Acta Scientiarum. Biological Sciences
ISSN: 1679-9283
eduem@uem.br
Universidade Estadual de Maringá
Brasil

Souza, Débora Cristina; Alves, Arielle Vanessa Barbosa; Tolomeotti, Luciana Oliveira; Silva, Jilvan Ribeiro da; Franco, Janaina de Melo
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Acta Scientiarum. Biological Sciences, vol. 35, núm. 2, abril-junio, 2013, pp. 203-209
Universidade Estadual de Maringá
Maringá, Brasil

Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9283
ISSN on-line: 1807-863X
Doi: 10.4025/actascibiolsci.v35i2.14810

Structure and regeneration capacity of a urban forest fragment

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ABSTRACT. Understanding the plant communities affected by human activities related to urbanization is an important tool to conserve these. In this way, this study on an urban forest fragment aimed to evaluate, through a phytosociological study and investigation of the germination of the seed bank, the current forest structure, the successional strata, and the regenerative capacity of the remnant. Three different stages comprised this research, the first with a floristic survey of the entire forest remnant, then the phytosociological study of the canopy (PAP above 10 cm) and regeneration strata (PAP 5-10 cm), and at last, the study on the seed bank. The phytosociological survey of the canopy stratum presented 1,368 individuals, with 41 species distributed into 24 families. The stratum of natural regeneration had 665 individuals, being 38 species distributed into 24 families. The seed bank was made up by only 8 native species, and 3 exotic species. The floristic diversity of the seed bank in all samples was low due to few species provide seeds to the soil. In addition, the strata and the seed bank had a low similarity, confirming thus the fragility and the need for preservationist attitudes.

Keywords: forest remnant, phytosociology, seed bank.

Estrutura e capacidade regenerativa de fragmento florestal urbano

RESUMO. Compreender as comunidades vegetais afetadas pelo desenvolvimento das atividades humanas relacionadas à urbanização é um importante instrumento para a manutenção desses. Assim, este trabalho, que trata de um remanescente florestal isolado junto ao meio urbano, procurou avaliar através de um estudo fitossociológico e de germinação de banco de sementes a estrutura florestal atual, os estratos sucessionais e a capacidade de regeneração do remanescente. O trabalho consistiu de três etapas diferenciadas, a primeira com o levantamento florístico de todo o remanescente florestal, após o estudo fitossociológico dos estratos maduro (PAP acima de 10 cm) e do estrato de regeneração (PAP de 5 a 10 cm) e por último o estudo do banco de sementes. O levantamento fitossociológico dos indivíduos maduros apresentou 1368 indivíduos sendo 41 espécies distribuídas em 24 famílias. O estrato de regeneração natural apresentou 665 indivíduos sendo 38 espécies distribuídas em 24 famílias. A composição do banco de sementes foi de apenas oito espécies nativas e três exóticas. Podemos afirmar que a diversidade florística do banco de sementes em todas as amostras foi baixa, isso porque são poucas espécies que proporcionam sementes para o solo. Aliado a isso temos que os estratos e o banco de sementes apresentaram baixa relação o que confirma sua fragilidade e a necessidade de atitudes preservacionistas.

Palavras-chave: remanescente florestal, fitossociologia, banco de sementes.

Introduction

The forest fragmentation and isolation of these fragments within an urban environment interfere with the dynamics and structure of the remnant. Studies on altered landscapes addressing biological characteristics are important to establish the dynamics of these environments and adequate measures for recovery and conservation (SAUNDERS et al., 1991).

Studies on plant communities affected by human activities related to urbanization are important tools to maintain these fragile ecosystems. Although the studies on natural regeneration of native vegetation are not recent, there is no consensus about what better defines this expression, nor a concept that embraces all situations found in the diverse tropical ecosystems. It is indispensable to know for instance how occur the processes related to the dynamics, ecological succession, and natural regeneration in the face of human disturbances (PEREIRA et al., 2001).

