Natural regeneration, composition and structure in a secondary Atlantic Forest fragment and in an abandoned *Eucalyptus saligna* Smith. (Myrtaceae) commercial plantation

Regeneração natural, composição e estrutura em um fragmento em sucessão secundária de Mata Atlântica e em reflorestamento comercial de *Eucalyptus saligna* Smith. (Myrtaceae) abandonado à regeneração

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Renata Picolo Scervino
Doutora em Ciências Biológicas pela Universidade Estadual de Londrina
Instituição: Docens Educação
Endereço: Avenida Rio de Janeiro, 448, Galeria Assahi, Centro, Assaí-PR, Brasil
E-mail: renatapicoloscervino@yahoo.com.br

Lya Carolina da Silva Mariano Pereira
Doutora em Recursos Florestais pela Escola Superior de Agricultura "Luiz de Queiroz" ESALQ/USP, Universidade de São Paulo
Instituição: Secretaria de Educação e do Esporte do Estado do Paraná - Núcleo Regional de Educação de Londrina
Endereço: Av. Maringá, 290 - Campo Belo, Londrina - PR, Brasil
E-mail: lyacarolina.smp@gmail.com

ABSTRACT

The litter horizon on forests ecosystems acts on the nutrient cycling and on the soil's microclimate conditions. However, to reforestation ecosystems the litter attributes can conduct to alterations that can diminish the seedling establishment, as well can act on the herbivory rates. In this context, this study aimed to verify the differences and relationships between woody species diversity, the herbivory index, the litter attributes, and the canopy openness among a fragment of Atlantic Forest on secondary succession and commercial plantation of *Eucalyptus saligna* Smith abandoned to regeneration. This study was conducted at the Klabin's Company "Ecological Reserve", at Telêmaco Borba – PR, Brazil. There weren't observed differences on the species richness and abundance among the studied sites. Litter mass and thickness were higher in *E. saligna* environment. However, the litter attributes only presented relationship with the woody vegetation at the Atlantic Forest site, such as abundance and species richness with litter mass (r^2=0.53 and r^2=0.40, respectively) and abundance with litter thickness (r^2=0.63). The herbivory index was greater on the forest patch. The canopy openness was superior in the *E. saligna* site. At this site, the herbivory index presented a positive relation with the canopy openness (r^2=0.48) and a negative with abundance (r^2=0.48). Abundance also presented a negative relation with the canopy openness (r^2=0.58) in the *E. saligna* environment. The litter horizon on the *E. saligna* plantation doesn't seem to offer restrictions to regeneration of the woody vegetation. However, at this site, the higher canopy openness and the herbivory pressure over the woody vegetation may lead to a lower rate of secondary succession compared to the Atlantic Forest fragment.

Keywords: canopy openness, restoration, secondary succession.

RESUMO
A serapilheira atua na fertilidade, na ciclagem de nutrientes e no microclima do solo. No entanto, a deposição deste material orgânico pode ser alterada em ambientes de reflorestamentos, causando alterações no estabelecimento de plântulas, nas taxas de herbivoria e na vegetação regenerante. O objetivo deste estudo foi avaliar a diversidade de plantas lenhosas, a herbivoria, os atributos da camada de serapilheira e a abertura do dossel em um fragmento de floresta secundária de Mata Atlântica e reflorestamento de *Eucalyptus saligna* abandonado à regeneração natural. O estudo foi conduzido na Reserva Ecológica da Klabin – Telêmaco Borba – PR, Brasil. O índice de herbivoria foi superior na floresta secundária. A massa e a espessura da serapilheira foram maiores no reflorestamento. A abertura do dossel foi superior no ambiente com *E. saligna*. Para o fragmento florestal a abundância apresentou relação com serapilheira (massa r^2= +0,53 e espessura r^2= +0,63), e riqueza com massa de serapilheira (r^2= +0,40), ambas com relações positivas. No reflorestamento o índice de herbivoria apresentou relação positiva com abertura do dossel (r^2= +0.48) e negativa com abundância (r^2= -0.48). A abertura do dossel neste ambiente apresentou relação negativa com a abundância (r^2= -0.58). Para o reflorestamento de *E. saligna* estudado a serapilheira não oferece restrição à regeneração de espécies lenhosas. Entretanto, a maior abertura do dossel e pressão de herbivoria neste ambiente podem conduzir a uma menor velocidade da regeneração natural quando comparado ao fragmento florestal.

Palavras-chave: restauração, sucessão secundária, serapilheira, abertura de dossel, herbivoria.

1 INTRODUCTION

The litter horizon is constituted by the organic matter accumulated above the soil deriving of the local vegetation (leaves, flowers, stems, fruits, and tree bark fragments) (TAKUO and TAKEDA 2004; SCHILLING et al., 2016). In this way, the litter accumulation is self-regulated by the amount of organic matter that falls of the aerial part of the plants and by the tax of their decomposition (THIRUKKUMARAN and PARKINSON, 2002; TATENO, TAKUO and TAKEDA 2004). This organic horizon above the soil provides shelter and food resources to a large of number of microorganisms and invertebrate species that acts as much in the litter decomposition and nutrient cycling as in the herbivory of the plants established in their foraging area (LEE et al., 2002, HOU et al., 2005).

This litter horizon is able to produce shadow and retain humidity creating microclimate conditions that benefits the seed germination, the plant recruitment, and the association to different fauna's ecological niche (KNACKER et al., 2003; HOU et al., 2005). However, different ecosystems, for example of native forests and commercial plantations with exotic species, store distinct litter mass and may present different proportions of the constituent fractions (LEHTONEN et al., 2004; GODINHO et al., 2013). These differences are a result of the biological cycle and the genetic characteristics of the plant species, the luminosity and climate conditions related to the canopy openness, and the local soil conditions (TANG et al., 2010, ZANG et al., 2014). To

reforestation environments these differences are also associated with the density and the age of the planting (TANG et al., 2010).

