CHANGES IN THE STRUCTURE DUE TO STRONG WINDS IN FOREST AREAS IN THE PANTANAL, BRAZIL

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ABSTRACT: The Pantanal climate presents marked seasonality and eventually strong winds occur, especially in the beginning of the rainy season, which may last from September or October until April. A phytosociological study was conducted to evaluate the effects of a strong wind on the composition and structure of two forest formations in Pantanal wetland, a semideciduous forest (19º 15' 32''S and 55º 45' 23.7''W) and a forested savanna - "cerradão" (19° 17' 21''S and 55º 45' 8.9''W), with trees with diameter at breast height (DBH) ≥ 5 cm. After the strong wind, a reduction of 6% of the basal area and volume in the semideciduous forest was observed, mainly due to the uprooting of *Xylopia aromatica* trees. In the forested savanna, the basal area and volume reduction was even higher; an estimated 10%, representing 69 uprooted trees per hectare, mainly of *Copaifera martii* trees. In both areas it was observed that the uprooted trees presented an average height and diameter bigger than the trees that remained intact. Usually, the trees that were uprooted presented higher wood density and the species that had broken branches had a lower density.

Key words: Basal area, natural disturbance, savanna forest, semideciduous forest.

ALTERAÇÕES NA ESTRUTURA DE ÁREAS FLORESTADAS CAUSADAS POR VENTANIA FORTE NO PANTANAL, BRASIL

RESUMO: *O clima do Pantanal é sazonal e eventualmente podem ocorrer ventanias fortes, especialmente no início do período chuvoso, que começa em setembro ou outubro e se estende até abril. Um estudo fitossociológico, para avaliar o efeito de ventania forte na composição e estrutura em árvores com diâmetro a altura do peito (DAP) ≥ 5 cm, foi realizado em duas formações florestais no Pantanal, uma floresta semidecídua (19º 15' 32''S e 55º 45' 23.7''O) e um cerradão (19º 15' 32''S e 55º 45' 23.7''O). Depois da ventania forte, ocorreu a redução de 6% da área basal e do volume na floresta semidecídua, principalmente por queda de árvores da espécie Xylopia aromatica. No cerradão, a redução da área basal e do volume foi mais alta, estimada em 10%, com 69 árvores caídas por hectare, principalmente da espécie Copaifera martii. Em ambas as áreas observou-se que as árvores caídas apresentaram altura e diâmetros maiores do que as árvores que permaneceram intactas. Geralmente, as espécies das árvores caídas apresentaram alta densidade de madeira, enquanto que as espécies que quebraram têm densidade de madeira menor.*

Palavras-chave: Área basal, distúrbio natural, cerradão, floresta semidecídua.

1 INTRODUCTION

The tropical forest is subject to different natural disturbances including strong winds, fire (SANFORD JUNIOR et al., 1985), and tree uprooting (BROKAW; GREAR, 1991) causing alterations in the forest structure (WALKER, 1991) and succession changes in species composition (DITTUS, 1985; WEAVER, 1989). The occurrence of these phenomena are of great importance to maintain species diversity in tropical forests (TERBORGH, 1992), many a time exerting direct influence over the mortality and recruitment process in these formations (WHITMORE, 1990). Adult trees may resist damages caused by strong winds, presenting high probability of surviving and re-establishment, however, the probability may vary among species (WALKER, 1991).

Authors report structure and composition changes in tropical and savanna forests (COOK; GOYENS, 2008; LAURANCE; CURRAN, 2008) because of strong winds, storms, and hurricanes. Several articles report structural changes in forest formation due to these events in Central America, where tropical storms are frequent (BROKAW; GREAR, 1991; ZIMMERMAN et al., 1995). Storm effects were also evaluated in the vegetation formation in southwest (BATISTA; PLATT, 2003) and southeastern of the United States (GRESHAM et al., 1991). Nechet (2002) reported that the occurrence of strong winds in the Amazonian Forest in Brazil, caused the uprooting of small trees, twisted branches, and tearing away of small trees.