Several studies point out the fragmentation of tropical forest as the highest threat to biodiversity. This process brings about many consequences, such

as: the edge effect, prevention or reduction of migration rate between fragments, decrease in the effective population size with consequent loss of genetic variability, and invasion of exotic species are the main deteriorating mechanisms of a landscape formed by forest fragments (FEARNSIDE et al., 2009; GEIST; LAMBIN, 2002; SILVA et al., 2008).

The intensity of these factors depends on the features of the landscape where the fragments are inserted (NASCIMENTO et al., 1999). Thus, the size, shape, number of fragments, and type of surroundings will influence the number of species able to survive in a forest fragment (SAUNDERS et al., 1991).

The continuous disturbance of an area leads to a progressive depletion of the seed bank, constrain the local regeneration, i.e., hampering the ecological succession and producing impacts like the death of several old tree species, and the lack of seedlings to replace them, and thus destroying the habitat to the fauna (KAGEYAMA; CASTRO, 1989).

The seed bank is able to indicate the recovery and sustainability, and can also determine the species richness and the proportion between native and invasive species, and detect any natural disturbance. From this, it can be identified the potential of invasive species to colonize the area, competing with native species, and affecting the sustainability of the forest fragment (SCHMITZ, 1992).

In this way, this study was conducted in an urban forest fragment and aimed to evaluate, through a phytosociological study and investigation of the germination of the seed bank, the current forest structure, the successional strata, and the regenerative capacity of the remnant.

Material and methods

The forest remnant is located at Chácara 5R, in the city of Campo Mourão, Paraná State, with borders with the urban area, with the backs limited by the flooplain of the km 119 River. It has about 3.5 ha area, and the legal reserve associated with the permanent preservation area has around 1.0 ha. The crops are for subsistence of the families living there, with for example watermelon, corn, coffee, vegetable garden, among others. According to a control mapping performed by the owner, inside the forest there is an ant nest that extends for more than 3 km, from the neighboring properties until the lots of the urban area.

Considering the phytogeographical formations, according to Roderjan et al. (2002), the municipality is located in a climatic transition area with different types of vegetation, with an ecotone of Seasonal Semideciduous Montane Forest and Mixed Rain Montane Forest (Araucaria Forest) and covers a disjunction of Cerrado. The predominant soil is the oxisol, clayey, deep, very fertile, and capable to support intense agriculture.

The study comprised three stages, the first with a floristic survey of the entire forest remnant, then, a phytosociological study, and at last the study on the seed bank.

The floristic survey lasted 13 months in a row, through weekly and random field trips throughout the area. Branches with fertile plant structures were collected and vouchers specimens were deposited at the Herbarium of the Federal Technological University of Paraná – Campo Mourão, Paraná State (HCF).

On the area, fifteen permanent plots (20 x 30 m) were established, with 9,000 m^2. At each plot, we registered and identified mature tree individuals with PAP (perimeter at height of 1.3 m) equal to or higher than 10 cm, and to survey those at natural regeneration, we sampled the individuals with PAP between 5 and 10 cm.

Samples of the seed bank were collected randomly from six plots, in two periods of the year (late spring, and late summer). At each plot, three soil samples were taken, including the litter, adding up 36 samples. These samples were taken using a 25 x 25 cm hollow metal structure, with 5 cm depth. In some samples (9), no germination occurred, and they were disregarded of the bank sampling, thus, a volume of 84.375 cm^3 and area of 1,6875 m^2 was sampled. The samples with no germination took place next the ant nest, which forms large clusters of soil.

Samples were sieved (6 mesh size) and placed on plastic trays, where the corresponding litter was put on. The trays were kept in an environment with relative humidity close to field capacity, by watering until the emergence of the seedlings. After this, the seedlings were identified, counted and removed. The non-identified species were planted on pots and allowed to develop at shaded place, for later identification. Some individuals did not adequately develop, and were identified to the family level.

