

## Environmental Variables and Tree Population Structures in Deciduous Forests of Central Brazil with Different Levels of Logging

Daniel Luis Mascia Vieira<sup>1,2\*</sup> and Aldicir Scariot<sup>3,4</sup>

<sup>1</sup>Embrapa Tabuleiros Costeiros; Av. Beira Mar, 3250; Jardins; 49025-040; dvieira@cpatc.embrapa.br; Aracaju - SE - Brasil. <sup>2</sup>Pós-Graduação em Ecologia; Universidade de Brasília; C. P. 04457; 70919-970; Brasília - DF - Brasil. <sup>3</sup>United Nations Development Programme; SCN quadra 2; bloco A, Ed. Corporate Financial Center; 7º andar, 70712-901; Brasília - DF - Brasil. <sup>4</sup>Laboratório de Ecologia e Conservação; Embrapa Recursos Genéticos e Biotecnologia; C. P. 02372; 70770-900; Brasília - DF - Brasil

### ABSTRACT

Population structures of six tree species in three fragments of intact seasonal deciduous forest and three fragments disturbed by logging were studied in the northeastern Goiás. Forty random 400 m<sup>2</sup> plots were allocated in each fragment to survey plant population structures, number of stumps, cattle feces, burnt logs, and canopy openness. Soil cover by life forms was estimated in 1m<sup>2</sup> sub-plots. Lianas were abundant in intermediately logged fragments and invasive herbs in the most disturbed fragment. Cattle avoided dense herbaceous strata, such as liana tangles. *Cavanillesia arborea*, *Eugenia dysenterica* and *Swartzia multijuga* trees occurred at very low densities in all the fragments and their seedlings were practically absent, which might endanger their future populations in these fragments. *Myracrodruon urundeuva*, *Tabebuia impetiginosa* and *Astronium fraxinifolium*, the most logged species, had high density of seedlings in all the fragments. However, the highest density of saplings and juvenile individuals occurred in the most disturbed fragment.

**Key words:** Seasonal forest; canopy openness; plant cover; cattle grazing; lianas

### INTRODUCTION

Selective logging causes soil compaction (Whitman et al., 1997; Fredericksen and Pariona, 2002) and soil disturbance (Fredericksen and Mostacedo, 2000; Fredericksen and Pariona, 2002). It damages trees and saplings in logged stands (Webb, 1997; Jackson et al., 2002) and also increases canopy openness (Uhl and Vieira, 1989; Veríssimo et al., 1992; Webb, 1997). Changes in canopy openness can promote regeneration of species that are present in seed, seedling and juvenile banks (Bawa and Seidler, 1998; Pinard et

al., 1999a; Fredericksen and Mostacedo, 2000). This may favor some species to the detriment of others, and may alter species composition in the logged forest (Kuusipalo et al., 1996; Bawa and Seidler, 1998; Kammesheidt, 1998; Webb, 1998). Lianas, herbs and pioneer trees are benefited by high canopy openness, frequently preventing the regeneration of other species (Chapman and Chapman, 1997; Kammesheidt, 1998; Fredericksen et al., 2000).

The understanding of how plant regeneration is affected by changes in the environmental factors in logged areas contributes to the development of

\* Author for correspondence

management techniques that may help diversity recovery. It may also contribute to increase regeneration of high-value timber species (Guariguata and Pinard, 1998; Pinard et al., 1999b; Fredericksen and Mostacedo, 2000). Logged forests have recently been recognized as important for biodiversity conservation (Johns, 1988; Chazdon, 1998; Pinard et al., 1999b) and for the functionality of ecosystems (Pinard and Putz, 1996), since few forest remnants are left in many ecosystems, and many of those are usually disturbed (Chazdon, 1998).

Dry forest is the most threatened tropical terrestrial ecosystem (Janzen, 1988; Khurana and Singh, 2001; Sanchez-Azofeifa et al., 2005) and one of the least known (Janzen, 1988, Vieira and Scariot, 2006a). In Central Brazil, it occurs in patches within the Cerrado biome. The Parana River basin (northeastern Goias state and Southeastern Tocantins state) has large patches of highly fertile soils, where these forests occur (Ratter, 1992). However, seasonally deciduous forests of the flat lands cover only 5% of their originally occupied area (Andahur, 2001), which is a consequence of deforestation for pasture (IBGE, 1995; Scariot and Sevilha, 2000; 2005). In addition, most of the remaining forested areas have been logged and disturbed by fire and cattle grazing (Scariot and Sevilha, 2005).

