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**BRAZILIAN JOURNAL OF ECOLOGY  
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**INDEX**

**1 Evaluation of aboveground growth and biomass in *Glycine max* plants exposed to various concentrations of copper.**

Karina Gonçalves, Marli Sá Torres, Patrícia Marinho, Juliana de Mello Botelho, Armando Reis Tavares, Shoey Kanashiro, Ana Paula N. Lamano Ferreira, Luis Alberto Valotta, Cleber da Silva, Rafael Souza Queiroz, Hilton Lourenço Ozório Filho, Maurício Lamano Ferreira. .... pag. 7

**2 Environmental characterization of the Lajeado Tunas watershed, RS, Brazil.**

Lisiane Zanella, Eloir Missio, Rosângela Alves Tristão Borém, Maurício Castro dos Santos, Marcos Antônio Ritterbuch. .... pag. 15

**3 Structure of avian guilds in a fragment-corridor in Lavras, Minas Gerais, Brazil.**

Bruno Senna Corrêa, Júlio Neil Cassa Louzada, Aloysio Souza de Moura. .... pag. 25

**4 Emergence and growth of *Ateleia glazioveana* Baill. seedlings in direct sowing in an early secondary succession stage.**

Ana Claudia Escao, Geodeli Adelita Penz Corrêa, Jonas Darci Noronha de Lima, Geraldo Ceni Coelho. .... pag. 34

**5 Plant richness in exotic tree plantations in Rio Grande municipality, Rio Grande do Sul State, Brazil. Plant richness in exotic tree plantations in Rio Grande municipality, Rio Grande do Sul State, Brazil.**

Quenie Januário, Caroline Igansi Duarte, Geraldo Ceni Coelho, Ubiratã Soares Jacobi ..... pag. 41

**6 The Influence of feeding tree spatial distribution and fruit abundance in the location of sleeping trees in the common marmoset, *Callitrix jacchus* (Primates: Callitrichidae).**

Gustavo André Fernandes Silveira, Carla Soraia Soares de Castro. .... pag. 49

**7 Environmental impacts caused by roads and trails in the Altomontana Private Reserve, Itamonte, Minas Gerais.**

Ana Cristina Magalhães de França, Felipe Santana Machado, Rosângela Alves Tristão Borém, Luís Antônio Coimbra Borges. .... pag. 57

**8 Floristic and spatial distribution of Orchidaceae species in the Serra do Mucambo, Conceição do Coité, Bahia, Brazil.**

Denis Nunes de Carvalho, Cássio van den Berg, Camila Magalhães Pigozzo ..... pag. 66

**9 Fluctuating Asymmetry in three *Basileuterus* (Passeriformes, Parulidae) species in a semideciduous forest fragment in the Brazilian Cerrado.**

Vanessa Fonseca Gonçalves, Celine de Melo. .... pag. 74

**10 Vascular plant diversity and substratum parameters as indicators of ecologically based degraded area recuperation.**

Maria Luiza Porto, Marisa Azzolini, Cíntia Silva Beauvalet, Telmo Focht. .... pag. 79

**11 Flowering phenology of a bromeliaceae community of an environmental protection area (EPA) in the restinga of Maricá (RJ, Brazil) as compared to other habitats of the southeastern Brazilian atlantic Rain forest.**

Camila V. Suizani, Heloísa A. de Lima, Ana Tereza A. Rodarte, Cristine Benevides. .... pag. 88

**12 Floral Biology and Pollination Ecology of *Chrysobalanus icaco* L. (Chrysobalanaceae) in an Environmental Protection Area (EPA) within the Restinga of Barra do Rio Mamanguape, Paraíba, Brazil.**

Túlio Freitas Filgueira de Sá, Evelise Locatelli. .... pag. 96

**13 Analysis of the landscape structure of the Coqueiral Environmental Protected Area, Coqueiral, MG.**

Carolina Gusmão Souza, Rosângela Alves Tristão Borém, Lisiane Zanella, Luis Marcelo Tavares de Carvalho, Rafaela Vidal Ambrosio. .... pag. 105

**14 Macroalgae species richness in beaches with consolidated arenite substrata and reef-pools with sandy bottoms in Piauí.**

Júlio Cesar Voltolini, Maria Gardênia Souza Batista, Edisa Ferreira Inocêncio Nascimento, Kerolen Carlota, Gomes Campos, Jéssica Sonaly da Silva Resende, Rebeca Araújo Machado, Liliana Oliveira Souza, Débora Dias de Oliveira, Kesley Paiva da Silva, Euro S. Lopes Filho. .... pag. 115

## EVALUATION OF ABOVEGROUND GROWTH AND BIOMASS IN *GLYCINE MAX* PLANTS EXPOSED TO VARIOUS CONCENTRATIONS OF COPPER

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### ABSTRACT

Soybean (*Glycine max*) represents a plant-species of considerable economical importance for Brazil, considered one of the main producers worldwide. The aim here was to analyze the influence of copper on the development of the plant's aboveground growth and biomass. With this in mind, an experiment was developed under natural conditions of humidity and temperature using 112 plants cultivated in vases with sand. The randomized block design was adopted, with each containing four blocks, seven treatments and four repetitions, all irrigated for 30 days with a solution of Hoagland & Arnon, enriched with various concentrations of  $\text{CuCl}_2$ . Subsequent variance analysis and Tukey testing showed that plants undergoing treatment with  $0.9 \text{ g CuCl}_2 \text{ L}^{-1}$  (T6) were

those that presented the least growth in relation to both control plants and those under lower-grade treatments. The values of stem-dry-mass were equivalent to the tendencies encountered in biometrics, whereby the conclusion that copper at high concentrations can exert an influence on growth in *Glycine max* plants.