On the other hand, in monocultures dominated by the *Eucalyptus* genus, the great accumulation of litter above the soil can act as a mechanical barrier to seed arrival and germination and this can alter the soil conditions on the *Eucalytus* sp. surroundings (URIBES et al., 2012). Also, the herbivory index can suffer changes on commercial plantations (CORRÊA NETO et al., 2001). Mostly the changes on the herbivory is related to the greater occurrence of clearings and the dominance of pioneer species with fast life cycle associated to the first stages of the succession that typically have more nutrient contents allocated to grow and lower taxes of defense metabolites, benefiting a higher diversity of the herbivorous fauna (BIEBER et al., 2004).

In areas of commercial plantations, the alterations in the herbivorous fauna and the magnitude of the effects associated to the herbivory damage may be potentially responsible for the depletion observed in different phases of the plant's development, such as in the recruitment, survival, and the spatial distribution (VIANI et al., 2010; ALENCAR et al., 2011; SOARES e NUNES, 2013). As well in the competitive capacity and reproductive success, acting on the course and the dynamics of the natural regeneration (SIMONETTI et al., 2007). Nevertheless, although natural regeneration in *Eucalyptus* genus monocultures has being observed in plantings with different abandonment ages, densities, and on several biomes (VIANI et al., 2010; ALENCAR et al., 2011; SOARES e NUNES, 2013), are rare studies that verify if the woody regenerating seedlings on abandoned reforestation can be influenced by the litter attributes and the herbivory damage. Also, are few studies that try to relate these variables with canopy openness and with woody forest species richness and abundance on the Atlantic Forest biome.

In this context, this study aimed to verify the relationships among woody species diversity, the herbivory index, the litter horizon attributes and the canopy openness, and the differences between a native Atlantic Forest fragment on secondary succession and an abandoned commercial plantation of *Eucalyptus saligna* Smith.

2 MATERIAL AND METHODS

2.1 STUDY SITE

This study was conducted in Monte Alegre Farm (24º27'55"S; 50º33'03"W, Ecological Reserve of Klabin Company), located at Telêmaco Borba district, eastern area of Parana state, Brazil. The local landscape is formed by a mosaic of Atlantic Forest ecosystems, encompassing Seasonal Atlantic Dry Forest, Araucaria Forest and smalls patches of natural grasslands fields within commercial reforestation areas with the exotics species *Pinus sp*. and *Eucalyptus saligna* Smith.,

and with the native Ombrophilus Forest specie *Araucaria angustifolia* (Bertol.) O. Ktze. (AZEVEDO et al., 2008). The regional climate is classified as a transition of Cfa and Cfb of Köppen, considered as sub-tropical climate with hot summers and humid winter with occasional frosts. The annual rain precipitation average is 1700 mm and the annual temperature is 19.5ºC (MENDONÇA and DANNI-OLIVEIRA, 2002).

The Research was executed at a fragment on secondary succession of Seasonal Atlantic Dry Forest and at an *Eucalyptus saligna* Smith. abandoned commercial plantation (with twelve years of abandonment). This Atlantic Forest site has suffered an intense wood exploration during the regional colonization period and is characterized by the presence of forest gaps dominated by herbaceous species with few centenaries trees (MEDRI et al., 2009). The *E. saligna* area was planted in 1987 and managed with traditional techniques (hand-operated) until 1988. The first timber harvesting occurred in 1993 (681,980 m^3 wood production), followed by another harvest in 1997 (750,210 m^3, wood production), and the last management plan was executed in 1998 with the use of herbicide and mechanical techniques, after that, the area was abandoned to natural regeneration (Klabin Company data, 2010).

2.2 SAMPLING DESIGN

Plots of 1 x 2 m were allocated at the Atlantic Forest fragment and at the *E. saligna* site, with ten plots per study sites with minimal distance between plots of 10 m. These plots were establish avoiding forest gaps and the borders of the fragments. In each plot, all woody plants were counted and identified or arranged in morpho-species. Botanical identification was done in field whenever possible, and samples were collected for later herbarium confirmation.

2.3 HERBIVORY SAMPLING

All woody juveniles with high between 0.10 and 1 m were recorded and had all leaves counted to later estimation of the herbivory index to each individual according to Dirzo and Domínguez (1995) classification. In this method each leave can be classified in six classes: 0 (not damaged leaves), 1 (1-6% of leave surface damage), 2 (6-12% of leave surface damage), 3 (12-25% of leave surface damage), 4 (25-50% of leave surface damage), 5 (50-100% of leave surface damage). The herbivory index was calculated for each recorded plant and obtained through the formula:

$$HI = \frac{\sum (n_i x_i)}{N}$$

(HI – herbivory index; n_i – number of leaves per category; x_i – leaves damage category value; N – total number of leaves).

2.4 LITTER SAMPLING

The litter above the soil was collected with the aid of a 0.5 x 0.5 m (0.25 m^2) square allocated in the center of each plot. The collected material was placed in paper bags and dried at 80°C until constant mass was achieved for later weight measure. To estimate the litter horizon thickness five drillings were made in different spots of each plot. This method quantifies the number of leaves drilled by a skewer forced to penetrate perpendicular to the soil, and each drilled leave is considered as a litter layer (VASCONCELOS, VILHENA and CALIRI, 2000).

2.5 CANOPY OPENNESS

The canopy openness was estimated through pictures taken in the center of each plot with the aid of a digital camera placed in a distance of 1 m high above the soil. In order to obtain the percentage of the canopy openness, these pictures were later analyzed with the software Gap Light Analyzer.