In this study, the population structure of six tree species was analyzed in six forest fragments, three of which were intact and three were selectively logged. Three studied species have high timber value and three produce fruits and seeds for wildlife. Environmental variables that characterize disturbance intensity caused by logging, fire and cattle were estimated. The following questions were addressed: (i) How were environmental factors affected by selective logging? (ii) How were population structures of the target species affected by logging? Then, environmental factors were indirectly related to the regeneration of the studied species.

### Study Area

The study was carried out in the Parana river basin (13°20' - 15°40' S, 46°35' - 47°30' W), at the municipality of Sao Domingos, in northeastern Goias state. This region presents a vegetational mosaic, and has some of the last remnants of seasonally deciduous forests in Brazil. The forest occurs at altitudes of 400-600 m, with annual precipitation of 1236mm ± 255 (SD, data from

1969 to 1994), of which 89% falls between October and March. The mean annual temperature is 23°C and is fairly constant throughout the year. The landscape is flat and consists of limestone geology, with occasional limestone outcrops containing a fairly distinct tree flora (Silva and Scariot, 2003; 2004a, 2004b). Soils are mostly nitosols with a clayey texture (IBGE, 1995; Scariot and Sevilha, 2005; following Embrapa, 1999).

On the flat lands, the forest canopy is 17-23m in height with a basal area of 23-28m<sup>2</sup>/ha (unlogged areas; Scariot and Sevilha, 2005). There are over 100 tree species, which are usually found in large Brazilian biomes such as Cerrado, Caatinga, Amazonia and Atlantic Forest (Scariot and Sevilha, 2005). Cattle farms, logging, and incipient agriculture are the main economic activities of the region. Wood has been mainly harvested for corral and fence building, for the production of woodchip, and for civil construction. The main exploited species are *Astronium fraxinifolium* Schott, *Myracrodruon urundeuva* Fr. All., *Schinopsis brasiliensis* Engl. and *Tabebuia impetiginosa* (Mart. ex DC.) Standl., which have been commercialized locally, regionally and in Southern Brazilian markets (IBGE, 1995).

### Methods

Study sites - Three forest fragments without evidence of logging (named Intact: I1, I2 and I3) and three fragments with different logging intensities and ages were selected (named Logged: L1, L2 and L3). The fragments varied from 60-200ha and were distant of each other from a few meters up to 5.5km. Logged 1 had been selectively logged approximately 18 years before the study. Logged 2 and L3 had been intensively logged five years before the study. Logged 3 had also suffered accidental fire some months after logging. There were no records of fire in the other fragments over the past 10 years. Landowners avoid reporting the harvested wood volume and the minimum diameter of the harvested trees, either because forest management has been illegally done or because they do not have records of the logging activities. Cattle forage in the fragments (approximately 0.5cows/ha) during the late dry season and early rains, when the planted pastures are dry.

Study species - *A. fraxinifolium*, *M. urundeuva* (Anacardiaceae), and *T. impetiginosa* (Bignoniaceae) are among the most valuable and

harvested tree species in northeastern Goiás State (IBGE, 1995). *Eugenia dysenterica* DC. (Myrtaceae) and *Swartzia multijuga* Vogel (Fabaceae) produce fleshy fruits, and like dry-fruited *Cavanillesia arborea* (Willdenow) K. Schum. (Bombacaceae), their seeds are highly consumed by wildlife (Vieira and Scariot, 2006b). *Eugenia dysenterica* occupies the midstory and the other species occupy the canopy layer.

Sampling and measurements - Parallel trails were made every 100m, perpendicular to the longest side of the fragments. In each fragment 40 20 x 20m sample units (SUs) were randomly established along the trails, with sub-sample units of 5 x 5m and 2 x 2m. Canopy openness was estimated with a spherical densiometer (Lemmon, 1957).

**Table 1** - Diameter classes (cm) corresponding to development classes of studied species. The individuals < 5cm (DBH) were measured at the base of the plant, while larger individuals were measured at the breast height.

	Seedling	Sapling	Juvenile	Adult
<i>Myracrodruon</i>	< 0.2	0.2 - 1	1 - 05	≥ 15
<i>Tabebuia</i>	< 0.2	0.2 - 1	1 - 05	≥ 30
<i>Astronium</i>	< 0.2	0.2 - 1	1 - 05	≥ 15
<i>Cavanillesia</i>	< 1.0	1.0 - 5	5 - 50	≥ 50
<i>Eugenia</i>	< 0.2	0.2 - 1	1 - 05	≥ 05
<i>Swartzia</i>	< 0.2	0.2 - 1	1 - 05	≥ 15

The SU was subdivided into four 10 x 10m quadrants and the estimation was taken at the center of each quadrant in four orthogonal directions. In each SU, feces and cattle trails were counted in order to estimate pasturing and trampling intensity by the cattle (Relva and Veblen, 1998). Stumps were counted in order to estimate logging intensity in the fragments. Dead individuals > 5cm (diameter at the breast height, DBH) were counted. Data were collected from December 2000 to January 2001, at the middle of the rainy season.