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The Pantanal region presents strong climate seasonality. There are strong winds, mainly during the beginning of the rainy season, which may last from October to April. Not much is known about the effects of this natural phenomenon over the structure and composition of the forest formation in the Pantanal area. The objective of this study is to evaluate the effect of a strong wind over a semideciduous forest and a savanna forest (cerradão) in the Pantanal of Nhecolandia, Mato Grosso do Sul State, Brazil.

2 MATERIAL AND METHODS

2.1 Study site

The studied areas are located in Baia das Pedras Farm, Pantanal of Nhecolandia, Aquidauana County, Mato Grosso do Sul State, and they are approximately 4 km apart. The semideciduous forest is located between the coordinates 19º 15' 32''S and 55º 45' 23.7''W and the savanna forest (cerradão), between 19º 17' 21'' S and 55º 45' 8.9''W.

According to the Köppen classification, the climate of the region is *Awa*, tropical, high altitude, mega-thermal, with average temperature during the coldest month above 18°C, dry winters and rainy summers (SORIANO, 2002). The measurements were carried out in November 2005, in Baia das Pedras Farm, approximately five days after a strong wind had damaged several trees, which were uprooted or broken. To estimate the wind velocity, the Beaufort scale was verified, according to Sonnemaker (2000).

2.2 Sampling and data analysis

The phytossociological study was carried out using the transect method (BROWER; ZAR, 1984). Four transects were used in the semideciduous forest (two of 150 m x 10 m and two of 200 m x 10 m) and one in the savanna forest (520 m x 10 m). All trees with diameter at breast height (DBH) ≥ 5 cm, including broken or uprooting trees, were sampled.

To avoid counting trees damaged before the wind effects, it was considered and sampled only trees with green leaves in the broken branches and trunks. To estimate the initial height of the trees (before the wind) it was measured for the broken trees, the length of fallen branches adding to the length of its remaining trunk, or the measure was taken from the fallen tree on the ground.

The trees were identified using specialized literature and by comparison with dried specimens from CPAP Herbarium of the Embrapa Pantanal.

The phytossociological parameters (absolute density, basal area, volume, and synthetic index of importance value), as discriminated by Martins (1991), were calculated using the Fitopac software (SHEPHERD, 1995). To each sampled physiognomy, two phytossociological analyses were carried out: in the first analysis all trees were included and in the second analysis, the uprooting trees were excluded, to evaluate the effect of the strong wind on the vegetation structure. The broken trees remained in the second analyses because they could sprout and still be part of the vegetation structure.

Statistical analyses were carried out (T test for two samples) by comparing the diameter and height of the uprooting or broken trees and the ones that remained intact.

3 RESULTS AND DISCUSSION

According to Beaufort scale, the wind speed was estimated between 67 and 90 km/h, characterized by the capacity to cause damage to the exposed parts or to uproot trees.

In the semideciduous forest, 245 trees from 44 species were recorded in 0.7 ha, representing an estimated absolute density of 350 trees.ha^{-1}. When excluding the uprooted trees from the analyses, a reduction to 339 trees/ha (Table 1) was observed, resulting also in a reduction of around 6% of the basal area and volume in this site, representing around 10m^3.ha^{-1} of fallen wood. Changes in the average height and diameter were also observed considering the population sampled (Tables 1 and 2). In this forest, around 9% of the sampled trees were damaged by the wind, 3% were uprooted, and 6% were broken. The percentage of uprooted trees was similar to that observed by Franklin et al. (2004) in a lowland tropical rain forest in Tonga (2%), whereas, for broken trees the values were much lower than the 16% observed in Tonga and the 26.5% broken trees in a semideciduous forest in southeast Brazil (MARTINI et al., 2008). Gresham et al. (1991) reported severe damage in 11% of the sampled trees in a swamp forest after a strong hurricane in South Carolina, USA, and the damaged individuals usually presented high DBH and height. Dittus (1985) observed a similar pattern for a mountain forest in Sri Lanka, where the individuals of higher diameter suffered more severe damage. *Inga laurina* was the species that presented the higher importance value index (IVI) in the first analysis. Excluding the fallen trees, *Xylopia aromatica* and *I. laurina* present similar IVI, followed by *Hymenaea stigonocarpa* (Table 2). Changes

Table 1 – Structure of a semideciduous forest and a savanna forest, before and after (values in parenthesis) the strong wind in Pantanal of Nhecolandia, Mato Grosso do Sul State, Brazil.