2.6 DATA ANALYSIS

Normality was checked by Kolmogorov-Smirnov test and homogeneity was tested by Levene's test. Data revealed to be non-parametric, thus the Mann-Whitney test was applied to compare the species richness and abundance, the herbivory index, the litter mass and thickness, and the canopy openness among the Atlantic Araucaria Forest fragment and the *E. saligna* plantation. A Correlation Matrix was used to identify relationships among litter mass and thickness, canopy openness, the species diversity and the herbivory index. Data that presented correlations were later analyzed by Linear Regression. Results were considered significant when $\alpha \leq 0.05$.

3 RESULTS

In the Atlantic Forest site, a total of 186 individuals were sampled, belonging to 39 species belonging to 17 botanical families. At the *E. saligna* site, a total of 142 individuals were sampled, belonging to 23 species of 16 botanical families. To the Atlantic Forest environment, the family with higher abundance of individuals was Sapindaceae, and the richest in species was Myrtaceae. For *E. saligna* site, the most abundant and richest family was Rubiaceae, followed by Melastomataceae and Piperaceae botanical families. No differences were observed on species richness and abundance among the studied sites.

The herbivory index differed among the environments ($p = 0.03$, Mann-Whitney), and was superior on the secondary Atlantic Forest (1.84) in detriment to the *E. saligna* site (1.49). Litter

mass (p = 0.0002, Mann-Whitney) and thickness (p = 0.02, Mann-Whitney) were greater in the *E. saligna* environment.

The canopy openness was superior in the *E. saligna* site (p = 0.01, Mann-Whitney). The Atlantic Forest environment presented an average of 16.8% of canopy openness whereas *E. saligna* site present an average of 23%.

For the Atlantic Forest the abundance is related to litter mass (r^2 =0.53) and thickness (r^2 = 0.63), both with positive relationships (Figures 1 A and B, Linear Regression). The species richness also presents a positive relationship with litter mass (r^2 = 0.40, Figure 1 C, Linear Regression).

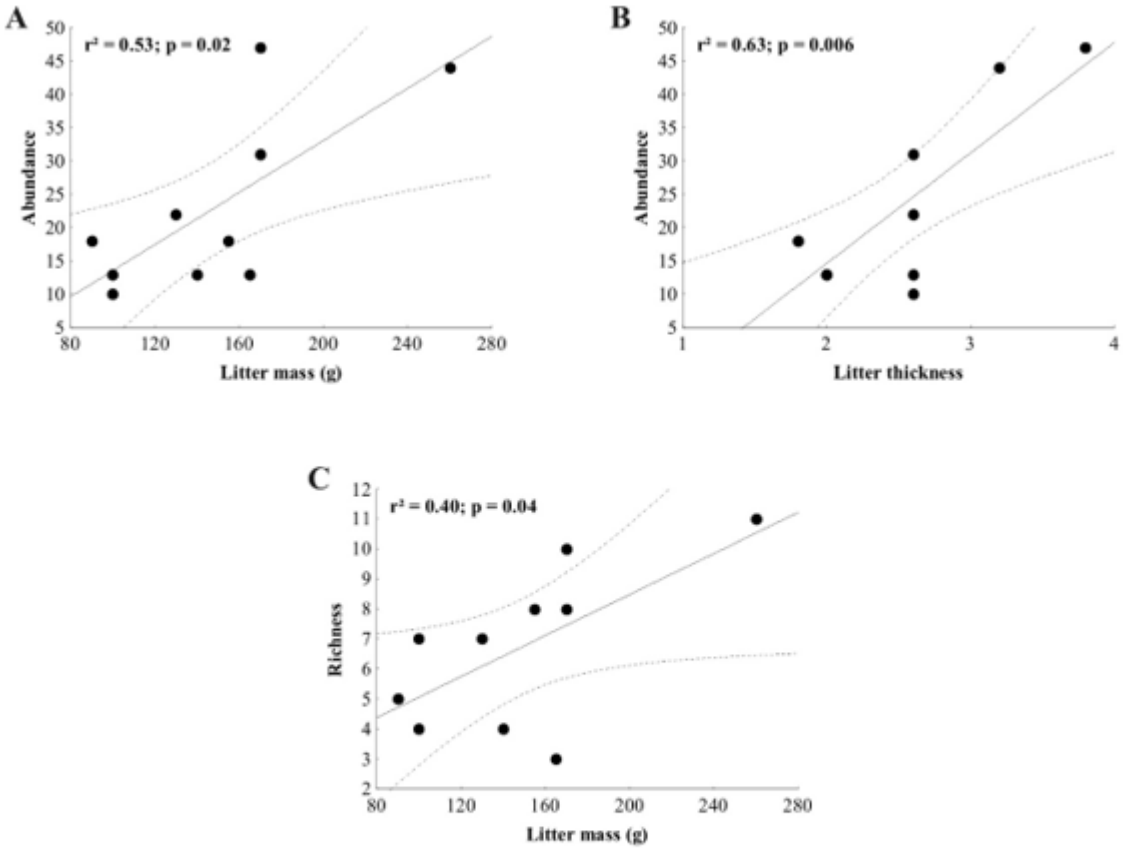

Figure 1: Woody species diversity and the litter horizon at the Auracaria Atlantic Forest fragment. Abundance and litter mass (A); Abundance and litter thickness (B) and Richness and litter mass (C). Figura 1:Diversidade de plantas lenhosas e características da serpailheira em um fragmento de Floresta Atlântica de Araucaria. Abundância e massa de serapilheira (A); Abundância e camada de serapilheira (B) e Riqueza e massa serapilehria (C).