Keywords: Soybean, plant biometrics, aerial organs, copper

## INTRODUCTION

In general, micronutrients, even though required in reduced amounts, are essential for completion of the plant vegetative cycle. Their deficiency, besides inducing reduced productivity and alterations in the defense system, may even interfere in phenology (7). Among such nutrients, copper is outstanding by being an important co-factor in anti-oxidizing enzymes, as, for example, the activator of some of the enzymes involved in oxidation and reduction, besides participating in the opening and closing of stomata and lignification in some cells (3). Through its involvement in several physiological and structural aspects in plant development, copper, in certain concentrations, can serve as manure, the lack thereof possibly giving rise to damage to the plant in various forms. Some of the main symptoms of copper deficiency can be observed in young leaves, which, besides very often presenting necrotic patches, become dark green in color, rolled up and deformed. Worthy of note, copper deficient plants can manifest lower protein synthesis and diminished photosynthetic activity, through this nutrient being an activator of those enzymes which participate in terminal electronic transport in respiration and photosynthesis. These symptoms of deficiency occur in newer tissues, due to their lower mobility in the plant (18). A good example is a study by Zampieri (2010), comprising an analysis of the effects of copper and zinc on *Aechmea blanchetiana* (Baker) L.B. Smith, whereby it was demonstrated that seedlings cultivated under high concentrations of  $\text{Cu}^{++}$  were those that presented the highest structural variation in morphometric and anatomic parameters. In studies by Silva *et al.* (2010) on the tolerance of certain *Cassia* species (*Peltophorum dubium*) seedlings in soils with an excess of copper, it was observed that, inversely to the increase in dose, there was a decrease in plant

biometric parameters, such as height and diameter.

Only required in small amounts in cultures, copper is one of the ultimate nutrients whereby symptoms of deficiency develop, when supply does not attend to plant requirements. Generally occurring at very low rates in the soil, its dynamics is very much affected by soil characteristics. Thus, besides pH and humidity, and apart from the plant itself, the degree of organic material and mineral and biological fractions in the soil, are factors that condition its availability and utilization by the plant, insofar as they interfere in the reactions, thereby giving rise to the formation of products of greater or lesser solubility (3). The normal concentration of this metal in the soil is  $20\text{mg kg}^{-1}$ , with variations to the rate of 6 to  $80\text{mg kg}^{-1}$  (20,11).

Another decisive factor in the activity of copper is the inner of a soil for the capacity cationic change (CTC). CTC is intimately linked to both the concentrations of changeable ions present in the solution of the soil, and the sites of changes on the colloidal intersurfaces of the system. High CTC facilitates greater retention of the metal. Organic material, even though representing only around 5% of soil components, is responsible for about 30% to 65% of the CTC in mineral soils, and for more than 50% in sandy and organic ones (10, 20).

Besides its natural distribution in the soil, copper can be further obtained in several other ways, such as by means of defensive chemicals, agricultural fertilizers, and more recently, through the widespread use of domestic and industrial residues. Emphasis must be given to the use of sewage sludge obtained in treatment stations, a mode which nowadays has been extensively adopted in several monocultures. Nevertheless, caution should be taken, for when in large concentrations, copper can induce toxic effects to plant tissue and cause a deficiency in other essential nutrients through

adverse interactions (8).

Urban residues, for example, through normally presenting high rates of heavy metals, when compared to those present in the soil, are liable to inducing toxicity or altering availability in certain agroecosystems (13). Furthermore, through possible absorption by plants, there is the possibility of their entering the food chains (14).

When in excess, the accumulation of copper in different parts of the plant can always be associated to cellular alteration in various forms, thereby interfering in physiological processes, to the point that, the toxicity so caused can eventually lead to oxidative stress, chlorophyll derangement and effects on Fe translocation, among others (9).

According to Sfredo (2008), over the latter years, leaf analysis has been applied to evaluating the availability of limitative nutrients for plants, thereby furnishing a new tool for improving recommendations as regards manure application, as a further means for increasing productivity.

The agricultural use of organic residues is only plausible, when there are no high inner concentrations of Cd, Pb, Cu, Cr, Ni and Zn, since these metals are prone to absorption by plant roots, with the subsequent transference to various organs (3), and consequently, into foodstuff for human consumption.

For the satisfactory development of a culture of the soybean *Glycine max* (L.), a grain of extreme importance in the Brazilian economy, it is essential that macro- and micronutrients be present in the appropriate concentrations.

## OBJECTIVES

The aim of this study was to analyze the aboveground growth and biomass of *Glycine max* (L.), under different copper treatments and natural conditions of temperature and humidity.

## METHODOLOGY

### *Study area*

The experiment took place in an open area for experiments of the University 'Nove de Julho', located in metropolitan São Paulo. São Paulo, in southeast Brazil, is located at around 770 meters

above sea level, within the coordinates 23°30'S and 46°40'W. Characteristically, winters (from June to August) are dry, and summers (from December to March) humid.

### *Plant exposure*

During the experiment, the plants were individually irrigated weekly with 50 ml of a Hoagland & Arnon solution contaminated with 0.0 (T0); 0.000009 (T1); 0.00009 (T2); 0.0009 (T3); 0.009 (T4) 0.09 (T5) and 0.9 (T6) g, with  $\text{CuCl}_2 \text{ L}^{-1}$  as element source. Approximately two weeks after germination, and before exposure to the contaminant, the plants were initially measured, both for height, starting from an average height of 10 cm from soil level in the vase up to the apical bud, as well as for stem diameter. The lot was homogeneous, especially as regards the required coloring of cotyledonal leaves. The experiments took place from November 6<sup>th</sup> to December 3<sup>rd</sup>, 2009. The plants were measured once again at the end of the experiment, whereat the diameter of the stem was measured with a common pachymeter, and height and leaf measurements with a meter tape.