Soil cover up to 1m in height was estimated by the life forms classified into (i) trees, (ii) lianas, (iii) herbaceous-shrubs, and (iv) invasive herbs. A 1 x 1 m metal frame subdivided into 100 10 x 10cm quadrants was used for the survey at the corner of the SUs. The number of occupied quadrats was recorded. Also, the number of occupied quadrats by every life form was recorded (modified from Kent and Coker, 1994). This method allowed more than one life form occupy the same quadrat. If a plant had only covered part of the cell, it was recorded. Invasive herbs were considered plants that did not naturally occur in the forests, although they can be abundant in pastures surrounding the fragments. Herbaceous-shrub species were plants that occupy the understory.

In the 20 x 20m SUs, individuals ≥ 5cm (DBH) were measured. In the 5 x 5m sub-sample units, individuals ≥ 1cm (diameter at the base of the

plant (DBP)) up to 5cm (DBH) were measured at the base of the plant. Individuals ≤ 1cm (DBP) were measured in the 2 x 2m sub-sample units.

Individuals were classified into seedling, sapling, juvenile and adult (Table 1), based on data from germination and seedling growth in the nursery and field observations. Seedlings were considered individuals that germinated in the same rainy season of the survey. Seeds of these species placed to germinate at the beginning of the rainy season (September-October) reached up to 2mm (DBP) in January (period of the survey). Only for *Cavanillesia*, the seedlings were ≤ 10mm (DBP). Saplings were considered those individuals that germinated in earlier rainy seasons and that were exposed to environmental factors for at least one year. Juveniles were individuals in the intermediate category between saplings and adults. Adults were individuals in the reproductive stage.

Data analysis - In order to describe the relationship among environmental variables and life forms, an exploratory analysis was carried out using PCA (R mode). Also, the PCA (Q mode) was carried out to ordinate the SUs, according to the factors generated from environmental variables (Tabachnick and Fidell, 2001). Data of the all variables were transformed by adding 0.5 and then square rooting in order to approximate normal distribution and reduce heteroscedasticity (Zar, 1999).

To contrast canopy openness, soil cover and population structures between logged and intact fragments, data from all intact fragments were grouped; generating the *Intact* category (n=120). This arrangement best represented the traits of intact fragments, reducing the effect of peculiarities not related to the disturbance conditions focused in this study. Besides, the comparison of each fragment would result in an excessive number of *post hoc* comparisons. Logged fragments were very different in disturbance history, therefore they were not grouped.

Canopy openness estimates within the SUs were averaged among the four quadrants, resulting in 40 measures of canopy openness for each fragment. The frequency distributions of canopy openness in the three combined intact fragments (*Intact*) were compared with each of the three logged fragments, using the Kolmogorov-Smirnov test for two samples (Siegel, 1975). Bonferroni's correction was used for the three comparisons;  $P \leq 0.05 \times 3^{-1} = 0.017$ . Soil cover for each life form and total cover was compared between the logged fragments and *Intact* using the Kruskal-Wallis test. This was done because percentage data had very asymmetrical frequency distribution, with frequent zero values and heteroscedasticity (Zar, 1999). Whenever significant differences were found, Dunn test ( $Q$ ) (Zar, 1999) was used to compare each logged fragment with the combination of the intact ones (*Intact*). The use of Bonferroni's correction was unnecessary, because  $Q$  test considers the number of comparisons.