At the *E. saligna* environment, the herbivory index presented a positive relation with the canopy openness (r^2 = 0.48) and a negative with abundance (r^2 = 0.48) (Figures 2 A and B, Linear Regression). Abundance also presented a negative relation with the canopy openness (r^2 = 0.58, Figure 2 C, Linear Regression). For this site, no relationships were observed among plant diversity (abundance and species richness) and the litter characteristics.

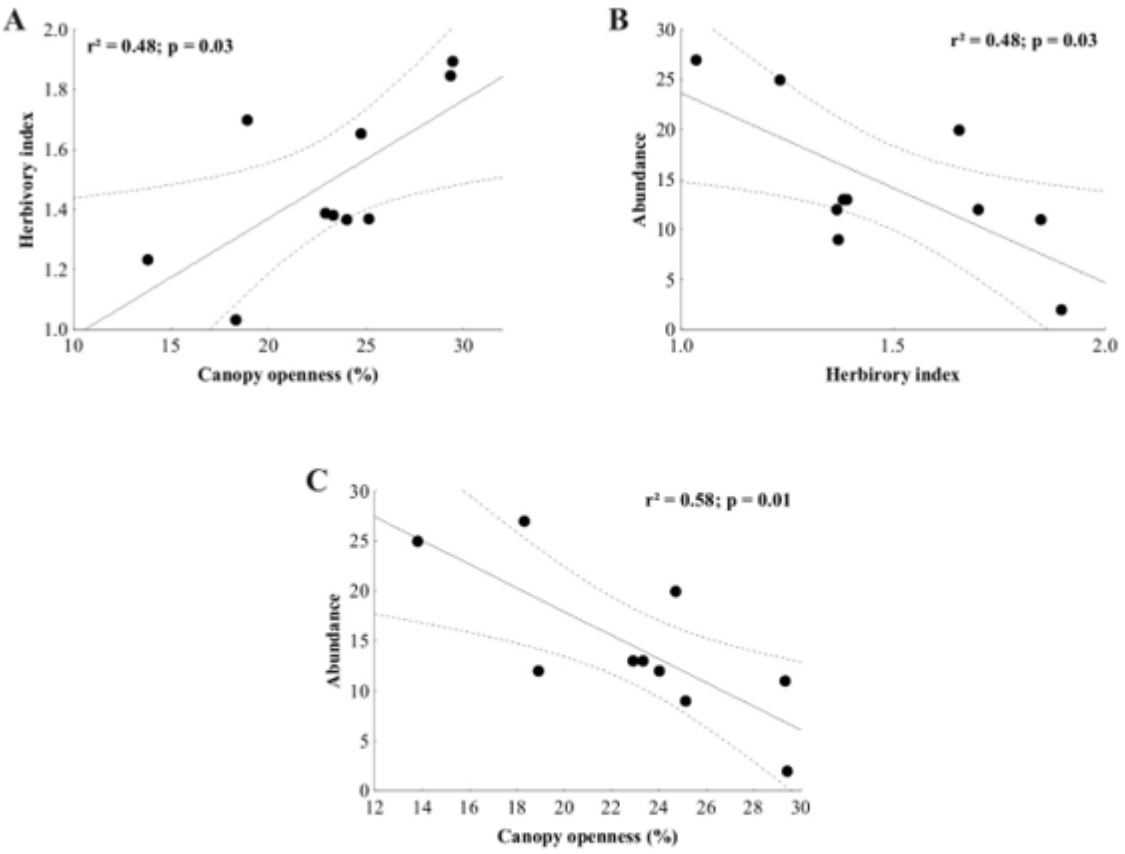

Figure 2: Herbivory index and canopy openness at a *Eucalyptus saligna* Smith. abandoned commercial plantation. Herbivory index and canopy openness (A); Abundance and herbivory index (B) and Abundance and canopy openness (C).
Figura 2: Índice de herbivoria e abertura de dossel em um reflorestamento comercial de *Eucalyptus saligna* abandonado à regeneração natural. Índice de herbivoria e abertura de dossel (A); Abundância e índice de herbivoria (B) e Abundância e abertura de dossel (C).

4 DISCUSSION

No difference was observed on species richness and abundance among the Atlantic Araucaria secondary forest and the *E. saligna* abandoned monoculture. However, in the *E. saligna* site it was observed a higher occurrence of pioneer species associated with the early phases of succession. Several authors (TABARELLI and MANTOVANNI, 1999; VACCARO, LONGHI and BRENA, 1999; CHADA, CAMPELLO and FARIA, 2004; BOYLE and BRONSTEIN, 2012) observed a tendency of substitution of botanical of families and species during the secondary succession on the on the Atlantic Forests biomes. This change on species richness occurs with the replacement of pioneers species to species tolerant to shadow and dispersed by animals (TABARELLI and MANTOVANNI, 1999; VACCARO, LONGHI and BRENA, 1999; CHADA, CAMPELLO and FARIA, 2004; BOYLE and BRONSTEIN, 2012).

This tendency of replacement of the species seems to occur on the Atlantic fragment where Myrtaceae and Lauraceae families, that represents a high number of understory species with zoochoric syndrome and tolerance to shadow, are more represented when compared to the *E. saligna* plantation. Also, at the *E. saligna* site, a high number of small shrubs and herbaceous species are still observed. At this site, the richest botanical families are Rubiaceae, followed by Melastomataceae and Piperaceae. They are families commonly associated to the first stages of succession on the Atlantic forests (TABARELLI and MANTOVANNI, 1999; CHADA, CAMPELLO and FARIA, 2004; HOSSAIN, 2012). However, pioneer's species as *Dalbergia brasiliensis* Vogel. (Fabaceae), typical of early phases of regeneration, still occurs on both study sites with a high abundance.