The phytosociological data were analyzed using the software Fitopac 1.6 (SHEPHERD, 2006). The standing dead individuals were included in the study. The forest structure and the similarity between the vegetation strata were examined with a correspondence analysis (DCA) calculated in the software PC-ORD 4.0 (MCCUNE; MEFFORD, 1999). For this analysis, we used the two strata together, being the abundance matrix previously log transformed (log (x+1)), removing the rare species (occurrence lower than 10%). The Shannon diversity index (H') was estimated for the two forest

strata (BROWER; ZAR 1984) and the Jaccard coefficient was employed to compare the similarity between the plots (MÜLLER-DOMBOIS; ELLENBERG, 1974).

Also, it was calculated the following phytosociologial values of the seed bank: Relative Frequency (Rf), Absolute Density (Ad), Relative Density (Rd), used to estimate the Importance Value Index of the seed bank (IVB).

Results and discussion

The phytosociological survey of the mature individuals (perimeter above 10 cm) registered 1,368 individuals, with 41 species distributed into 24 families (table 1). The Shannon diversity (H') was 2.93, and the mean height, around 10.79 m. The stratum of natural regeneration (perimeter between 5 and 10 cm) presented 665 individuals, being 38 species distributed into 24 families, with a diversity index (H') of 3.03 and a mean height, around 4.77 m.

In total, were sampled 2,033 individuals belonging to 42 species distributed into 24 families. The species exclusive to the canopy stratum were: *Araucaria angustifolia* (Bert.) O. Kuntze, Apocynaceae 1, *Cabralea canjarana* (Vell.) Mart, *Syagrus romanzoffiana* (Cham.) Glassman, *Psidium guajava* L. Only two species were exclusive to the stratum of natural regeneration: *Cestrum strigillatum* Ruiz & Pavón and *Inga edulis* Mart.

The species with IVI higher than 10.0 in the canopy stratum were: *Eugenia uniflora* L., *Acacia* sp., Myrtaceae 1, Fabaceae 1, *Casearia sylvestris* Sw., undetermined and *Casearia lasiophylla* Eichler (Table 1).

In the regenerative stratum, once again *Eugenia uniflora,* Fabaceae 1 Myrtaceae*, Casearia sylvestris* (Table 2). *Eugenia uniflora* and the category 'dead' were prominent in the two perimeter classes as for the IVI 31.75 and 37.53, respectively, among mature individuals, and 38.39 and 24.80, respectively, at the regeneration stratum (Tables 1 and 2). These represented 32% of total individuals sampled, and no other species reach 8% of the total. The dominance of few species in the area reflects its successional stage, which can be classified as advanced secondary.

Table 1. Phytosociological descriptors of individual tree species of the canopy stratum (perimeter above 10 cm) of the Forest Remnant of Chácara 5R. N. Ind.= number of individuals; Rel. Dens. = Relative Density; Rel. Dom. = Relative Dominance; Rel. Freq.= Relative Frequency; IVI= Importance Value Index.