Population structures were analyzed for each species. The null hypothesis that there were no differences in the proportion of individuals in the development classes among the fragments (logged versus *Intact*) was tested. If significant differences were detected, each logged fragment was compared with *Intact*. Although the total densities were not analyzed (only proportions), they were considered in the results and discussion. The Likelihood Ratio Chi-Square test ( $G^2$ ) was used when the observed and expected frequencies satisfied its assumptions. Data violating the assumptions were analyzed through the simulation of the  $G^2$  statistics. This method generated an empirical distribution of the statistics for the data set. The procedure generated 10,000 random tables with the same marginal totals as in the original table, and the statistical tests for each of them were computed. Finally, the probability of occurrence of

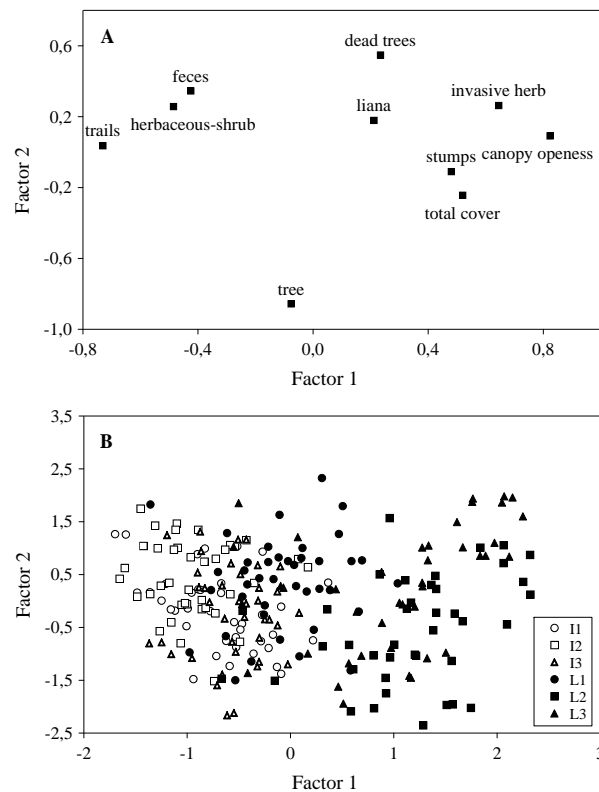
$G^2$  statistics equal or greater than those in the observed table was verified (Zelterman, 1999). Bonferroni's correction was used for the three *a post hoc* comparisons;  $P \leq 0.05 \times 3^{-1} = 0.017$ . The Statistica package (Statsoft, 2000) was used to run analysis, except for population structure data run in the SAS (SAS, 1999).

## RESULTS

Environmental variables and soil cover - The PCA factor 1 of environmental variables and soil cover explained 26.5% of the variance, while the second factor explained only 14.0%. Canopy openness had the most contribution to the factor 1 (Fig. 1a). The number of stumps and dead trees was weakly related to the canopy openness (Fig. 1a). Canopy openness of intact fragments was significantly smaller and less variable (mean = 12%; range: 3-22%) than in the logged fragments (mean = 43%, range: 7-95%, Fig. 2), (K-S,  $P < 0.001$  for the comparisons of *Intact* with L1, L2 and L3). Canopy openness constituted a gradient among the logged fragments (L1 to L3; Fig. 2). Cattle feces were found in high density in all fragments, but were related to plots with lower canopy openness, where plant cover was low (Fig. 1a). Cattle trails made the largest negative contribution to PCA factor 1 (Fig. 1a).

Sample units of the six fragments were distributed along the factor 1 of environmental variables in a gradient, where most L3 SUs had the largest positive values (Fig. 1b). Logged 2 had similar tendencies, but with smaller values. Logged 1 had intermediate values between the most disturbed and the intact fragments, with the latter showing similar and negative values (Fig. 1b).

Soil cover by life forms varied significantly among the fragments (Fig. 3). The total soil cover was directly related to canopy openness (Fig. 1a), which meant that L3 and L2 had the highest soil cover (Fig. 3). Cover by lianas increased with disturbance, with L1 and L2 having larger percentages than *Intact*, although this did not happen in L3. Invasive herbs rather than lianas increased significantly in L3, and this was strongly related to canopy openness (Fig. 1a). Herbaceous-shrub cover was associated with low canopy openness (Fig. 1a), and it was higher in intact fragments and in L1 than in the more disturbed areas (Fig. 3).