The higher litter mass and thickness was observed on the *E. saligna* environment. This may be due to the low decomposition rates for this species, compared to native areas (PINTO et al., 2016). There weren't observed relationships among the litter attributes with woody plant diversity. In this way, it seems that for this environment, the litter horizon doesn't restrict woody species regeneration. Although, it was not found relationship among the litter attributes and species diversity at this study site, the allelopathy mechanism was observed on *Eucalytus* genus in abandoned monocultures environments (LEE et al., 2002; URIBES et al., 2012). In addition to changes on the soil characteristics related to an acid pH on the plantation area when compared to forests, which may influence species diversity through the deplete of the germination and growth (SOUTO et al., 2001; LEE et al., 2002; URIBES et al., 2012). Furthermore, Gonçalves (1995) observed that the great accumulation of litter of *Ecalyptus grandis* can stimulate the growth of a thin root web on the superficial soil horizons. This can act as mechanical barrier that also may have influence on woody species recruitment and regeneration.

On the other hand, at the Atlantic fragment, the woody species richness and abundance presented a positive relationship with both litter mass and thicknesses. This suggests that litterfall production is related to plant diversity (TANG et al., 2010), and for this site the litter horizon present better conditions to plant development (HOSSAIN, 2012). This positive effect is related to an increase of the soil fertility trough the input of organic matter and their decomposition, the reduction of evapotranspiration (ETc) and the erosion process (ZANG et al., 2014). Also, can rase the humidity and shadow conditions above the soil, which can benefit the seed germination, recruitment and the establishment of forest species (ZANG et al., 2014).

The higher herbivory index was observed on the Atlantic fragment. This can be associated to the higher diversity of shelters, nesting areas and food resources to the herbivorous fauna in native forests environments (SOARES, MARINHO and DELLA LUCIA, 1998; CORRÊA et al., 2010;

PERIN and GUIMARÃES, 2012). Also the forest litter is associated to a higher diversity of the animal fauna than monocultures environments (CORRÊA NETO et al., 2001). However, no relationship was observed among the litter attributes and the herbivory index for both studied environments. In this way, to these abandoned environments, the maintenance of the herbivorous fauna may be more related to the composition and quality of the organic matter stored than with the amount of accumulated litter above the soil.

To the *E. saligna* site, the herbivory index presents a positive relationship with canopy openness. Barone and Coley (2002) also observed that more open areas are more visited by herbivorous animals. In addition, at *E. saligna* plantation, it was observed a higher proportion of pioneer species that occur in locations with higher brightness. These sites are typically preferred by the herbivorous fauna due to the lower investment is defense metabolites and higher nutrient contents (water, proteins and carbohydrates) (CORRÊA et al., 2010; PERIN and GUIMARÃES, 2012).

At the *E. saligna* abandoned monoculture the higher canopy openness is also leading to a decrease of the abundance of woody regenerating vegetation. This can be related to the higher luminosity in this area which conduces to a high variation of soil and air temperature and humidity. This that affects the establishment of species non tolerant to open areas and those that belongs to the mature stages of succession (PARROTTA, TURNBULL and JONES, 1997). The abundance had also negative relationship with the herbivory index at this site, which can, over time, reflect in plant establishment, spatial distribution, growth and on others phases of the plant development (COLEY and BARONE, 1996; CORRÊA et al., 2010; PERIN and GUIMARÃES, 2012). And thus, lead to a lower rate of the secondary succession on this abandoned reforestation when compared to the Atlantic Forest fragment, acting on the velocity and on the trajectory of the successional process.

On the other hand, several national and international agreements, such as the renewal of the political compromises of sustainable development of Rio +20, the Pact of Atlantic Forest (2009), and the Bonn-Challenge (2011), were established with the compromise to restore and monitor degraded lands in Brazil and all over the world (SAYER, CHOKKALINGAM,e PULSEN 2004, BRANCALION et al. 2010, LE et al. 2011, IUCN e GPFLR, 2011, WORTLEY, HERO, e HOWES 2013).

In this scenario, the restoration of Tropical Forests is currently an important strategy to conservation of the biodiversity in the Tropics and to maintenance of ecosystem services sustained by forests (CHAZDON 2009, BRANCALION et al. 2010, GANDOLFI 2013). In this way, commercial plantations have great potential for restoration issues, as an increase in species diversity that can occur due to natural regeneration, depending on surrounding landscape structure. In

addition, the mix of commercial and native species in restoration programs could be an alternative to lower the costs though restoration process (BRANCALION et al. 2019).

5 CONCLUSION

Woody plants diversity is related to the litter attributes only on the Atlantic Forest fragment, and despite presenting the higher herbivory index this does not influences the regenerating species diversity. For the abandoned *E. saligna* plantation, it wasn't observed neither positive or negative relationships with the litter horizon. This indicates that, for this environment the litter above soil doesn't seem to offer restrictions to the arrival and establishment of woody species.

The higher herbivory index occurred on the environment with the less canopy openness (Atlantic Forest fragment). However, relationships between canopy openness and herbivory index were only observed on the *E. saligna* site. To the *E. saligna* plantation, the higher canopy openness and herbivory pressure over the woody vegetation may, according to the diversity of the herbivorous fauna and to the intensity of the foraging activity, lead to a lower rate of the secondary succession compared to the Atlantic Forest site. But, if over time the canopy openness of abandoned commercial plantation areas reaches out the patterns of a native forest, it is expected to see an increment of native species with the increase of later succession species diversity and of the structural complexity of this environment.