Tabela 1 *– Estrutura de uma floresta semidecídua e de um cerradão, antes e depois (valores entre parênteses) da passagem de uma ventania forte no Pantanal da Nhecolândia, Mato Grosso do Sul, Brasil.*

Parameters	Semideciduous Forest	Savanna Forest
Average height (m)	7.3 ±4.0 (7.2±4.0)	6.1±2.7 (6.1±2.8)
Average diameter (cm)	18.8±14.4 (18.6±14.3)	13.4±8.4
Absolute density (trees.ha^{-1})	350 (339)	577 (517)
Basal area ($m^2.ha^{-1}$)	15.36 (14.49)	11.36 (10.18)
Total volume ($m^3.ha^{-1}$)	164 (154)	95 (85)
Number of trees of uprooted (tree.ha^{-1}) and %	11 = 3%	69 = 10%
Number of trees of broken (tree.ha^{-1}) and %	21 = 6%	121 = 21%

in the species absolute density were observed in *I. laurina, Xylopia aromatic* and *H. stigonocarpa* (Table 3), but the number of species remained the same.

Twenty-one broken trees were observed in one hectare of semideciduous forest, mostly *Xylopia aromatica* (10 trees), *Licania octandra* (4) and *Inga laurina* (3). It was observed in one hectare eleven uprooted trees of the following species: *X. aromatica*, *I. laurina*, *Eugenia egensis,* and *Hymenaea stigonocarpa*. *Hymenaea stigonocarpa* is among the tallest tree (with average height above 12 m) and with higher number of individuals (13) when compared to the others, so it would be expected to be more vulnerable to damages by strong wind. However, although there were 13 trees of this species in the area, only one was damaged, and it was uprooted. As this is a species with high density wood (0.78 $g.cm^{-3}$) (VALE et al., 2002), considered a hard and resistant wood, that might have being the cause of the tree being uprooted, without breakage of the trunk.

Walker (1991) also observed the fall of *Inga laurina* after a strong storm in Porto Rico. According to this author, the difference in the falling down of trees between species is directly related to the diameter and height, as individuals of higher dimensions were uprooted in significantly larger numbers. In semideciduous forest trees of *Inga laurina* were uprooted and broken too, probably because this species presents a moderate dense wood (0.71 $g.cm^{-3}$), which is not resistant (LORENZI, 1998). *Xylopia aromatica* presents also a low density and coarse texture, according to Lorenzi (1992), which may be the reason why most of the trees of this species on the site were broken by the strong wind. Putz et al. (1983) observed higher occurrence of snapped trees with lighter wood in a semideciduous forest in Panama and Martini et al. (2008) in a semideciduous forest in Brazil. These authors also observed that the trees with higher wood density were uprooted, as observed with *Hymenaea stigonocarpa*.

In the savanna forest, 300 trees from 42 species in 0.52 ha were observed, representing an estimated absolute density of 577 trees.ha^{-1} (Table 3). In the analyses, excluding the uprooted trees, a reduction to 517 trees/ha was observed (Table 1), due mainly to the uprooting of *Copaifera martii* (25 individuals in one hectare), *Protium heptaphyllum,* and *Qualea grandiflora* with two individuals each (Table 3). The wind occurrence through this savanna forest area resulted in 31% of the trees being damaged (three times higher than in semideciduous forest), with 10% (69) fallen trees, and 21% (121) broken ones (Table 1). The 69 fallen trees caused reduction of basal area and volume in the tree community, which was estimated at 10%, representing 10 $m^3.ha^{-1}$ of wood. Dubs (1992) reported that for most of the species from the savanna forest, most of the lateral roots tend to grow very close to the soil surface, do not head very deep, which in a certain way provides a low mechanical resistance to these species.