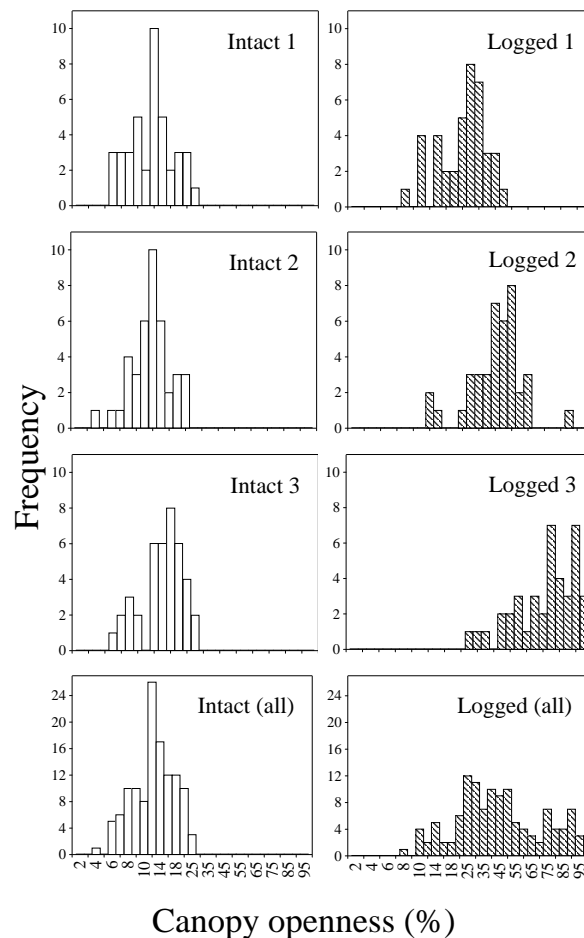


**Figure 1** - Plot of Factor 1 and Factor 2 of the Principal Component Analysis (PCA) with the environmental variables and soil cover by life forms in tree intact forest fragments and tree logged fragments. Factor 1 explains 26.5% and Factor 2 14.0% of variance. A. Factor loadings of environmental variables and soil cover. B. Factor scores of sample units (N = 40 sample units per forest fragment)

Although herbaceous-shrub vegetation was also linked to feces density and cattle trails (Fig. 1a), there were no indications of causality between them. Trees of up to 1m in height covered 10-25% (median) of soil in the studied fragments (Fig. 3), but they were not related to the studied environmental variables or to other life forms (Fig. 1a).

Population structures - The number and proportion of individuals in the development classes are

shown in Table 2. Adult individuals of *Myracrodruon* and *Tabebuia* had higher densities in intact than in logged fragments. About 33-55 adults/ha of *Myracrodruon* were found in the intact fragments, while logged fragments had 4-16 adults/ha. *Tabebuia* had 14-25 adults/ha in intact and 1-15 adults/ha in logged fragments. *Astronium* had low density of adults (8-13 adults/ha) in intact fragments, similar to logged fragments.



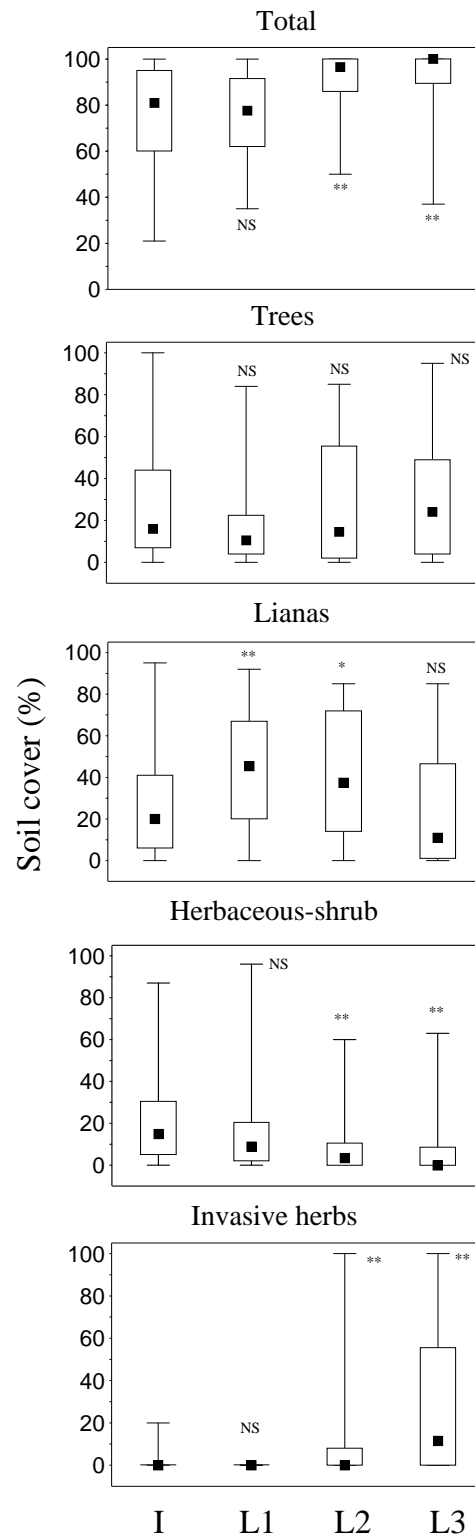
**Figure 2** - Frequency of canopy openness classes in tree intact forest fragments and their combination (Intact (all)), and tree logged forest fragments and their combination (Logged (all)). N = 40 per fragment. Note that the size of the classes is not the same

The seedlings of *Tabebuia*, *Myracrodruon* and *Astronium* were relatively abundant. For these species, which produced copious small wind-dispersed seeds, seedling density was roughly proportional to adult density, although there were proportionally more seedlings of *Astronium* related to adults in *Intact* and of *Myracrodruon* in L3.