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REFERENCES

ALENCAR, A.L.; MARANGON, L. C.; FELICIANO, A.L.P.; FERREIRA, R.L.C.; TEIXEIRA, L.J Regeneração natural avançada de espécies arbóreas nativas no sub-bosque de povoamentos de *Eucalyptus saligna* Smith. na zona da Mata Sul de Pernambuco. **Ciência Florestal**, v.21, n.2, p.183-192, 2011

AVILA, A. L. Regeneração natural em sub-bosque de *Eucalyptus camaldulensis* Dehnh., Santa Maria, RS. **Revista Brasileira de Biociências**, v.5, p.696-698, 2007.

AZEVEDO, T.I.N.; SEKIAMA, M.L.; VIEIRA, A.O.S.; BENNEMANN, S.T. Descrição física da micro bacia do Ribeirão Varanal e caracterização dos trechos. In: BENNEMANN, S.T.; VIEIRA, A.O.S.; SHIBATTA, O.A. (Org.). **A flora e a fauna do Ribeirão Varanal: um estudo da biodiversidade no Paraná**. Londrina: EDUEL, 2008, p. 6-14.

BARONE, J.A.; COLEY, P.D. Herbivorismo y las defensas de las plantas. In: GUARIGUATA, M. R.; KATTAN, G. H. (eds.). **Ecología y Conservación de Bosques Neotropicales**, Libro Universitario Regional, Cartago, 2002. p.466-492.

BIEBER, A.B.; MARTINS, E.G.; WERNECK, F.; ZUQUIM, G.; BALDISSERA, R.; CARBALLIDO, V.C. Variação interespecífica nos mecanismos de defesa contra herbivoria: um teste da hipótese da disponibilidade de recursos. In: **Livro do Curso de Campo "Ecologia da Floresta Amazônica".** INPA/PDBFF. Manaus, AM, 2004.

BOYLE, A.; BRONSTEIN, J.L. Phenology of tropical understory trees: patterns and correlates. **Rev. Biol. Trop.**, v.60, n.4, p.1415-1430, 2012.

BRANCALION, P.H.S.; AMAZONAS, N.T.; CHAZDON, R.L.; MELIS, J.V.; RODRIGUES, R.R.; SILVA, C.C.; SORRINI, T.B.; HOLL K.D. Exotic eucalypts: From demonized trees to allies of tropical forest restoration? **Journal of Applied Ecology**, v.57, p.55-66, 2019.

CHADA, S.S.; CAMPELLO, E.F.C.; FARIA, S.M. Sucessão vegetal em uma encosta reflorestada com leguminosas arbóreas em Angra dos Reis, RJ. **Revista Árvore**, v.28, n.6, p.801-809, 2004.

COLEY, P.D.; BARONE, J.A. Herbivory and plant defenses in tropical forests. **Annual Review of Ecology and Systematics**, Palo Alto, v.27, p.305-335, 1996.

CORRÊA, M.M.; SILVA, P.S.D.; WIRTH, R.; TABARELLI, M.; LEAL, I.R. How leaf-cutting ants impact forests: drastic nest effects on light environment and plant assemblages. **Oecologia**, v.162, p.103-115, 2010.

CORRÊA NETO, T.A.; PEREIRA, M.G.; CORREA, M.E.F.; ANJOS, L.H.C. Deposição de serrapilheira e mesofauna edáfica em áreas de eucalipto e floresta secundária. **Floresta e Ambiente**, v.8, n.1, p.70-75, 2001.

DIRZO, R.; DOMÍNGUEZ, C.A. Plant herbivore interactions in Mesoamerican tropical dry forests. In: BULLOCK, S.H.; MEDINA E.; MOONEY, H.A. (eds) **Seasonally dry tropical forests**. Cambridge University Press. Cambridge, 1995, p.304-325.

DURIGAN, G.; CONTIERI, W.A.; MELO, A.C.G.; GARRIDO, M.A. O. Regeneração da mata ciliar sob plantio de *Pinus elliottii* var. *elliottii* em diferentes densidades. In: VILAS BOAS, O.; DURIGAN, G. **Pesquisas em conservação e recuperação ambiental no oeste paulista: resultados da cooperação Brasil/Japão**. São Paulo: Páginas & Letras Editora, 2004, p.363-376.

ELLIS, L.M.; CRAWFORD, C.S.; MOLLES, M. Jr. Comparison of litter dynamics in native and exotic riparian vegetation along the Middle Rio Grande of central New Mexico, U.S.A. **Journal of Arid environments**, v.38, p.283-296, 1998.

GODINHO, T.O.; CALDEIRA, M.V.W.; CALIMAN, J.P.; PREZOTTI, L.C.; WATZLAWICK, L.F.; AZEVEDO, H.C.A.; ROCHA, J.H.T. Biomassa, macronutrients e carbono orgânico na serapilheira depositada em trecho de floresta Estacional Semidecidual Submontana, ES. **Scientia Forestalis**, v. 41, p. 131-144, 2013

GONÇALVES, J.L.M. Efeitos do cultivo mínimo sobre a fertilidade do solo e ciclagem de nutrientes. In: Seminário sobre cultivo mínimo do solo em florestas, 1, 1995, Curitiba. **Anais CNPFloresta/IPEF/UNESP/SIF/FUPEF**. Curitiba: 1995. p.43-60.

HANLEY, M.E. Seedling herbivory, community composition and plant life history traits. **Perspectives in Plant Ecology, Evolution and Systematics**, v.1/2, p.191-205, 1998.

HOSSAIN, M.M. Germination and initial growth of tree seedlings on deforested and natural forest soil at Dulhazara, Bangladesh. **Rev. Biol. Trop.**, v.60, n.4, p.1479- 1489, 2012.

HOU, P.C.; ZOU, X.; HUANG, C.Y.; CHIENG, H.J. Plant litter decomposition influenced by soil animals and disturbance in a subtropical rainforest of Tawain. **Pedobiologia**, v.49, p.539-547, 2005.