Subsequent to exposure and the collection of stem and leaf biometric data, the leaf area index (LAI) were calculated for leaves 1-7 through multiplication of the width by the length, i.e.,

$$\text{LAI} = \text{WIDTH} \times \text{LENGTH}$$

After the experimental period, the plants were collected from the vases and split up by organ, which were then separately weighed on a digital balance, to so obtain the weights of fresh-matter-mass of the aerial parts and stems. These were then placed in identified paper bags, and subsequently dried at 80°C for 48 hours (12), thereby obtaining dry-matter-mass values.

### *Statistical analysis*

The process adopted was the statistical analysis of randomized blocks containing one *Glycine max* plant per vase with sand, cultivated from the seedling to the fruit stages. The procedure consisted of seven treatments and four repetitions, with four plants per treatment, thus 112 plants all told. The Tukey test was applied to the averages of the results obtained for all the variables in the  $\text{CuCl}_2$  concentration, using  $P \leq 0.05$  in the SISVAR program.

## RESULTS

Rainfall was high throughout the experiment, even more so than that registered in the preceding years. According to data furnished by the Astronomy, Geophysics and Atmospheric Sciences Institute (IAG), from University of São Paulo (USP), the average during the months of study was around 25% higher than that registered for the years 1993 to 2002 (Table 1).

Although there were no statistic differences between treatments, there was an enhanced tendency for growth in stem diameter at the end of the

observed in T3, and the highest in T1, whereas for the intermediate ones (3, 4 and 5), the tendency for development remained the same until T4. Once again, T6 proved to be that which presented the lowest development (Table 2).

Amongst the newest leaves in this experiment, it was observed that, throughout the treatment, and in the case of leaf 6, the doses were insufficient to induce statistical differences, whereas for leaf 7, the tendency was similar to that noted for the remainder. In other words, T6 was the treatment in which the plants presented the lowest

Tabela 1. Average values of temperature (°C) and relative humidity (%) of the air, rainfall (mm), number of days with rain, irradiation (MJ/m<sup>2</sup>.dia), and wind velocity (m/s) in the city of São Paulo during the period of culture

Month	October	November	December
Temperature (°C)	19 (24-15)	23 (29-19)	22 (27-18)
Relative humidity (%)	86 (95-67)	80 (95-56)	84 (95-62)
Rainfall (mm)	138.0	234.4	208.5
Number of days with rain (days)	19	21	22
Irradiation (W/m <sup>2</sup> )	13.3	17.6	16.4
Wind velocity (m/s)	5.9	6.5	5.8

experiment. The greatest stem heights encountered at the end of the experiment were those corresponding to treatments T0 and T1, whereas those related to high T6 doses were the lowest (Table 2).

growth, and T3 and T4 the highest (Table 2).

Equivalence was observed, as regards values for leaf dry-biomass. Moreover, the same tendency encountered for leaves was also observed

Tabela 2. Results for mean values and standard deviation of biometric variables in stem height (SH), stem diameter (SD) and leaf area index (LAI), obtained at the end of plant exposure to the different concentrations of copper.

	T0	T1	T2	T3	T4	T5	T6
SH	26.6 ±5.6a	27.1 ±3.8a	23.8 ±2.8a	23.4 ±2.3a	24.5 ±2.7a	23.9 ±1.8a	22.4 ±2.8a
SD	0.4 0.03ab	0.4 ±0.04b	0.4 ±0.04a	0.4 0.02ab	0.4 0.02ab	0.4 0.02ab	0.4 ±0.07a
LAI1	14.1±0.7ab	15.6±1.1b	13.8±2.1ab	13.5±0.2a	15.4±2.2b	15.2±1.5ab	13.3±0.2a
LAI2	14.9±2.6ab	15.2±1.5b	12.9±2.7ab	20.2±13.1a	13.5±0.9ab	13.9±1.1b	12.2±1.4a
LAI3	14.3±1.9b	13.1±2.7ab	12.8±1.9ab	12.4±2.0ab	13.2±1.6ab	12.8±2.4ab	10.9±0.8a
LAI4	14.0±1.4b	13.4±0.7ab	12.9±1.6ab	12.6±1.4ab	12.2±1.6ab	13.2±2.3ab	11.2±1.3a
LAI5	16.6±2.1b	16.3 2.2ab	15.1±1.5ab	16.8±3.1b	17.6±2.8b	16.3±1.4b	14.7±3.2a
LAI6	19.2±1.4a	20.3±4.4a	18.6±1.6a	19.7±2.6a	18.5±1.8a	17.6±2.6a	16.5±3.4a
LAI7	20.2±4.6ab	21.8±0.6ab	18.8±2.7ab	22.0±1.4b	19.5±1.04b	19.4±2.03b	12.6±1.8a

As regards leaf biometrics, over time there was greater differentiation between treatments. Thus, in the case of leaves 1 and 2 (the oldest leaves on the main branch), the lowest LAI values were

for stem-dry-mass, in that treatments with higher concentrations of Cu (T5 and T6) were those in which plants accumulated less dry mass.

Table 3. Mean values in grams and standard deviation of leaf and stem dry mass at the end of the experiment.

