importance values for six floristic groups established in the Seasonal Semideciduous Forest fragment under the influence of selective logging, Amazonian Biome, 2014. *W* = Kendall's concordance coefficient; *F* = Fisher-Snedecor test statistic; X^2 = Friedman's Chi-Square test statistic; *P* = the p-value. * – significant at the level of 5% error probability.
Tabela 4. Resultados do teste de concordância de Ward quanto às espécies com os maiores valores de importância para seis grupos florísticos estabelecidos no fragmento de Floresta Estacional Semidecidual sob influência da exploração seletiva, Bioma Amazônico, 2014. *W* = coeficiente de concordância de Kendall; *F* = estatística do teste de Fisher-Snedecor; X^2 = estatística do teste Qui-Quadrado de Friedman; *P* = o valor p. * – significativo ao nível de 5% de probabilidade de erro.

Tests	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
W	0.6090	0.5698	0.4760	0.3844	0.5695	0.3437
F	0.1477	0.2530	0.0412	0.0010	0.0023	0.0065
χ^2	9.2296	27.3487	34.2685	46.1250	41.0045	41.2416
P	0.1490	0.2250	0.0490*	0.0010*	0.0040*	0.0050*

Table 5. Paired averages of Spearman's correlation among the species with the greatest importance values, calculated with Kendall's concordance test to determine the ideal number of floristic groups in the Seasonal Semideciduous Forest fragment under the influence of selective logging, Amazonian Biome, 2014.
Tabela 5. Médias pareadas da correlação de Spearman entre as espécies com os maiores valores de importância, calculadas com o teste de concordância de Kendall para determinar o número ideal de grupos florísticos no fragmento de Floresta Estacional Semidecidual sob influência de exploração seletiva de madeira, Bioma Amazônico, 2014.

Test with 3 groups			Test with 4 groups			Test with 5 groups			Test with 6 groups		
Group	Sp.	$\bar{r}$	Group	Sp.	$\bar{r}$	Group	Sp.	$\bar{r}$	Group	Sp.	$\bar{r}$
	Y1	-0.0257		Y1	-0.0257	1	Y1	0.2179	1	Y1	0.2179
	Y12	0.0772		Y12	0.0772		Y12	0.2179		Y12	0.2179
	Y10	0.0470		Y10	0.0470		Y10	0.0999	2	Y10	0.1396
1	Y19	-0.0295	1	Y19	-0.0295		Y19	-0.0055		Y19	0.1396
	Y7	0.0070		Y7	0.0070	2	Y7	0.0270		Y7	0.0942
	Y11	0.0981		Y11	0.0981		Y11	0.1572	3	Y11	0.2562
	Y15	0.1438		Y15	0.1438		Y15	0.1526		Y15	0.2740
	Y2	0.1091		Y2	0.1634		Y2	0.1634		Y2	0.1634
	Y13	0.1251		Y13	0.2246		Y13	0.2246		Y13	0.2246
	Y16	0.2132		Y16	0.3115		Y16	0.3115		Y16	0.3115
2	Y17	0.0820	2	Y17	0.1151	3	Y17	0.1151	4	Y17	0.1151
	Y20	0.2252		Y20	0.3019		Y20	0.3019		Y20	0.3019
	Y14	-0.1387									
	Y4	0.0884		Y4	0.4245		Y4	0.4245		Y4	0.4245
	Y6	0.0679	3	Y6	0.2965	4	Y6	0.2965	5	Y6	0.2965
	Y9	0.1788		Y9	0.3612		Y9	0.3612		Y9	0.3612
3	Y3	0.1253		Y3	0.2563		Y3	0.2563		Y3	0.2563
	Y5	0.0840		Y5	0.2270		Y5	0.2270		Y5	0.2270
	Y8	0.0646	4	Y8	0.2149	5	Y8	0.2149	6	Y8	0.2149
	Y18	0.1788		Y18	0.1280		Y18	0.1280		Y18	0.1280
				Y14	0.1086		Y14	0.1086		Y14	0.1086

where: $\bar{r}$ = paired averages of Spearman's correlation; Yi = species with the greatest importance values, ranging from 1 to 20.
onde: $\bar{r}$ = médias emparelhadas da correlação de Spearman; Yi = espécies com maior valor de importância, variando entre 1 e 20.