n. sp	*Specie*	N. Ind.	Rel. Dens	Rel. Dom	Rel. Freq	IVI
1	*Eugenia uniflora* L.	268	19.59	13.36	5.45	38.39
2	*Acacia* sp.	62	4.53	20.73	5.45	30.71
3	Myrtaceae 1	116	8.48	5.03	5.06	18.57
4	Fabaceae 1	89	6.51	6.43	4.67	17.60
5	*Casearia sylvestris* Sw.	100	7.31	4.51	4.28	16.10
6	Undetermined	65	4.75	7.19	3.89	15.84
7	*Casearia lasiophylla* Eichler	56	4.09	5.14	4.28	13.51
8	*Zanthoxylum rhoifolium* St. Hil	52	3.80	2.07	3.50	9.37
9	*Rollinia silvatica* (St. Hil.) Mart.	42	3.07	2.65	3.11	8.83
10	Fabaceae 2	29	2.12	2.90	3.50	8.52
11	*Tabernaemontana catharinensis* A.DC.	30	2.19	2.77	3.50	8.46
12	*Matayba elaeagnoides* Radlk	29	2.12	1.91	4.28	8.31
13	*Cordia americana* (L.) Gottdchiling & J. E. Mill.	35	2.56	2.19	3.50	8.25
14	*Nectandra megapotamica* (Spreng.) Mez.	18	1.32	2.91	2.72	6.95
15	*Campomanesia xanthocarpa* Berg	26	1.90	1.12	3.11	6.13
16	*Allophylus edulis* (A. St.-Hil., Cambess. & A. Juss.) Radlk	18	1.32	1.12	2.72	5.16
17	*Miconia* sp.	29	2.12	0.30	1.95	4.36
18	*Alchornea triplinervia* (Spreng.) M. Arg	12	0.88	0.50	2.72	4.10
19	*Styrax leprosus* Hook. & Arn.	13	0.95	0.26	2.72	3.93
20	*Dalbergia frutescens* (Vell.) Britton	9	0.66	0.11	2.33	3.10
21	*Endlicheria paniculata* (Spreng.) Macbr.	8	0.58	0.15	2.33	3.07
22	*Celtis iguanaea* (Jacq.) Sarg.	10	0.73	0.37	1.95	3.05
23	*Araucaria angustifolia* (Bert.) O. Kuntze	4	0.29	0.99	1.56	2.84
24	Apocynaceae 1	8	0.58	0.19	1.95	2.72
25	*Diatenopteryx sorbifolia* Radlk.	9	0.66	0.11	1.95	2.71
26	*Aegiphila brachiata* Vell.	7	0.51	0.60	1.56	2.66
27	*Aegiphila sellowiana* Cham.	6	0.44	0.54	1.56	2.54
28	*Chrysophyllum marginatum* (Hook. & Arn.) Radlk.	4	0.29	0.78	1.17	2.24
29	*Myrcia* sp.	11	0.80	0.17	1.17	2.15
30	*Sebastiania brasiliensis* Spreng.	10	0.73	0.20	0.78	1.71
31	*Ficus* sp.	4	0.29	0.44	0.78	1.51
32	*Cabralea canjarana* (Vell.) Mart.	4	0.29	0.19	0.78	1.26
33	*Syagrus romanzoffiana* (Cham.) Glassman	2	0.15	0.20	0.78	1.12
34	Myrsinaceae	2	0.15	0.15	0.78	1.08
35	*Xylosma siliatifolium* (Clos) Eichler).	3	0.22	0.04	0.78	1.04
36	*Sebastiania commersoniana* (Baill.) Smith & Downs	2	0.15	0.01	0.78	0.94
37	*Trichilia elegans* A.Juss.	4	0.29	0.03	0.39	0.72
38	*Psidium guajava* L.	1	0.07	0.14	0.39	0.61
39	*Citrus* sp.	2	0.15	0.04	0.39	0.57
40	*Solanum granuloso-leprosum* Dunal	1	0.07	0.01	0.39	0.47

Table 2. Phytosociological descriptors of individual tree species of the regeration stratum (perimeter between 5-10 cm) of the Forest Remnant of Chácara 5R. N. Ind.= number of individuals; Rel. Dens. = Relative density; Rel. Dom. = Relative dominance; Rel. Freq.= Relative frequency; IVI= Importance value index.