Treatment	Dry Mass (leaf)	Dry Mass (stem)
T0	0.96 ±0.08	1.37 ±0.31
T1	1.10 ±0.59	1.30 ±0.26
T2	1.06 ±0.09	1.07 ±0.18
T3	1.00 ±0.20	1.07 ±0.22
T4	1.23 ±0.17	1.17 ±0.30
T5	1.02 ±0.13	1.02 ±0.19
T6	1.11 ±0.24	1.06 ±0.19

## DISCUSSION

Heavy rainfall occurred in São Paulo during the period of plant exposure. As was observed by Bertoni *et al.* (1999), since the element  $\text{Cu}^{++}$  is extremely prone to edaphic conditions, mainly humidity, this may have influenced the results, as regards percolation, the availability of the element and its interaction with the plant. Variations in chemical attributes in the soil may have induced changes in the micronutrient content, consequently leading to its deficiency or toxicity (3). Hence, results which did not present significant differences, such as the diameter of the stem, the LAI values for newer leaves, and biomass variables, could be explained by this momentarily excessive rainfall, with the consequential washing out of the soil. This was observed by Viera *et al.* (2005), who, on studying the availability of nutrients in the soil, the quality of soybean grains and their productivity in soil manured with sewage sludge, and when evaluating the rates of N in the soil in the first cultivation of the plant, demonstrated that, in the treatment I + L3, the amount of biosolids applied may have induced the loss of N by lixiviation. Thus, seeing that the plants were not exposed under controlled conditions of climatic variables, high percolation of the element in the soil may have interfered in the rates of Cu root absorption.

On analyzing stem heights, it was noted that in the first, lower-concentration treatments, the low doses of  $\text{Cu}^{++}$  probably functioned as manure, hence with a greater tendency to induce growth. Santos *et al.* (2009), when analyzing the effects of  $\text{Cu}^{++}$  and  $\text{Zn}^{++}$  on sorghum cultivated in three

classes of soils, obtained different results from those observed with soybean, since stem-heights did not present significant differences between treatments, whereas diameters did, both as regards treatments and the soils in which they were cultivated, thus contrary to our results, whence stem heights were significantly greater in treatments 0 and 1.

With the exception of new leaves, leaf measurements followed the same pattern. It was noted that growth was less in the more concentrated treatments, a possible indication of toxicity, with the consequential prejudice to the development of organs. Copper is a prerequisite for the satisfactory development of the plant, seeing that there is a reduction in leaf area in those with a deficiency or excess of this nutrient (13). According to Anjos and Mattiazzo (2000), in studies with corn in soils enriched with a biosolid (sewage sludge), it was noted that the highest rates of this metal were concentrated in the leaves, even though in this method of fertilization, independent of either the treatment or the soil, this element presented no toxic effects for the plants.

According to Rangel *et al.* (2006), when studying the rates of heavy metals in the leaves and grains of corn on applying sewage sludge, it was noted that of the heavy metals assayed, copper was that which presented rates in the leaf within the range considered to be phytotoxic, although, until the third culture, notably not above the upper range of toxicity. Significant effects of the application of doses of sewage sludge were only observed in leaf-copper-rates in the first LB-culture and the third LF, an indication of the absence of response in leaf-rates with the application of increased doses of the sludge. Another factor which came under consideration, not only by Rangel (2006), but also by several other authors (6, 16), is that  $\text{Cu}^{+}$  tends to accumulate more in roots than in leaves, thereby indicating that the lower response to the addition of sewer sludge, in terms of leaf-copper-rates, could also be related to the low translocation of this nutrient in the plant.

Dry biomass variables presented no statistic differences between treatments. In a study by Araujo *et al.* (2005) of the effects of a textile sludge compound on seedlings of soybean and wheat, it was observed that the increase in concentrations of the compound above  $19 \text{ g L}^{-1}$

caused a significant decrease in total dry-matter-mass, height of the aerial part and root length in those of both plant-species. In the case of soybean, there was a reduction, in relation to the control, of 29% to 34% in total dry-matter-mass, 15% to 36% in the height of the aerial part, and 28% to 67% in root length with the application of 38, 76 and 152 g L<sup>-1</sup>, respectively. The author emphasized that, although the amount of heavy metals present in textile sludge was in accordance with the values stipulated by CETESB, the decrease in total dry matter could be an indication of the effect of toxicity in the plants induced by heavy metals, especially copper and zinc. Moreover, Araujo *et al.* (2005) also noted that in soybean and wheat seedlings, there was a significant decrease in chlorophyll content, simultaneous with a corresponding decrease in liquid photosynthesis, from the 76 g L<sup>-1</sup> concentration one.

In a study of the growth and mineral nutrition of *Eucalyptus maculata* and *Eucalyptus urophylla* in concentrations of Cu<sup>++</sup> (19), it was noted that symptoms of phytotoxicity already appeared in the first five days of the experiment, even at the lowest concentrations, such as 32 and 64 µM of Cu<sup>++</sup> supplied as CuSO<sub>4</sub>. As to the aerial part and leaf area, there was a decrease in dry matter at concentrations above 32 µM of Cu<sup>++</sup>. In studies with sorghum (15), it was noted that doses of 1.07, 1.24 and 1.26 mg/Kg of copper applied induced an increase in dry matter.

In certain studies of toxicity with chlorine, no direct relationship linking the element with effects on growth was observed. In neither of two studies, one involving chemical sterilization with chlorine dioxide in an *in vitro* culture of Anthurium (4), and the other (21), the *in vitro* culture of *Eucalyptus pellita* in a medium sterilized by NaOCl, were toxic effects arising from these solutions observed in plant development. On the other hand, there was a considerable increase, distribution and accumulation of copper and zinc in conifers (*Jatropha curcas*), where copper and zinc chlorates were used as sources of contamination (5). The authors only noted toxicological effects on increasing the doses of both elements, which seems to imply that chlorine itself did not interfere in these effects in the cultivars analyzed, thereby facilitating transposition to the present work with specimens

of *G. max*, and thus making it possible to attribute tendencies for growth in plants cultivated in more concentrated solutions, only to copper.

## CONCLUSION

With these results, it was noted that *Glycine max* plants can present a tendency for aboveground growth inversely proportional to Cu rates, thereby inferring their sensitivity to high doses of this element.