Qualea grandiflora presented the highest IVI in the savanna forest in both analyses. It had been noted that among the fallen trees in the evaluated site, there were two individuals that were representative of only two species (*Kielmeyera coriacea* and *Rhamnidium elaeocarpum*), resulting in a reduction of the species number from 42 to 40 species. Due to the high number of trees that were uprooted after strong winds, several changes in the IVI and absolute density (AD) were observed for *Q. grandiflora*, *Hymenaea stigonocarpa*, and *Protium heptaphyllum*, among others. What can be pointed out is the considerable reduction in AD and IVI observed for *Copaifera martii* after the wind (Table 3).

Table 2 – Structure of a semideciduous forest before and after (values in parentheses from analyses excluding uprooted trees) the strong wind in Pantanal of Nhecolandia, Mato Grosso do Sul State, Brazil.

Tabela 2 *– Estrutura de uma floresta semidecídua antes e depois (valores entre parênteses obtidos com a exclusão das árvores caídas) da passagem de uma ventania forte no Pantanal da Nhecolândia, Mato Grosso do Sul, Brasil.*

Species	Importance value (%)	Number of trees	Absolute density	Basal area (m^2)	Height (m)		Diameter (cm)	
					average	maximum	average	maximum
Inga laurina (Sw.) Willd.	36.0 (33.5)	35 (33)	50.0 (47.1)	2.095 (1.759)	8.5 (8.2)	18.0	22.3 (20.9)	67.0
Xylopia aromatica Mart.	34.5 (33.5)	61 (57)	87.1 (81.4)	0.785 (0.732)	5.9 (5.8)	12.0	11.4	34.0
Attalea phalerata Mart. ex Spreng.	26.2 (27.5)	11	15.7	20.895	5.0	6.0	47.5	69.0
Licania octandra Kuntze	20.2 (21.1)	16	22.9	12.235	9.4	15.0	26.6	55.0
Hymenaea stigonocarpa Mart. ex Hayne	20.0 (18.5)	13 (12)	18.5 (17.1)	1.340 (1.127)	12.3 (12.7)	16.0	34.8 (33.3)	52.2 (43.9)
Alchornea discolor Hook f.	11.0 (11.4)	19	27.2	0.108	5.0	6.0	8.1	13.0
Handroanthus impetiginosus (Mart. ex DC.) Mattos	9.0 (9.4)	4	5.7	0.551	16.8	20.0	40.7	50.0
Astronium fraxinifolium Schott	7.5 (7.7)	6	8.6	0.296	12.8	18.0	23.7	39.0
Buchenavia tomentosa Eichler	6.0 (6.1)	4	5.7	0.220	9.0	10.0	26.1	32.0
Sterculia apetala (Jacq.) H. Karst	5.6 (5.8)	2	2.9	0.272	12.0	18.0	34.2	58.0
Protium heptaphyllum L. Marchand	5.5 (5.7)	6	8.6	0.087	6.8	10.0	12.6	20.0
Mouriri elliptica Mart.	5.5 (5.7)	5	7.1	0.131	3.9	5.0	16.9	29.0
Eugenia egensis DC.	5.0 (4.7)	5 (4)	7.1 (5.7)	0.078 (0.075)	4.4 (5.0)	6.0	12.3 (13.8)	25.0
Dipteryx alata Vogel	5.0 (5.1)	4	5.7	0.112	6.8	12.0	17.8	26.0
Cordia glabrata A. DC.	4.8 (5.0)	2	2.9	0.187	12.0	18.0	28.1	48.0
Luehea paniculata Mart.	4.8 (4.9)	3	4.3	0.136	9.5	12.0	21.4	30.0
Terminalia argentea Mart.	4.6 (4.7)	2	2.9	0.160	13.5	17.0	31.8	35.0
Gomidesia palustris (DC.) D. Legrand	4.4 (4.5)	4	5.7	0.050	5.0	6.0	11.6	18.0
Handroanthus ochraceus (Cham.) Mattos	4.2 (4.3)	2	2.9	0.122	9.5	12.0	26.1	36.0
Campomanesia sp.	4.1	4	5.7	0.018	3.1	3.5	7.0	12.0
Rhamnidium elaeocarpum Reissek	4.0 (4.1)	4	5.7	0.012	4.0	4.0	6.0	7.3
Anadenanthera colubrina (Vell.) Brenan	3.8	1	1.4	0.115	9.0	9.0	38.2	38.0
Pouteria ramiflora Radlk.	3.7 (3.8)	2	2.9	0.066	10.5	12.0	20.3	23.0
Miconia albicans (Sw.) Steud.	3.7	3	4.3	0.019	3.5	4.0	8.8	10.0
Qualea parviflora Mart.	3.6	2	2.9	0.051	12.0	12.0	18.0	19.0
Dilodendron bipinnatum Radlk.	3.5 (3.6)	1	1.4	0.093	12.0	12.0	34.4	34.0