n.	Species	N. Ind.	Rel. Dens.	Rel. Dom.	Rel. Freq.	IVI
1	*Eugenia uniflora* L.	84	12.63	13.45	5.67	31.75
2	Fabaceae 1	59	8.87	8.08	6.19	23.14
3	Myrtaceae 1	50	7.52	7.09	5.67	20.28
4	*Casearia sylvestris* Sw.	40	6.02	6.02	5.15	17.19
5	Undetermined	34	5.11	5.01	3.61	13.73
6	*Rollinia silvatica* (St. Hil.) Mart.	26	3.91	3.57	5.15	12.63
7	*Casearia lasiophylla* Eichler	26	3.91	3.46	5.15	12.52
8	*Miconia* sp.	22	3.31	4.20	3.09	10.60
9	*Allophylus edulis* (A. St.-Hil., Cambess. & A. Juss.) Radlk	23	3.46	3.20	3.61	10.27
10	*Cordia americana* (L.) Gottdchiling & J. E. Mill.	25	3.76	3.66	2.58	10.00
11	*Matayba elaeagnoides* Radlk	24	3.61	2.76	2.58	8.95
12	*Zanthoxylum rhoifolium* St. Hil	15	2.26	1.96	4.12	8.34
13	*Dalbergia frutescens* (Vell.) Britton.	12	1.80	1.62	3.61	7.04
14	*Alchornea triplinervia* (Spreng.) M. Arg	13	1.95	1.77	3.09	6.82
15	*Styrax leprosus* Hook. & Arn.	10	1.50	1.30	3.09	5.90
16	*Ficus* sp.	5	0.75	3.61	1.03	5.40
17	Fabaceae 2	10	1.50	1.30	2.58	5.38
18	*Acacia* sp.	8	1.20	1.03	2.58	4.81
19	*Chrysophyllum marginatum* (Hook. & Arn.) Radlk.	9	1.35	0.86	2.06	4.27
20	*Diatenopteryx sorbifolia* Radlk.	7	1.05	1.08	2.06	4.19
21	*Tabernaemontana catharinensis* A.DC.	7	1.05	1.01	2.06	4.12
22	*Endlicheria paniculata* (Spreng.) Macbr.	8	1.20	1.10	1.55	3.85
23	*Sebastiania brasiliensis* Spreng.	7	1.05	0.94	1.55	3.54
24	*Sebastiania commersoniana* (Baill.) Smith & Downs	6	0.90	1.00	1.55	3.45
25	*Cestrum strigillatum* Ruiz & Pavón	6	0.90	0.94	1.55	3.39
26	*Campomanesia xanthocarpa* Berg.	4	0.60	0.58	2.06	3.24
27	*Myrcia* sp.	5	0.75	0.73	1.55	3.02
28	*Aegiphila sellowiana* Cham.	3	0.45	0.35	1.55	2.35
29	*Celtis iguanaea* (Jacq.) Sarg.	3	0.45	0.49	1.03	1.97
30	*Citrus* sp.	2	0.30	0.40	1.03	1.73
	Xylosma siliatifolium (Clos) Eichler)	2	0.30	0.36	1.03	1.69
32	*Trichilia elegans* A.Juss.	2	0.30	0.32	1.03	1.65
33	*Solanum granuloso-leprosum* Dunal	2	0.30	0.29	1.03	1.62
34	*Nectandra megapotamica* (Spreng.) Mez.	2	0.30	0.19	0.52	1.00
35	*Inga edulis* Mart.	1	0.15	0.29	0.52	0.95
36	*Aegiphila brachiata* Vell.	2	0.30	0.13	0.52	0.95
37	Myrsinaceae 1	1	0.15	0.06	0.52	0.72

Rosa and Schiavini (2006) have registered 11.45% dead individuals, and emphasized the severity of this result, once a significant number of standing dead individuals influences the recruitment of new individuals, being directly related to the slow opening of the canopy.

The high number of stand dead individuals in the area may be associated with the fragmentation and isolation of the forest remnant. In newly isolated fragments, the death of trees is probably due to microclimatic changes caused by the isolation. On the other hand, in fragments isolated for a long time, a great number of dead trees show that the increased mortality occurs not only immediately after the isolation, but persists for a long period (TABANEZ et al., 1997).

The assessment of species distribution did not point out any group among the species, which were randomly distributed throughout the area of both strata (Figures 1a and b), the axes presented low explanation value (axis 1 = 0.221 and axis 2 = 0.129 for the canopy stratum, and axis 1 = 0.216 and axis 2 = 0.16 for the regeneration stratum). However, some species had a restricted distribution, along the forest edges, next the floodplain of the km 119 river, such as *Inga edulis*, *Ficus* sp., *Myrcia* sp. and *Sebastiania commersoniania*. The location of these species reflects the way the plots are distributed randomly (Figures 1c and d).