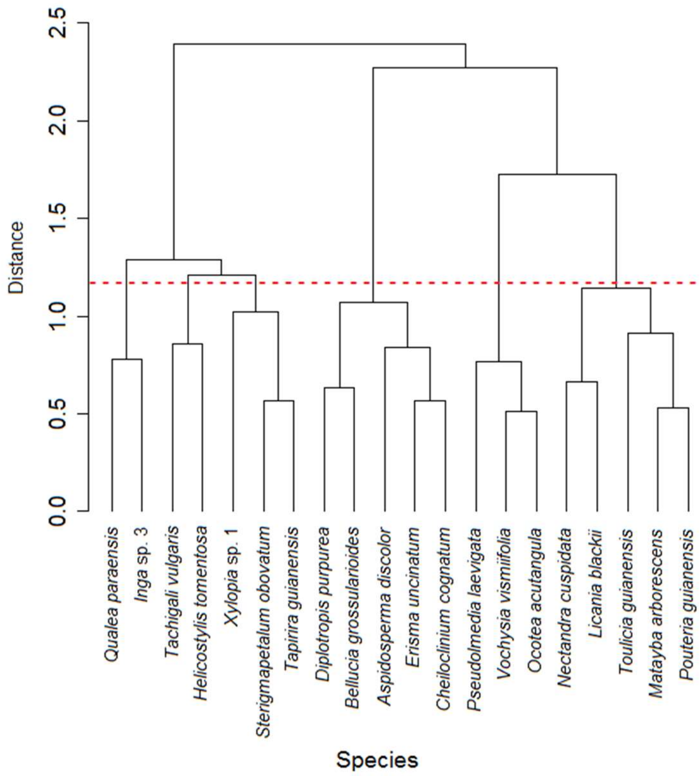

Figure 2. Classification of the species with the greatest importance values in six floristic groups through "Ward's" hierarchical method. The species were located in the Seasonal Semideciduous Forest fragment under the influence of selective logging, Amazonian Biome, 2014.
Figura 2. Classificação das espécies com os maiores valores de importância em seis grupos florísticos através do método hierárquico de "Ward". As espécies foram localizadas no fragmento de Floresta Estacional Semidecidual sob influência da exploração seletiva, Bioma Amazônico, 2014.

Table 6. Descriptive characteristics of the established groups in the Seasonal Semideciduous Forest fragment under the influence of selective logging, Amazonian Biome, 2014.
Tabela 6. Características descritivas dos grupos estabelecidos no fragmento de Floresta Estacional Semidecidual sob influência da exploração seletiva, Bioma Amazônia, 2014.

GROUP	N° SSub	Sample area	N° Families	N° Species	N° Trees	D	Average DBH	Max DBH	$\bar{g}$	G
1	24	1.20	2	2	52	42	26.67	72.16	0.5393	10.7862
2	16	0.80	2	2	26	21	17.54	41.22	0.1436	2.8729
3	21	1.05	3	3	45	36	17.91	36.76	0.1901	3.8029
4	21	1.05	5	5	80	64	17.31	50.93	0.2807	5.6133
5	21	1.05	3	3	66	53	18.75	50.93	0.3393	6.7855
6	24	1.20	4	5	123	98	18.46	55.07	0.4953	9.9054
TOTAL		6.35			392				1.9883	
MEDIA	21	1.06			65	52	19.44	51.18	0.3314	6.6277

in which: N° SSub = number of sampled subunits in the group; Sample area = group sampled area in hectares (ha); N° Families = number of families in the group; N° Species = number of species in the group; N° Trees = number of sampled trees in the group; D = sample density in the group by hectare (ha); DBH = diameter at 1.3 m (cm); Max DBH = maximum diameter (cm); $\bar{g}$ = group basal area for sample subunit ($m^2.500\ m^{-2}$); G = group basal area ($m^2\ ha^{-1}$).
em que: N° SSub = número de subunidades amostradas no grupo; Sample area = área amostrada do grupo em hectares (ha); N° Families = número de famílias no grupo; N° Species = número de espécies no grupo; N° Trees = número de árvores amostradas no grupo; D = densidade amostral no grupo por hectare (ha); DBH = diâmetro a 1,3 m (cm); Max DBH = diâmetro máximo (cm); $\bar{g}$ = área basal do grupo por subunidade amostral ($m^2.500\ m^{-2}$); G = área basal do grupo por hectare ($m^2.ha^{-1}$).

4. DISCUSSION

In at least one group, all of the tested possibilities accepted the H0 (P>0.05 and F>0.05). That is, there was at least one independent species in one group that should be with only concordant species. Legendre's recommendation (2005) is that the group that accepted H0 be redefined until it is composed of concordant species only. However, in the present study, working with more than six floristic groups would make the process unfeasible, as it would result in a high number of groups with only one species.

Spearman's paired average is an a posteriori test that is recommended to identify discordant species inside groups. However, the test does not reveal whether there are one or many groups of concordant species among those for which the independence null hypothesis is rejected. This information is obtained by calculating Spearman's correlation among species and by grouping them inside positively correlated groups (LEGENDRE, 2005).