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Table 2 – Continued...
Tabela 2 *– Continuação...*

Species	Importance value (%)	Number of trees	Absolute density	Basal area (m^2)	Height (m)		Diameter (cm)	
					average	maximum	average	maximum
Curatella americana L.	3.5 (3.6)	2	2.9	0.044	5.5	8.0	16.5	19.0
Acrocomia aculeata Lodd. ex Mart.	3.5	2	2.9	0.043	7.3	12.0	16.5	18.0
Cecropia pachystachya Trécul	3.4 (3.5)	2	2.9	0.033	6.5	7.0	14.5	16.0
Casearia sylvestris Sw.	3.3 (3.4)	2	2.9	0.024	4.5	6.0	12.3	12.0
Tabebuia aurea (Silva Manso) S. Moore	3.2 (3.3)	1	1.4	0.058	10.0	10.0	27.1	27.0
Erythroxylum suberosum A. St.-Hil.	3.2	2	2.9	0.010	3.0	3.0	8.1	8.6
Ocotea diospyrifolia (Meisn.) Mez	3.2	2	2.9	0.010	3.5	4.0	7.8	9.5
Eugenia aurata O. Berg	2.9	1	1.4	0.022	10.0	10.0	16.9	17.0
Lafoensia pacari A. St.-Hil.	2.9	1	1.4	0.021	5.5	5.5	16.5	17.0
Copaifera martii Hayne	2.9	1	1.4	0.022	5.5	5.5	16.6	17.0
Simarouba versicolor A. St.-Hil.	2.8	1	1.4	0.015	6.0	6.0	13.7	14.0
Byrsonima orbignyana A. Juss.	2.8	1	1.4	0.011	2.0	2.0	11.9	12.0
Qualea multiflora Mart.	2.7	1	1.4	0.005	5.0	5.0	8.0	8.0
Chrysobalanaceae	2.7	1	1.4	0.005	6.0	6.0	8.0	8.0
Zanthoxylum riedelianum Engl.	2.7	1	1.4	0.004	5.0	5.0	7.3	7.3
Vatairea macrocarpa Ducke	2.7	1	1.4	0.003	4.0	4.0	6.4	6.4
Alibertia edulis A. Rich.	2.7	1	1.4	0.003	2.0	2.0	5.7	5.7
Caryocar brasiliense Cambess.	2.7	1	1.4	0.002	2.0	2.0	4.8	4.8
Total	300	245 (237)	350.0 (338.6)	40.569 (39.964)				

Table 3 – Structure of a savanna forest before and after (values in parenthesis from analyses excluding uprooted trees) strong winds in Pantanal of Nhecolandia, Mato Grosso do Sul State, Brazil.