The proportion of saplings and juveniles of *Myracrodruon* in logged fragments was higher than in *Intact*, with sapling density being 2.5 times higher in L3 than in any other fragment. *Tabebuia* saplings and juveniles contributed more to population size in L3 and L2 than did in *Intact*, but in L3 the proportion and density was higher than in any other fragment. Logged 1 had a high proportion of juveniles, but a smaller proportion of saplings of *Tabebuia*. *Astronium* had high juvenile density in L3, but saplings were not sampled in

any fragment, and juveniles were proportionally more abundant in L2 and L3 than in *Intact*.

Population structures of *Cavanillesia*, *Eugenia* and *Swartzia* were not different between logged and *Intact*. They occurred in low densities even in intact fragments. Seedlings of these species were not sampled in most fragments.



**Figure 3** - Soil cover percentage by life forms and total soil cover in *Intact* (I) forest fragments (combination of tree intact forest fragments) and tree logged forest fragments (L1, L2 and L3). Maximum and minimum, quartiles and median are shown. Significant differences between each logged fragment and *Intact* are indicated. N = 40 per fragment and N = 160 in *Intact*

## DISCUSSION

Environmental variables - Canopy openness is the variable best describing logging and fire disturbance in the fragments, and can be particularly useful when there is no information about the frequency and the intensity of site management. The weak relationship between the number of stumps and canopy openness is probably due to: (1) different logging ages among fragments that resulted in different rates of stump decomposition; (2) the fire that occurred in L3, which probably caused high canopy openness and possibly eliminated some of the present stumps present. Therefore, the number of stumps does not seem to be a good indicator of the logging intensity in the studied forests. However, in tropical flooded forests of Costa Rica recently logged, the number of stumps is strongly correlated with canopy openness (Webb, 1997).

Canopy openness found in L1, L2 and L3 were higher than logged forests of other regions, even considering only canopy openness of gaps. For instance, 80% of 4-11 year-old gaps generated by selective logging in semi-deciduous forests of Mexico had 20-40% of canopy openness (Dickinson et al., 2000). The canopy openness in gaps recently formed by conventional selective logging was approximately 29% in the eastern Brazilian Amazon (Pereira et al., 2002) and approximately 12% in the humid subtropical forests of Belize (Whitman et al., 1997). The reason why canopy openness was higher in the logged dry forests of this study is not clear. Many interacting variables were not surveyed in this study, as logging procedures and forest structure (e.g. canopy height, tree density, understory structure and liana density connecting trees). Independent of the reason, the high canopy openness changes radically forest microclimate (Uhl and Vieira, 1989; Veríssimo et al., 1992; Webb, 1997), which can affect proportionally the community composition (Bawa and Seidler 1998). The amount of cattle feces and trials depends on the cattle density and the time they spend in the fragments, which varies between areas and years, following the farmer's decisions. The high variation of feces density in the fragments indicates that animals use them in clumps. In fact, cattle is associated to shade, where the stratum up to 1m height is less dense. Places with dense shrub

vegetation, such as liana tangles, limit the movement of animals (Valiente-Banuet et al., 1991).

Soil cover - There was considerable soil cover in all the fragments, so that even the smallest total soil cover was about 80% in *Intact*. These results agreed with findings from deciduous forests of Bolivia, where the total soil cover (up to 2m in height) reached 81% in unlogged areas and 95-99% in logged areas (Frederiksen and Mostacedo, 2000), suggesting that in tropical deciduous forests high herbaceous and shrub cover prevented tree regeneration, independent of canopy disturbance.

High soil cover by lianas is associated with elevated light levels (Schnitzer et al., 2000; Alvira et al., 2004). This statement was confirmed in the studied fragments. However, in L3, fire might have eliminated the lianas, favoring invasive herbs instead. In Bolivian dry forests, three years after a forest fire, the density of lianas was lower than in an unburned forest (Gould, 1999), although in the more humid forests, lianas have spread promptly after fire occurrence (Pinard et al., 1999a). Invasive herbs were very frequent in pastures surrounding the fragments, and were closely related to completely open areas, dominating the herbaceous layer in patches where the canopy was fully open in L3.