KNACKER, T.; FORSTER, B.; ROMBKE, J.; FRAMPTON, G.K. Assessing the effects of plant protection products on organic matter breakdown in arable fields- litter decompositions test systems. **Soil Biology & Biochemistry**, v.35, p.1269-1287, 2003.

LEE, J.; MORRISON, I.K.; LEBLANC, J.D.; DUMAS, M.T.; CAMERON, D.A. Carbon sequestration in trees and regrowth vegetation as affected by clearcut and partial cut harvesting in a second-growth boreal mixed wood. **Forest Ecology and Management**, v.169, p.83-101, 2002.

LEHTONEN, A.; SIEUÄNEN, R.; MÄKELÄ, A.; MAKIPÄÄ, R.; KORHONEN, K.T.; HOKKANEN, T. Potencial litterfall of Sctos pine branches in southern Finland. **Ecological Modelling**, v.180, p.305-315, 2004.

MEDRI, P.S.; FERRACIN, T.P.; SILVA, V.T. da; TOREZAN, J.M.D.; PIMENTA, J.A.; BIANCHINI, E. Comparação de parâmetros bióticos e abióticos entre fragmento de floresta secundária e reflorestamento de *Araucaria angustifólia* (Bertol.) O. Kuntze. *Semina:* **Ciências Biológicas e da Saúde,** v.30, n.2, p.185-194, 2009.

MENDONÇA, F.A.; DANNI-OLIVEIRA, I.M. Dinâmica atmosférica e tipos climáticos predominantes da bacia do Rio Tibagi. In: MEDRI, M.E.; BIANCHINI, E.; SHIBATTA, O. A.; PIMENTA, J. A. (eds.). **A bacia do rio Tibagi**.Londrina, PR, 2002. p. 63-66.

NÉRI, A.V.; CAMPOS, E.P.T.; DUARTE, G.; MEIRA NETO, J.A.A.; SILVA, A.F.; VALENTEL, G.E.V. Regeneração de espécies nativas lenhosas sob plantio de *Eucalyptus* em área de Cerrado na Floresta Nacional de Paraopeba, MG, Brasil. **Acta Botânica**, v.19, n.2, p.369-376, 2005.

PALMA, R.M.; PRAUSE, J.; FONTANIVE, A.V.; JIMENEZ, M.P. Litter fall and litter decomposition in a Forest of the Parque Chaqueño Argentino. **Forest Ecology and Management**, v.106, p.205-210, 1998.

PARROTTA, J.A.; TURNBULL, J.W.; JONES. N. Catalyzing native forest regeneration on degraded tropical lands. **Forestry Ecology and Management**, v99, p.1-7, 1997.

PERIN, M.A.A.; GUIMARÃES, J.F. Efeitos dos ninhos de *Atta laevigata* (Fr. Smith, 1858) (Hymenoptera: Formicidae) sobre a vegetação do cerrado. **Revista Árvore**, v.36, n.3, p. 463-470, 2012

PINTO, H.C.A.; BARRETO, P.A.B.; GAMA-RODRIGUES, E.F.; OLIVEIRA, F.G.R.B.; PAULA, A.; AMARAL, A.R. Decomposição da serapilheira foliar de floresta nativa e plantios de *Pterogyne nitens* e *Eucalyptus urophylla* no Sudoeste da Bahia. **Ciência Florestal**, v. 26, p. 1141-1153, 2016

SARTORI, M.S.; POGGIANI, F.; ENGEL, V.L. Regeneração da vegetação arbórea nativa no sub-bosque de um povoamento de *Eucalyptus saligna* Smith. Localizado no Estado de São Paulo. **Scientia Forestalis**, v.62, p.86-103, 2002.

SCHILLING, E.M.; WARING, B.G.; SCHILLING, J.S.; POWERS, J.S. Forest composition modifies litter dynamics and decomposition in regenerating tropical dry forest. **Oecologia** v.182, p.287–297, 2016.

SIMONETTI, J.A.; GREZ, A.A.; CELIS-DIEZ, J.L.; BUSTAMANTE, R.O. Herbivory and seedling performance in a fragmented temperate forest of Chile. **Acta Oecologica**. v.32, p.312-318, 2007.

SOARES, M.P.; NUNES, Y.R.F. Regenração natural de cerrado sob plantio de *Eucalyptus camaldulensis* Dehn. No norte de minas Gerais, Brasil. **Ver. Ceres**, v.60, n.2, p-205-214, 2013

SOARES, S. M.; MARINHO, C. G. S.; DELLA LUCIA, T. M. C. Diversidade de invertebrados edáficos em áreas de eucalipto e mata secundária. **Acta Biol. Leopol.**, v.19, p.157-164, 1998.

SOUTO, X.C.; BOLAÑO, J.C.; GONZÁLVES, L; REIGOSA, M.J. Allelopathic effects of tree specie on some soil microbial populations and herbaceous plants. **Biologia Plantarum**, v.44, p.269-275, 2001.

SOUZA, P.B.; MARTINS, S.V.; COSTALONGA, S.R.; COSTA, G.O. Florística e estrutura da vegetação arbustivo-arbórea do sub-bosque de um povoamento de *Eucalyptusgrandis* W. Hill ex Maiden em Viçosa, MG, Brasil. **Revista Árvore**,v.31, n.3, p.533-543, 2007.

SUNDARAPANDIAN S.M.; SWAMY P.S. Litter production and leaf-litter decomposition of selected tree species in tropical forests at Kodayar in the Western Ghats, India. **Forest Ecology and Management**, v.123, p.231-244, 1999.