Tabela 3 *– Estrutura de um cerradão antes e depois (valores entre parênteses obtidos com a exclusão das árvores caídas) da passagem de uma ventania forte no Pantanal da Nhecolândia, Mato Grosso do Sul, Brasil.*

Species	Importance value (%)	Number of trees	Absolute density	Basal area (m^2)	Height (m)		Diameter (cm)	
					average	maximum	average	maximum
Qualea grandiflora Mart.	31.6 (31.5)	32 (30)	61.5 (57.7)	1.092 (0.941)	6.1 (5.9)	12	17.4 (16.6)	49.3
Hymenaea stigonocarpa Mart. ex Hayne	25.5 (27.9)	26 (25)	50.0 (48.1)	0.851 (0.847)	7.8 (7.9)	15	15.8 (16.1)	55.1

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Table 3 – Continued...
Tabela 3 – *Continuação...*

Species	Importance value (%)	Number of trees	Absolute density	Basal area (m^2)	Height (m)		Diameter (cm)	
					average	maximum	average	maximum
Copaifera martii Hayne	24.6 (18.6)	43 (30)	82.7 (57.7)	0.463 (0.257)	5.4 (5.0)	10 (8)	10.9 (9.7)	23.5
Protium heptaphyllum L. Marchand	23.2 (24.7)	37 (35)	71.1 (67.3)	0.499 (0.481)	6.0	12	11.8	23.6
Mouriri elliptica Mart.	17.0 (18.8)	23	44.2	0.406	4.7	8	13.0	29.5
Curatella Americana L.	13.3 (14.7)	10	19.2	0.446	8.0	12	22.3	39.5
Qualea parviflora Mart.	11.3 (9.9)	12 (11)	23.1 (21.1)	0.288 (0.173)	7.5 (7.1)	15	15.3 (13.3)	38.2 (21.0)
Alibertia edulis A. Rich.	9.2 (8.6)	15 (12)	28.8 (23.1)	0.103 (0.084)	4.3 (4.8)	6	9.0	14.9
Eugenia egensis DC.	8.3 (8.4)	8 (7)	15.4 (13.5)	0.191 (0.169)	5.6	8	16.6	26.0
Xylopia aromatica Mart.	7.7 (7.0)	10 (8)	19.2 (15.4)	0.113 (0.077)	7.1 (6.9)	10	11.3 (10.4)	17.8 (16.0)
Astronium fraxinifolium Schott	7.6 (7.9)	11 (10)	21.1 (19.2)	0.087 (0.085)	6.2 (6.4)	10	9.1 (9.5)	16.6
Lafoensia pacari A. St.-Hil.	7.4 (8.1)	8	15.4	0.135	4.3	7	13.6	24.2
Dipteryx alata Vogel	6.5 (7.0)	3	5.8	0.124	7.7	12	15.5	21.3
Terminalia argentea Mart.	6.5 (7.0)	6	11.4		11.7	15	26.7	33.1
Alibertia sessilis K. Schum.	5.9 (6.4)	8	15.4	0.047	4.4	7	8.3	11.9
Vatairea macrocarpa Ducke	5.7 (6.2)	3	5.8	0.136	7.0	10	22.6	29.6
Caryocar brasiliense Cambess	5.7 (6.2)	2	3.9	0.155	14.0	18	30.4	38.2
Bauhinia rufa Steud.	5.6 (5.0)	7 (5)	13.5 (9.6)	0.051 (0.033)	5.8 (5.3)	9	9.0 (8.7)	14.4
Campomanesia sp.	4.9 (5.3)	5	9.6	0.049	3.3	5	10.2	18.8
Zanthoxylum riedelianum Engl.	4.9 (5.3)	2	3.9	0.105	7.8	12	21.2	36.0
Agonandra brasiliensis Benth. & Hook. f.	4.1 (4.4)	1	1.9	0.079	12.0	12	31.8	31.8
Tabebuia aurea (Silva Manso) S. Moore	4.0 (3.8)	3 (2)	5.8 (3.9)	0.035 (0.028)	6.3 (6.5)	8	11.4 (12.1)	17.5
Luehea paniculata Mart.	3.9 (4.2)	2	3.9	0.047	10.0	12	16.9	20.7
Handroanthus serratifolius (Vahl) S. O. Grose	3.6 (3.9)	2	3.9	0.030	7.5	10	12.3	18.5
Handroanthus ochraceus (Cham.) Mattos	3.6 (3.8)	2	3.9	0.026	7.5	8	12.4	15.9
Pseudobombax longiflorum (Mart. & Zucc.) A. Robyns	3.5 (3.8)	2	3.9	0.025	5.5	6	12.6	14.0
Gomidesia palustris (DC.) D. Legrand	3.5 (3.7)	2	3.9	0.023	7.0	8	11.9	14.6
Myrtaceae	3.4 (3.6)	2	3.9	0.015	5.5	6	9.7	10.5
Simarouba versicolor A. St.-Hil.	3.2 (3.4)	1	1.9	0.022	7.0	7	16.9	16.9
Handroanthus heptaphyllus (Mart.) Mattos	3.1 (3.3)	1	1.9	0.020	12.0	12	15.9	15.9