Population structure - The low density of seedlings and saplings of *Cavanillesia*, *Eugenia* and *Swartzia* suggested high mortality between seed dispersal and early seedling development. In fact, seed predation of these species reached 65-100%, part of them eaten by cattle (Vieira and Scariot, 2006b). Once seeds were protected from vertebrates, germination increased by 75%. Seedling density of *Astronium*, *Myracrodruon* and *Tabebuia* is generally related to adult density, although this is not the only factor determining seedling density. Mature individuals occurring in the adjacent forest fragments and pastures produce a high number of small wind-dispersed seeds, which can reach the logged fragments. Seeds of *Tabebuia* and *Astronium* have high germination rates under different canopy openness and do not suffer high predation (Vieira and Scariot, 2006b).



**Table 2** - Stem density (individuals/ha) of six tree species in three intact (I) and three logged (L) forest fragments in the Paran river basin, GO, Brazil. The *Intact* category is an average of the Intact fragments. The percentages of individuals in the development classes to the total population are shown. Significant differences in the proportion of development classes between each logged forest fragment and *Intact* are indicated (\*).

Fragment	Seedling		Sapling		Juvenile		Adult	
I 1	875		63		200		43	
I 2	63		125		100		33	
I 3	63		250		300		55	
<i>Intact</i>	333	45%	146	20%	200	27%	44	6%
L 1 *	63	9%	250	34%	400	55%	4	1%
L 2 *	125	9%	313	21%	1000	68%	16	1%
L 3 *	438	22%	813	41%	700	36%	9	<1%
<b>a) <i>Myracrodruon urundeuva</i></b>								
I 1	115750		1063		200		17	
I 2	145938		63		0		14	
I 3	428313		188		0		25	
<i>Intact</i>	230000	100%	438	<1%	67	<1%	19	<1%
L 1 *	308125	100%	188	<1%	200	<1%	15	<1%
L 2 *	90500	98%	625	1%	1000	1%	6	<1%
L 3 *	21500	81%	1688	6%	3300	12%	1	<1%
<b>b) <i>Tabebuia impetiginosa</i></b>								
I 1	3875		0		100		8	
I 2	1938		0		100		6	
I 3	5563		0		100		13	
<i>Intact</i>	3792	97%	0	0%	100	3%	9	<1%
L 1 *	500	98%	0	0%	0	0%	4	1%
L 2 *	813	87%	0	0%	100	11%	11	1%
L 3 *	63	8%	0	0%	700	91%	2	<1%
<b>c) <i>Astronium fraxinifolium</i></b>								
I 1	0		0		0		4	
I 2	0		200		1		4	
I 3	63		400		3		13	
<i>Intact</i>	21	9%	200	87%	1	<1%	7	3%
L 1	0	0%	200	98%	2	1%	3	1%
L 2	0	0%	0	0%	0	0%	1	100%
L 3	0	0%	100	97%	0	0%	3	3%
<b>d) <i>Cavanillesia arborea</i></b>								
I 1	0		0		20		0	
I 2	0		0		0		0	
I 3	0		63		80		0	
<i>Intact</i>	0	0%	21	39%	33	61%	0	0%
L 1	63	16%	250	65%	70	18%	0	0%
L 2	0	0%	188	76%	60	24%	0	0%
L 3	0	0%	125	93%	10	7%	0	0%
<b>e) <i>Eugenia dysenterica</i></b>								
I 1	0		0		0		0	
I 2	0		0		0		0	
I 3	0		63		80		0	
<i>Intact</i>	0	0%	21	39%	33	61%	0	0%
L 1	63	16%	250	65%	70	18%	0	0%
L 2	0	0%	188	76%	60	24%	0	0%
L 3	0	0%	125	93%	10	7%	0	0%
<b>f) <i>Swartzia multijuga</i></b>								
I 1	0		125		0		3	
I 2	0		63		0		1	
I 3	0		125		0		4	
<i>Intact</i>	0	0%	104	97%	0	0%	3	3%
L 1	0	0%	63	64%	30	30%	3	3%
L 2	0	0%	250	100%	0	0%	1	<1%
L 3 <sup>a</sup>	0	0%	0	0%	0	0%	0	0%

<sup>a</sup> Statistical test not run because no individual was sampled in the forest fragment.