The plants presented no evident toxicological effects under the parameters analyzed in this study, which can be justified by the possible percolation of the element, as a result of the high rainfall which occurred during the experimental period. It is therefore proposed that new experiments be undertaken with *G. max* and copper under controlled conditions, in order to determine the relationship of toxicity between the element and the development of this plant species.

## RESUMO

A soja (*Glycine max*) apresenta-se como sendo uma espécie de grande importância econômica para o Brasil, que é considerado um dos grandes produtores desta cultura. O trabalho objetivou analisar a influência do cobre sobre o desenvolvimento de órgãos aéreos da espécie. Para tanto foi desenvolvido experimento em condições naturais de umidade e temperatura utilizando 112 plantas cultivadas em vasos com areia. Foi adotado um delineamento de blocos casualizados contendo, quatro blocos, sete tratamentos e quatro repetições, que foram irrigadas com solução de Hoagland & Arnon enriquecida com diferentes concentrações de CuCl<sub>2</sub> por 30 dias. Após este período foram realizadas análises de variância e teste Tukey, onde se observou que as plantas submetidas ao tratamento 0,9 g CuCl<sub>2</sub> L<sup>-1</sup> (T6) foram as que apresentaram menor crescimento em relação as plantas controles ou aos menores tratamentos. Os valores de massa seca do caule apresentaram equivalência às tendências encontradas na biometria. Conclui-se assim que o cobre em altas concentrações pode influenciar no crescimento de plantas de *Glycine max*.

**Palavras chave:** soja, biometria vegetal, órgãos aéreos, cobre.

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## ENVIRONMENTAL CHARACTERIZATION OF THE LAJEADO TUNAS WATERSHED, RS, BRAZIL

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### ABSTRACT

Geographic Information System (GIS), Remote Sensing Imagery and Global Positioning System (GPS) coordinates were employed to characterize landscape structure and land use features of the Lajeado Tunas watershed, Frederico Westphalen, Rio Grande do Sul State, Brazil. Based on data so obtained, two land-cover maps were compiled. These were after compared in order to evaluate the methodology employed. The watershed, spread over approximately 650 ha, is apparently on a mild, east-to-west slope (6.95%). Due to this relative flatness, local conditions are favorable for farming. Notwithstanding, preservation is a prerequisite for controlling erosion and protecting water resources. The land uses mapping has shown how the predominant occupation for anthropogenic usage has exerted negative effects on the quality of the environment and the conservation of biodiversity. Even though only a simple set of GIS tools were used for analyzing the focal landscape, these have helped to arrive at an adequate understanding of the structurally important characteristics of the landscape in a regional context. The results obtained have proved to be of interest for understanding which conservation action is more appropriate for improving the maintenance of local and regional biodiversity, to so guarantee the long-term maintenance of agricultural ecosystems, and, in future analyses, for generating knowledge on how local fauna and flora respond to regional landscape characteristics, the key-points for guaranteeing the maintenance of biodiversity.

**Key-words:** Environmental Planning, Landscape Structure, Sustainable Management, Geographic Information Systems (GIS)

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### INTRODUCTION

Increased anthropic action has given rise to important alterations in the environment, with consequential impacts. Among the main aspects of

these modifications we can cite the loss of habitat, and the fragmentation and decrease in quality in the remaining areas (4). Environmental planning has acquired pre-eminence over the latter decades, due to the interest in redirecting for consideration, not

only the environments so created and modified by human-kind, but also the remaining, surrounding natural environments.

The growing need to present solutions and strategies, with a mind to interrupting and reverting the effects of environmental degradation and the impoverishment of natural resources, has led to intense questioning, mainly as to (a) how to face the agglomeration of environmental problems detected in large urban centers, (b) how to elaborate and develop efficient strategies for their solution, and (c) how to guarantee the application of such strategies.

In order to respond to such questions, the environmental issue should be analyzed within a perspective that surpasses urban limits. We must take into consideration that cities and human-kind do not exist apart from the natural elements (water, air, soil, among others), but all together compile a natural global system – the planet Earth - on which we have been acting and intervening without concern for the eventual accumulative effects, thus compromise not only the present, but especially, the very future of their own existence. We need to recognize that human-kind subsist as part of this controversy. Thus, on contemplating the principles of landscape ecology, anthropic action should come under consideration throughout all the phases of planning, inasmuch as, if well conducted, better equilibrated alternatives may be arrived at, as means of inducing the sustainable usage of the environment.

Even though each study may present distinct forms of partitioning the space to be analyzed or planned (14), several authors give preference to water basins, in special watersheds, since these constitute minimum units in the environment planning approach, due to the agglomeration of important pertinent components aggregated to their structuring, such as characteristic fauna and flora, besides the drainage itself (3.12).

The management of watersheds involves a process that permits formulating an integrated assemblage of actions on the environment (social, economic, institutional and legal structures of a watershed), in order to promote the conservation and sustainable utilization of prevalent natural resources, whereby the prerequisite of acquiring knowledge on the structure, composition and dynamics of the catchment itself and surroundings.

The Geographic Information System (GIS), within the context of the integrated planning of and systemic approach to watersheds, has been the way of applying the methodology and philosophy of analysis and synthesis of organizational problems and questions related to the environment, with world-wide application in terms of relationships and integration (15). Due to its characteristics of data integration, GIS, together with remote sensing products, functions as probably one of the most adequate tools in support of decision making for systemic-focusing, in the management of natural resources.