To be continued...
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Table 3 – Continued...
Tabela 3 – *Continuação...*

Species	Importance value (%)	Number of trees	Absolute density	Basal area (m^2)	Height (m) average	Height (m) maximum	Diameter (cm) average	Diameter (cm) maximum
Hancornia speciosa Gomez	3.0 (3.2)	1	1.9	0.015	5.0	5	13.7	13.7
Eugenia aurata O. Berg	3.0 (3.2)	1	1.9	0.012	4.0	4	12.1	12.1
Ocotea diospyrifolia (Meisn.) Mez	3.0 (3.2)	1	1.9	0.012	6.0	6	12.1	12.1
Kielmeyera coriacea Mart.	3.0 (0)	1 (0)	1.9 (0)	0.012 (0)	8.0 (0)	8 (0)	12.1 (0)	12.1 (0)
Rhamnidium elaeocarpum Reissek	2.9 (0)	1 (0)	1.9 (0)	0.005 (0)	5.0 (0)	5 (0)	7.6 (0)	7.6 (0)
Chomelia obtusa Cham. & Schltdl.	2.8 (3.0)	1	1.9	0.004	3.0	3	7.0	7.0
Strychnos pseudoquina A. St.-Hil.	2.8 (3.0)	1	1.9	0.003	4.0	4	6.4	6.4
Pouteria ramiflora Radlk.	2.8 (3.0)	1	1.9	0.003	5.0	5	5.7	5.7
Alchornea discolor Hook f.	2.8 (3.0)	1	1.9	0.002	3.5	3.5	5.1	5.1
Eriotheca gracilipes (K. Schum.) A. Robyns	2.8 (3.0)	1	1.9	0.002	3.0	3	5.4	5.4
Qualea multiflora Mart.	2.8 (3.0)	1	1.9	0.002	2.0	2	5.1	5.1
Total	300	300 (269)	576.9 (517.3)	5.906 (5.292)				

Copaifera martii, mainly species uprooting, presents hard wood, with 0.98 wood density (CORREA, 1931). Therefore, most of the trees did not break with the wind due to trunk resistance. However, the uprooted trees were mainly those above 6 m in height. The most affected species in this site were: *Protium heptaphyllum* (21 trees), *Qualea grandiflora* (19), *Mouriri elliptica* (15), and *Lafoensia pacari* (8). These species present moderate wood density, varying between 0.77 and 0.80 (LORENZI, 1992), with medium texture, which might have been the reason they broke.