The density of *Astronium* and *Tabebuia* juveniles, as well as the density of *Tabebuia* and *Myracrodruon* saplings, might have increased in L3 because of the fast growth of smaller sized individuals favored by canopy openness, once these species are light demanding (Pinard et al., 1999b). Although there were many canopy gaps available for the regeneration of shade-intolerant species in L1, L2 and L3, the high liana cover in L1 and L2 might limit regeneration, as observed in tropical deciduous forests in Bolivia (Frederiksen and Mostacedo, 2000; Frederiksen et al., 2000). Lianas can dominate canopy gaps and prevent succession for years even in tropical moist forests (Babweterra et al., 2000; Schnitzer et al., 2000; Tabanez and Viana, 2000). Lianas differ from invasive herbs in competitive ability because: (1) they climb seedling or juvenile tree stems (Putz, 1991; Alvira et al., 2004), (2) they are perennial, while the sampled invaders only occur in the rainy season, and (3) they reduce the amount of light that reaches the herbaceous stratum.

Implications for management and conservation - The evaluation of threat to a species population must take into account the seed dispersal, abundance of recruits, growth rate, sprouting capacity after felling or damage, resistance to fire, geographical range and abundance of adults (Martini et al., 1994). Large-seed species, which include *Eugenia*, *Swartzia* and *Cavanillesia*, have low seedling densities. Cattle eat many of the seeds, especially those of *Cavanillesia* and *Swartzia* (Vieira and Scariot, 2006b). The association of cattle with areas of closed canopy, where the herbaceous layer is less dense, suggests that in such places the populations of these species are suffering more impact than where herbaceous and shrub cover is dense. In fact, seeds of these species were less removed under liana tangles (colonizing gaps) than in closed canopy sites (Vieira and Scariot, 2006b). Therefore, logged forests, with high number of gaps and dense herbaceous layer have more escape sites for large seeds. On the other hand, in very disturbed forests with scarce resources and poor vertical structure, the absence of efficient seed dispersers can compromise the regeneration of species (Bawa and Seidler, 1998), such as *Eugenia* and *Swartzia* in this study. While the effects of logging on the fauna in these forests are unknown, there is generally increased abundance and decreased

diversity of primate and rodent species in logged tropical forests (Bawa and Seidler, 1998).

*Astronium*, *Myracrodruon* and *Tabebuia* have a high capacity for production, dispersal and, at least for *Astronium* and *Tabebuia*, also germination in these forests (Vieira and Scariot, 2006b). These are typically heliophytic species (Lorenzi, 1992; for *Myracrodruon* and *Tabebuia* see Pinard et al., 1999b). Roots of *Tabebuia* (Pinard et al., 1999b), *Myracrodruon* and *Astronium* are also known for their great ability to resprout (Salomão and Leite, 1993; Pinard et al., 1999b; Vieira et al., 2006). These species can present high regeneration rates in logged forests, since lianas do not cover the soil excessively. In dry forest fragments of the Paranã river basin, where (1) liana tangles are escape sites for seeds (Vieira and Scariot, 2006b), (2) sapling and juvenile abundance is low (this study) and (3) lianas are expected to recover gaps rapidly after cut treatments (Alvira et al., 2004; Pariona et al., 2003; Schnitzer et al., 2004), it is recommend to clean the competing vegetation around tree sapling or juvenile, instead of eliminating every liana tangle in gaps.

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## RESUMO

As estruturas populacionais de seis espécies de árvores foram estudadas em três fragmentos de floresta estacional decidual intactos e três fragmentos impactados pela exploração seletiva de madeira no nordeste goiano. Quarenta parcelas de 400m<sup>2</sup> foram estabelecidas em cada fragmento para a amostragem de populações, número de tocos, fezes de gado, troncos queimados e abertura de dossel. A cobertura do solo por formas de vida foi estimada em sub-parcelas de 1m<sup>2</sup>. Lianas foram

mais abundantes em fragmentos com perturbação intermediária, enquanto herbáceas invasoras no fragmento mais perturbado. *Cavanillesia arborea*, *Eugenia dysenterica* e *Swartzia multijuga* ocorreram em densidades muito baixas em todos os fragmentos e plântulas foram praticamente ausentes, o que pode ameaçar o futuro de suas populações. *Myracrodruon urundeuva*, *Tabebuia impetiginosa* e *Astronium fraxinifolium*, as espécies mais exploradas da região, tiveram alta densidade de plântulas em todos os fragmentos. Entretanto, a maior densidade de plântulas estabelecidas (>1 ano) e juvenis ocorreu no fragmento mais perturbado.

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PÁGINA  
EM  
BRANCO