TABARELLI, M; MANTOVANNI, W. A regeneração de uma floresta tropical Montana após corte e queima (São Paulo- Brasil). **Revista Brasileira de Biologia**. v.22, p.239-250, 1999.

TANG, J.W.; CAO, M.; ZHANG, J.H.; LI, M.H. Litterfall production, decomposition and nutrient use efficiency varies with tropical forest types in Xishuangbanna, SW China: a 10-year study. **Plant and Soil,** v.335, p. 271–288, 2010

TATENO, R.; TAKUO, H.; TAKEDA, H. Above and below ground biomass and net primary production in a cool temperature deciduous Forest in relation to topographical changes in soil nitrogen. **Forest Ecology and Management**, v.193, p.297-306, 2004.

THIRUKKUMARAN, C.M.; PARKINSON, D. Microbial activity, nutrient dynamics and litter decomposition in a Canadian Rocky Mountain pine forest as affected by N and P fertilizers. **Forest Ecology and Management**, v.159, p.187-201, 2002.

URIBES,S.; HUERTA, E.; GEISSEN, A.; MENDOZA, M.; GODOY, R.; JARQUÍN, A. *Pontoscolex corethrurus* (Annelida: Oligochaeta) indicador de La calidad del suelo em sítios de *Eucalyptus grandis* (Myrtaceae) con manejo de tumba y quema. **Re. Biol. Trop.**, v.60, n.4, p.1415-1430, 2012.

VACCARO, S.; LONGHI, S.J.; BRENA, D.A. Aspectos da composição florística e categorias sucessionais do estrato arbóreo de três *subseres* de uma Floresta Estacional Deciadual, no município de Santa Tereza, RS. **Ciência Florestal**, v.9, n.1, p.1-18, 1999.

VASCONCELOS, H.L.; VILHENA, J.M.S.; CALIRI, G.J.A. Responses of ants to selective logging of a central Amazonian forest. **Journal of Applied Ecology**, v.37, p.508-514, 2000.

VIANI, R.A.G.; DURIGAN, G.; MELO, A.C.G. A regeneração natural sob plantações florestais: desertos verdes ou redutos de biodiversidade? **Ciência Florestal**, v.20, n. 3, p. 533-552, 2010

WELLBAUM, C.; CRUSIUS, I.H.S.; SANTOS,V.B. Fungos filamentos em folhas do ambiente terrestre e aquático da ilha dos *Eucalytus*, represa do Guarapiranga, São Paulo-SP**. Revista Brasileira de Botânica**, v.22, p.69-74, 1999.

ZHANG, H.; YUAN, W.; DONG, W.; LIU, S. Seasonal patterns of litterfall in forest ecosystem worldwide. **Ecological Complexity**, v. 20, p. 240–247, 2014.

APPENDIX

Table 1: List of woody species sampled at Atlantic Forest and *Eucalyptus saligna* Smith. commercial reforestation abandoned to natural regeneration, Telêmaco Borba, Paraná, Brazil.
Tabela 1: Lista de espécies lenhosas amostradas em um fragmento de Floresta Atlântica e em um reflorestamento comercial de *Eucalyptus saligna* Smith. abandonado à regeneração natural, Telêmaco Borba, Paraná, Brasil.

Family	**Specie**	**Abundance**			
		Secondary Forest		***Eucalyptus* Forest**	
ANNONACEAE	*Rollinia sylvatica* (A. St-Hil.) Mart.	X		X	
APOCYNACEAE	*Tabernaemontana catharinensis* A. DC.	X			
ARECACEAE	*Syagrus romanzoffiana* (Cham.) Glassman			X	
AQUIFOLIACEAE	*Ilex sp.* (Sp1)	X		X	
	Ilex sp. (Sp2)	X			
EUPHORBIACEAE	*Alchornea triplinervea* (Spreng.) M. Arg				X
FABACEAE	*Dalbergia brasiliensis* Vogel.		X		X
	Sp 1	X			
	Sp 2	X			
	Sp 3	X			
ICACINACEAE	*Citronella paniculata* (Mart.) R.A. Howard		X		X
	Sp 1			X	
LAURACEAE	*Nectandra megapotamica* (Sreng.) Mez.	X			
	Octea elegans Mez.	X			
	Sp 1	X		X	
	Sp 2	X			
MELASTOMATACEAE	Sp 1	X		X	
	Sp 2	X			
	Sp 3			X	
MIMOSACEAE	Sp 1	X			
MYRSINACEAE	Sp1		X		
MYRTACEAE	*Campomanesia xanthocarpa* (O.Berg) Nied.		X		X
	Eugenia flavensces DC.		X		
	Eugenia pyriformis Camb.	X			
	Sp 1	X			
MYRTACEAE	Sp 2	X			
	Sp 3	X			
	Sp 4	X			
	Sp 5	X			
	Sp 6	X			
PIPERACEAE	*Piper sp.*			X	
PROTEACEAE	*Roupala brasiliensis* Klotzsch.			X	
ROSACEAE	*Prunus myrtifolia* (L.) Urb.	X			
RUBIACEAE	*Palicourea sp.*		X		X
	Psychotria vellosiana Berg.	X		X	
	Sp 1	X		X	
	Sp 2			X	
RUTACEAE	*Zanthoxylum sp.*	X			
SALICACEAE	*Casearia sylvestris* Sw.		X		X
SAPINDACEAE	*Cupania vernalis* Cambes.	X		X	
	Sp 1	X		X	
	Sp 2	X			
SOLANACEAE	*Solanum sp.*	X		X	
	Solanum argentum Blanch. ex. Dun.			X	
VIOLACEAE	*Hybanthus bigibbosus* (A. St. Hil.) Hass	X		X	
	Sp 1		X		