The diameters and height of fallen and intact trees presented statistically significant differences when comparing the damaged trees in the semideciduous ($P < 0.001$) and savanna forest ($P = 0.014$). In this case, all the trees were considered for both areas. Brokaw and Grear (1991) reported similar reduction of the average tree height in a tropical forest in Porto Rico after a storm, suggesting that higher trees were more susceptible to hurricanes and tropical storms. Another analysis for the two species, *Copaifera martii* and *Xylopia aromatica*, was carried out with the highest number of broken or uprooted trees**.** *Copaifera martii* presented the higher number of fallen trees in the savanna forest. The uprooted trees presented an average height and diameter at breast height bigger when compared to those that were not damaged by the wind ($P = 0.014$) (Figure 1). However, *Xylopia aromatica*, did not present this pattern (Figure 2), probably because this species has a low density and a coarse wood texture (LORENZI, 1992), resulting in being vulnerable to strong winds, independent of their height and diameter.

By comparing the two sampled sites, it was possible to emphasize that in the savanna forest the wind caused severe damage, as was seen by the percentage of uprooted and broken trees. This difference in damage intensity could be due to the structure and floristic composition in the areas. In the savanna forest, the trees were thinner (mean diameter of 13.4 cm) and there were many trees with low density wood, although with higher tree density per area, which would be more susceptible to wind damage. According to Zimmerman et al. (1995), stronger wind effects were observed in the fast growing and soft-wooded species. Franklin et al. (2004) also observed higher proportion of broken trees, with trees having 10 – 15 cm diameter at breast height (DBH), whereas, trees with higher DBH (20 – 30 cm) would be more susceptible to be uprooted.

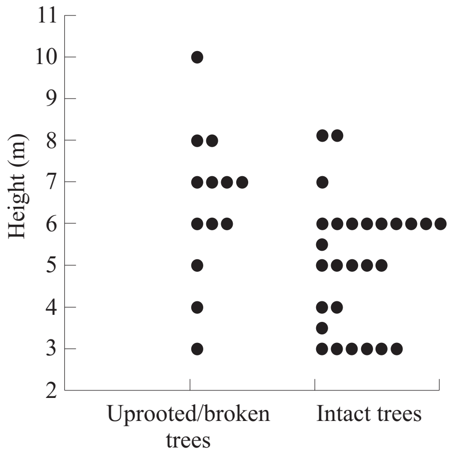

Figure 1 – Height of fallen (uprooted and broken) and intact trees of *Copaifera martii* (Fabaceae) that presented significant differences among the averages (P = 0.014; t = 2.552) in the savanna forest site, in Pantanal of Nhecolandia, Mato Grosso do Sul State, Brazil.

Figura 1 – *Altura das árvores afetadas (caídas e quebradas) e intactas de Copaifera martii (Fabaceae), mostrando diferenças significativas entre as médias (P = 0,014; t = 2,552) na área de cerradão, Pantanal da Nhecolândia, Mato Grosso do Sul, Brasil.*

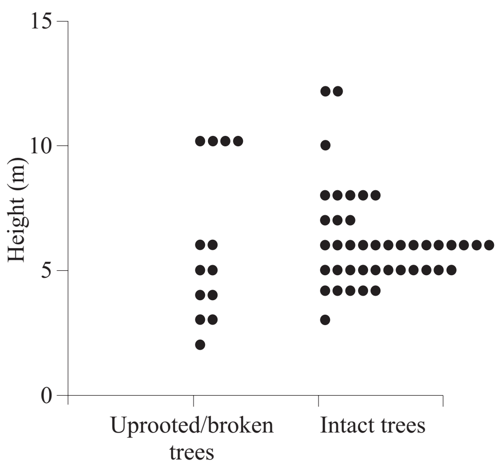

Figure 2 – Height of fallen (uprooted and broken) and intact trees of *Xylopia aromatica* (Anonnaceae) that did not present significant differences among the averages (P = 0.852; t = 1.596) in the semideciduous forest site, Pantanal of Nhecolandia, Mato Grosso do Sul State, Brazil.

Figura 2 – *Altura das árvores afetadas (caídas e quebradas) e intactas de Xylopia aromatica (Anonnaceae), mostrando diferenças significativas entre as médias (P = 0,852; t = 1,596) na área de floresta semidecídua, Pantanal da Nhecolândia, Mato Grosso do Sul, Brasil.*

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