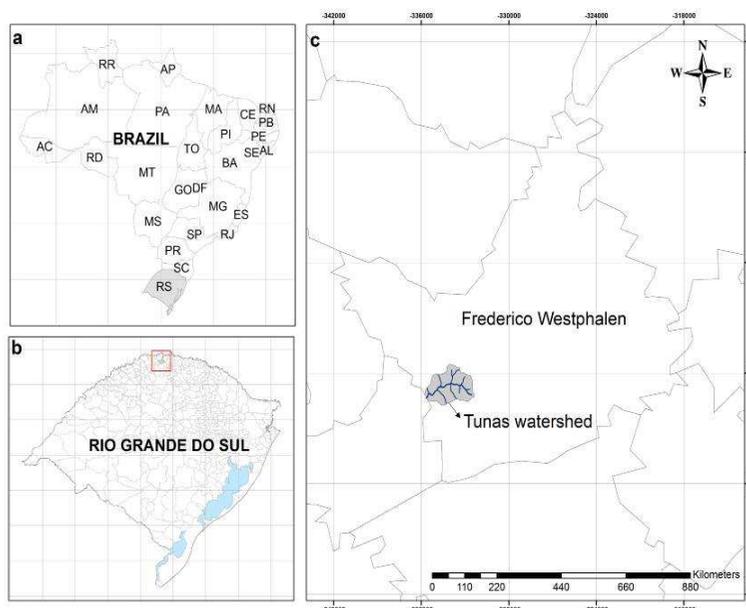


Figure 1 – Localization of the Lajeado Tunas watershed, Frederico Westphalen – RS, Brazil.

Thus, the aim of this study was to apply two methodologies to the analysis and comparison of the land use geographic distribution, as well as to elaborate thematic maps of the study area, with an eye to the environmental characterization of a watershed in the south of Brazil, thereby supplying subsistence for the elaboration of a plan for its territorial management.

## METHODOLOGY

### Localization of the Study Area

The Lajeado Tunas watershed (Fig. 1) is located in Frederico Westphalen County, Rio Grande do Sul, Brazil, between the parallels 27°22' and 27°33' south and the meridians 53°24' and 53°27' west. It discharges into the Rio Pardo, pertaining to the Rio Uruguay Basin, at around 200 m from the dam of the Companhia Riograndense de Saneamento – CORSAN, thereby contributing to the water supply of the urban area (7).

Frederico Westphalen presents a humid subtropical climate (Cfa), according to the Köppen classification, with average minimum and maximum temperatures of 13°C and 31°C, respectively (8). Annual rainfall, of between 1.800 and 2.100 mm, is well distributed throughout the year (8).

The pattern of drainage in the watershed is dendrite-like, with wide-spreading branches and tributaries at various angles (Howard, 1967). Aluminum-ferric red latosol predominates in the highest and flattest parts, and neosoils closer to the river mouth (17).

The region of the Upper Uruguay, where Frederico Westphalen county is located, was originally totally covered by Atlantic Forest *latu senso*, composed of deciduous seasonal and mixed ombrophylous forests (17). Based on the biogeographic region delimitation proposed by Silva & Casteletti (2003), the study area corresponds to a transition region between interior and araucaria forests (14). With the introduction of farming, the original native vegetation experienced profound modifications. The present scenario is composed by forest fragments, vegetal cover characterized by the predominance of early secondary forest in various successive stages, diversified farming and other agricultural activities (10).

### Methodological procedures

The first step involved the construction of a cartographic base of the study area, using the softwares Idrisi Kilimanjaro (1) and MapInfo (7.8 9), together with information contained in the topographic chart Folha SG.22-Y-C-II-3 MI 2885/3, of Frederico Westphalen, scale 1:50.000, elaborated by the Diretoria de Serviços Geográficos of the Brazilian Army – DSG (IBGE, 1979), and in the LandSat TM 5 satellite image, orbit 223/079, of 8/3/2004 at 13h 12' and 59".

We obtained the watershed delimitation starting from the identification of the corresponding drainage area, or rather that referring to the area drained by the entire fluvial system confined within topographic limits, all projected onto a horizontal plane (21). The perimeter of the watershed consisted of the length of an imaginary line drawn along the water divisors, which in turn coincide with geomorphometric aspects of the region under analysis.

Water bodies and road network were digitized from DSG charts, and complemented with field data obtained with a Garmin 12 GPS. This process allowed us to include roads and other forms of access to rural properties, as well as streams and springs, which do not appear in the official charts.

The ordering of water courses and drainage density were both used to characterize regional drainage. This arrangement, which represents the degree of branching of the system of watershed drainage (23), was defined according to the classification proposed by Strahler (1952), by which, watercourses with no tributaries are considered of the first order, those of the second order only receive tributaries of the first order, independent of the number of tributaries, those of the third order receive two or more tributaries of the second order, although they are also capable of receiving tributaries of the first order, and so on.

Drainage density refers to the efficiency with which rainwater quits the watershed. It is calculated as the relationship between the total combined length of all the water courses present, and the entire area occupied by the system (4).

Hypsometry was elaborated from the interpolation of vectorial maps of the level curves, which gave rise to the generation of a digital elevation

model (DEM). Hypsometry was divided into four different altimetrical classes (400 – 450 m; 450 – 500 m; 500 – 550 m; 550 – 600 m). A clinographic map, elaborated with the aid of models available in Idrisi and using DEM as a base, was applied to classifying the area into five different patterns of declivity (13). Land use mapping was based on the application of two methodologies: (i) the supervised classification of satellite images and (ii) data obtained in the field with GPS geographic coordinates.

We used methods of image processing, as recommended by Easteman (1998) for the supervised classification of the Landsat TM5 satellite image (bands 3, 4 and 5), thereby simplifying the elaboration of one of the land use maps with Idrisi software.