The seed bank was composed of only 8 native species and 3 exotic species, among them, *Morus nigra* considered invasive and dispersed by bird and bat. Among exotic one, *Geophila repens* presented the highest number of individuals, with 33.3% of frequency. Although it had been observed the occurrence of *Eugenia uniflora* and *Campomanesia xanthocarpa*, they had low frequency, 22.2 and 11.1%, respectively (Table 3).

Few individuals were recorded in the plot 1, the place with the largest mature individuals, such as *Araucaria angustifolia*. The plots 2 and 15 also had low density; in addition, in the plot 2 no individual was sampled in the regeneration layer. Although the density was higher in the plot 8, it was compounded mainly of stand dead individuals.

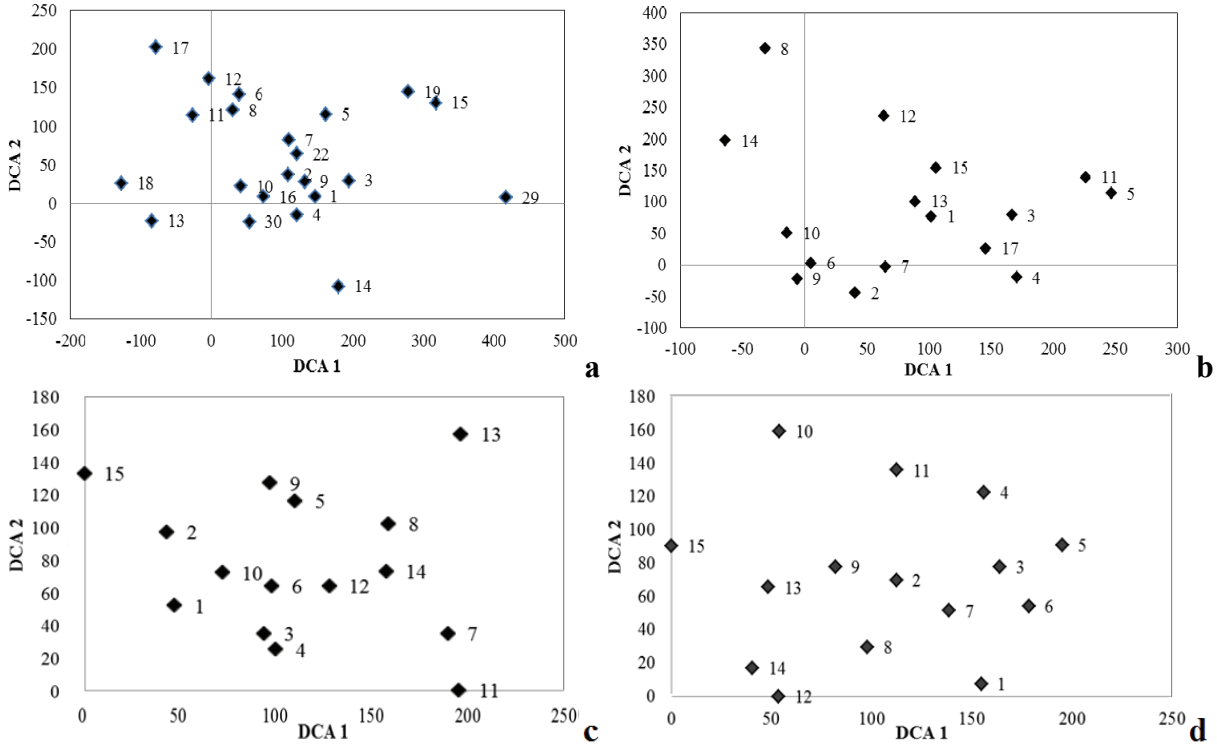

Figure 1. Result of the DCA of the canopy stratum and regeration stratum of the Forest Remnant located in Chácara 5R. a) scores of the species from the canopy stratum, b) scores of the species from the regeration stratum c) scores of the plots from the canopy stratum, d) scores of the plots from the regeration stratum. The species number are the same of the Tables 1 and 2.