The low Spearman's correlation among the 20 species with the greatest importance values of the studied fragment – r ≤ |0.60| – can be attributed to the fact that the fragment suffered from disturbances due to selective logging (Table 3). In fragments altered by human interference, clearing and canopy reconstruction are among the most important factors in the dynamics. The formation of small clearings increases the levels of luminosity and temperature, which lead the species to show some degree of physiological and morphological adaptation in response to sun or shade environments, and these variations can occur up to the intra-specific level (FELFILI et al., 2001; BARROS, 2007).

In general, the logging results in species found at the end and/or beginning of their cycle and opportunistic and/or generalist species, which changes the typology's original characteristic. Over time, in response to interference, these species obtained a higher importance value (LARA et al., 2017).

Although groups 1 and 2 accepted the H0 (Table 4), the species that composed the groups presented positive correlations (r) (Table 3). Groups 4 and 6 were the only groups that presented species with negative correlations (r). These groups were the largest groups and were composed of five species (Figure 7). Even with the negative correlation of *Aspidosperma discolor* A.DC. species with *Bellucia grossularioides* (L.) Triana in group 4, and *Toulicia guianensis* Aubl. species with *Licania blackii* Prance in group 6, the Euclidean distances with Hellinger's transformation among species were like the further groups (Table 2).

Groups 1, 4 and 6 were well distributed throughout the entire fragment, and they occurred in 96% of the sampled studied subunits (Table 6). Group 1 was composed of *Qualea paraensis* Ducke and Inga sp., which were classified as late secondary and non-classified (NC), respectively (Table 1). Species that belong to the late secondary ecological group are species that evolved in undergrowth in conditions with light or dense shadow. These species are able to remain in these conditions for all of their life, or they grow until they reach the canopy or an emergent condition (GANDOLFI et al., 1995).

Regarding the propagating material dispersion type, *Qualea paraensis* was classified as autochorous (Table 1), where fruits fall by gravity due to their own weight or with explosive dispersion (VAN DER PIJL, 1982). The autochorous syndrome has been frequently recorded in secondary forests and is considered more advantageous in open places (LÓPEZ-MARTÍNEZ et al., 2013). This advantage explains the individual's occurrence and their high average DBH (Table 6) in group 1 in the entire fragment. Although the fragment has some subsequent glades from selective logging, the fragment also has good coverage of the Canopy (Table 1).

The distributions of groups 4 and 6 can be attributed to the fact that they have classified species in every ecological group (Table 1). Pioneer species are clearly light-dependent and do not occur in the undergrowth but rather in glades or forest borders. Moreover, the early secondary species prefer average shading conditions or low-intensity luminosity, and they occur in small glades, borders of large glades, forest borders or in the non-densely shaded undergrowth (GANDOLFI et al., 1995).

In addition to the succession characteristics, the distributions of groups 4 and 6 can also be attributed to the propagating material dispersion type. Group 4 presented a predominance of the anemochorous dispersal (Table 1), which is seeds dispersed by the wind (KULMANN;

RIBEIRO, 2016). Researchers highlight that smaller area are probably more permeable to the arrival of seeds dispersed by the wind, which are capable of being transported for long distances (THOMSON et al., 2011). In fact, it is expected that in more irregular fragments, which have a greater proportion of borders than regular fragments, anemochorous species are efficient in their dispersion and settlement (GOTTSBERGER; SILBERBAUER-GOTTSBERGER, 2018).

Group 6 presented only zoochorous species (Table 1), where the propagating material dispersion is intrinsically related to fauna maintenance (MELO et al., 2016). The animals necessary for seed dispersion inhabit the lake and river borders and the forest track around the fragment part (Figure 1). Zoochorous dispersion is the most important dispersion mechanism in rainforests (GUILHERME et al., 2021) and is significantly influenced by the isolation effect and fragment connectivity (MELO et al., 2016).

The species from groups 2 and 3 were concentrated in the sampled subunits that were close to the agricultural areas (Figure 1). The species in both groups were classified as early secondary species (Table 1). They are also classified as zoochorous, but group 3 presented more developed individuals, with higher values for DBH and basal areas (Table 6). In group 5, the species preferred the subunits that were closer to the forest tracks (Figure 1), and there was a predominance of late secondary and zoochorous species (Table 1).

5. CONCLUSIONS

The species association method through Kendall's concordance test (W) is suitable for determining the floristic groups in the Seasonal Semideciduous Forest fragment under the influence of selective logging.

The species association and similarity inside each determined floristic group showed similar auto-ecological characteristics of the species, mainly the propagating material dispersion type, and the average DBH of each species.

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