In this study, the following land use for mapping were defined: (a) *natural vegetation*; all the vegetal forms, as fragment forest, riverine forest and early secondary forest; (b) *agriculture* – areas allocated to annual culture and those with exposed soil in the phase of preparation or implantation of annual cultures; (c) *pasture* – areas with pasture and those allotted to cattle raising; (d) *waterbodies* – water bodies, either naturally formed or reservoirs and ponds; (e) *urban area* – urban lots and rural buildings.

The edition of refinement classification was done with Mapinfo 7.8 software. On completion, the results were introduced into PhotoImpact 4.0 software for the manipulation of images and elaboration of the figures corresponding to consolidated thematic charts.

Geographic coordinates obtained in the field with GPS were used in the second methodology. For mapping the outlines of land use classes in the watershed, area marking was based on the limits of rural properties, urban areas and the main land uses within each rural property. Within the limits that were being investigated and duly registered, each point corresponded to an extremity of the polygon or line that was being mapped.

Simultaneous with the collection of points, a manual outline of the mapped properties was drawn up, this contributing as a source of orientation for elaborating the layers corresponding to differences in land use and occupation, as recognized and identified in the field. Field work lasted for around two months (January and February, 2006), running

up to approximately 400 work-hours carried into effect by a team of 2.

The points collected were transferred from GPS to the software GPS Track Maker, and stored in a geographic database. These were introduced into MapInfo 7.8. for the manipulation and development of layers corresponding to the following land use classes: (i) *forest* – those with primary or secondary vegetation in an advanced stage of succession; (ii) *secondary forest* – areas covered by vegetation in the initial to mid stages of regeneration; (iii) *groves* – areas with few trees which do not constitute a forest; (iv) *swamp* – flooded areas, generally located near to springs and reservoirs; (v) *annual agriculture* – annual cultures and areas with exposed soil; (vi) *eucalyptus* – areas for planting eucalyptus; (vii) *perennial agriculture* – areas for the plantation of Paraguay tea; (viii) *citrus* – areas specifically allotted to producing grapes and oranges; (ix) *pasture* – grassland, ultimately used for cattle raising; (x) *waterbodies* – bodies of water and artificial lakes (reservoirs); (xi) *farms* – small properties, not for farming and without rural installations; (xii) *built-up areas* – an area comprising elaborated properties and their respective rural surroundings; (xiii) *urban area* – an assemblage of lots with buildings of low standard; (xiv) *Roads/access routes* – comprising areas for public use (roads, streets, etc.).

## RESULTS

The area occupied by the Lajeado Tunas watershed (around 650 ha), with a perimeter of 10.6 km, represented only 2.5% of the total area of Frederico Westphalen county. It was mostly situated in a region occupied by small rural properties characterized as family concerns, which, as such, were strongly exploited as regards natural resources. Orientation was east-to-west, and the main watercourse was around 5 km in extent. The calculated drainage density was 22.3 m/ha.

The watershed itself, comprising an extension of 14.5 km, was drained by a main perennial watercourse composed of 14 springs, three located in the urban perimeter, and the remainder in the rural zone.

The greater part of the watershed was located in the rural zone. The smaller part, which

was in the urban zone, presented a paved federal highway, but only 238 m of which encroached upon watershed limits. Unpaved roads, 22.67 km all told, and characterized as earth roads, also included routes of access to rural properties. We took the drainage density as a base to obtain the density of roads, which was also high (35 m/ha) in the watershed.

The surface of the watershed presented a variation of 200 m in height, between the quotas 400 to 600 m above sea level, the greater part of which (more than 80%) being situated between 450 and 550 m. The two extremes referred to the highest and lowest altitudes, corresponding to 13.3% and 4.1%, respectively, of the whole area.

The biggest part of watershed relief (92.77%) consisted of low declivity areas (0 – 13%), classified as flat, and slightly or moderately wavy. Wavy relief (13 to 20%) occurred in less than 5% of the whole. On the other hand slopes between 20 and 45% were found in 15.57 ha of the whole area, whereas those above 45%, considered mountainous to cliff-like, were not registered. The average declivity was estimated at 6.95%.

Although satellite images interpretation allowed us to classify the study area in five main land use classes, a larger number of classes were diagnosed only through the GPS mapping methodology (Table 1).

(545.69 ha), distributed among 54 small rural family properties, entirely or partially inserted into the watershed. Annual cultures consist of planting corn and soybean, and to a lesser extent, beans and tobacco. Other activities, such as olericulture and fruit culture are also undertaken in some properties, but only for family consumption. Animal breeding is basically restricted to dairy cattle and pigs.

The extension of agriculture diagnosed by GPS mapping methodology occupied 57.63 % of the area and corresponded to annual cultures, including areas of perennial cultures and horticulture, as can be seen in Figure 2. According to field mapping (GPS approach) of this class, this percentage was reduced to 31.56%.

Although eucalyptus, citrus and perennial agriculture were distinguished from annual cultures, their areas were little representative, and occupy only 4.19 ha, 1.87 ha and 2.71 ha, respectively. Other classes lacking in the satellite image mapping, were identified through GPS approach (Figure 3): (i) roads/access routes (1.07%); (ii) built-up areas (2.97%); and, (iii) farms (2.17%). Urban area occupied only 16% of the watershed.