Table 3. List of species germinated in the study of the seed bank of the Chácara 5R in Campo Mourão – Paraná State. Ad: Absolute density; Rd: Relative density; Rf: Relative frequency; IVB: Importance Value Index of the seed bank.

Species	Ad (n m^{-2})	Rd (%)	Rf (%)	IVB
Zanthoxylum rhoifolium St. Hil	6.47	28.74	33.30	62.04
Geophila repens (L.) I.M.Johnst.	5.29	23.50	33.30	56.80
Alchornia triplinervea (Spreng.) M. Arg	3.53	15.68	22.20	37.88
Eugenia uniflora L.	1.76	7.82	22.20	30.04
Undetermined (vine)	1.18	2.56	11.11	23.67
Campomanesia xanthocarpa Berg.	1.18	5.24	11.11	16.24
Chatalia sp.	0.58	2.56	11.11	13.67
Miconia sp.	0.58	2.56	11.11	23.67
Morus migra L.	0.58	2.56	11.11	23.67
Polygala klotzsckii Chodat	0.58	2.56	11.11	23.67
Talium sp.	0.58	2.56	11.11	23.67

The area did not feature a numerous flora or fruit species important to the fauna. Despite presenting several individuals of *Eugenia uniflora* and *Campomanesia xanthocarpa*, zoochoric species, these did not fruit throughout the study period. The great number of dead individuals in the area also influences the ecological processes that maintain the forest environment. Stand dead trees, have ecological value for the wildlife, providing shelter, nesting site, indirect source of food, among others (SILVA; SOARES, 2002). This condition support the idea of importance of fragments dispersed in the agricultural landscape for maintaining the biodiversity of the region, because they increase the probability of survival of threatened species (SANTOS et al., 2007).

In relation to the seed bank, the results are punctual but may indicate the vulnerability of the area, given the germination density of 22.51 seeds m^{-2}. This density can be considered very low, especially when compared to a study performed in a similar area, which found a density ranging from 500 to 800 seeds m^{-2} (MARTINS; ENGEL, 2007).

The low germination and diversity highlight the fragility of the remnant, both by the isolation, once there is no external source for the input of new seeds into the area, and by the size of the fragment that presents a quite clear edge effect. Then the seed bank is the only possible source of natural regeneration for this area, considered thus essential for the dynamic balance of the forest (SCHMITZ, 1992). Nevertheless, the continuous disturbance, may lead to the progressive depletion of the seed bank, making the place restricted to regeneration at the first successional stage (KAGEYAMA; GANDARA, 2000).

The forest was characterized by herbaceous and tree species, according to the seed bank. The species with higher IVB *Zanthoxylum rhoifolium* and *Geophila repens* (62.04 and 56.8 respectively) support that the forest area had been altered and is at advanced secondary stage of ecological succession.

With our results, an uneven distribution of the species along the plots was registered, the Jaccard similarity between the plots remained below 0.5, and thus can be related to the high environmental heterogeneity controlling the species occurrence in the area. The determining factors are: the soil that vary from the driest area to the wettest area (next to the floodplain); the low and concentrated occurrence of birds in the place, and sites more opened in the forest that enable the entrance of mainly exotic species.

Furthermore, the disturbance may be also related to the size of the fragment, and its isolation within an urban area, which can determine the loss of tree individuals and the low regeneration of the seed bank. Very small fragments are more susceptible to disturbances, probably owed the larger edge in relation to the interior area, and the supposition that a human disturbance promotes the invasion of exotic species into forest patches (SANTOS et al., 2007). The isolation degree and economic activity developed in the vicinity are also important to the floristic composition of the fragment (VIEIRA et al., 2009).

Conclusion

The low relationship between the forest strata and the seed bank validates its fragility and highlights the importance of its preservation. The floristic diversity of the seed bank in all samples was low, this because few species supply seeds to the soil. The tree life form was predominant in the seed bank, but this does not indicate forest renewal, given the low similarity between the studied tree strata.

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Received on September 20 2011.
Accepted on July 2, 2012.