According to GPS mapping approach, pastures occupied 105.2 ha, and natural vegetation around 86 ha. On the other hand, according to image

Tabela 1. Distribution of land use classes in hectares and percentages of the Lajeado Tunas watershed, based on GPS mapping and LandSat image classifications

Land use classes	LandSat		GPS		
	Area (ha)	Area (%)	Area (ha)	Area (%)	
Natural cover	Forest		156.20	24.04	
	Secondary forest	86.31	13.29	14.11	2.17
	Groves		5.61	0.86	
	Swamp		0.20	0.03	
Anthropic cover	Annual agriculture		205.00	31.56	
	Eucalyptus	374.41	57.63	4.19	0.64
	Perennial agriculture		1.87	0.29	
	Citrus		2.71	0.42	
	Pasture	82.53	12.70	105.20	16.19
	Waterbodies	0.09	0.01	5.41	0.83
	Farms		14.10	2.17	
	Built-up areas	106.29	16.36	19.28	2.97
	Urban areas		108.80	16.75	
	Roads/access routes		6.95	1.07	
Total	649.63	100.00	649.63	100.00	

The area of the watershed situated in the rural zone corresponded to 84% of the landscape

classification approach, pastures occupied 81.89 ha, and natural vegetation was divided in four classes:

forest (24.04%), secondary forest (2.17%), groves (0.86%) and swamps (0.03%).

classification, this class was not identified due to the waterbodies being smaller in size than the pixel

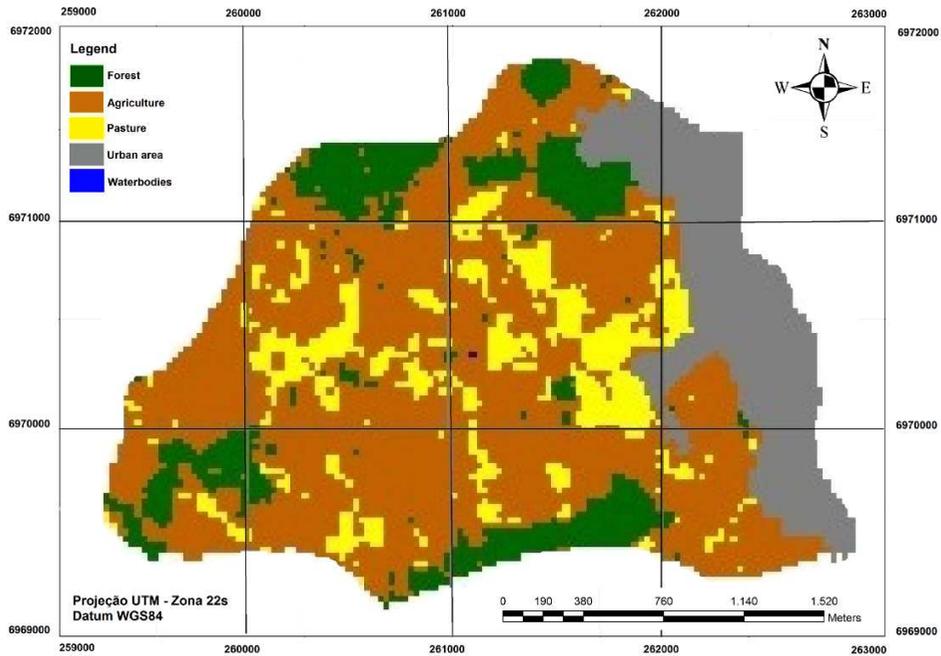


Figure 2 – Chart of land use mapping using LandSat TM5 image classification approach of the Lajeado Tunas watershed, Frederico Westphalen – RS.

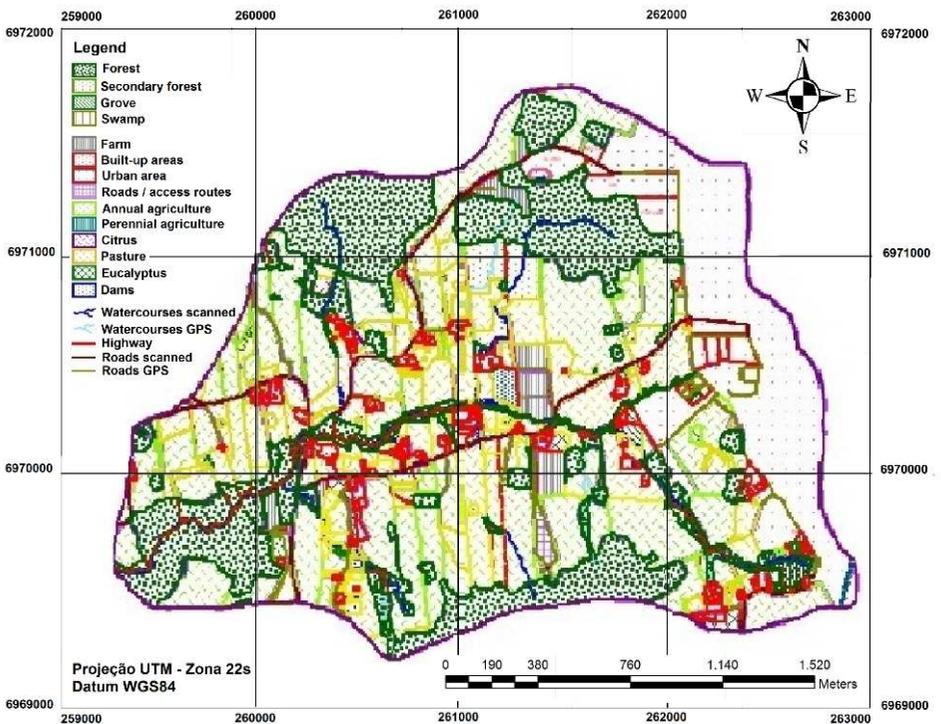


Figure 3 – Chart of land use mapping using GPS field mapping approach of the Lajeado Tunas watershed, Frederico Westphalen – RS.

The class ‘waterbodies’ corresponded to an area of 5.41 ha in field mapping approach. In image

of the LandSat image employed in the study (pixel = 30 x 30 m).

## DISCUSSION

The Lajeado Tunas watershed, classified as of the third order, can be considered a small unit, with high drainage density (4) and thus, with favorable conditions for constraining local intervening factors. This high drainage density means that infiltration is more difficult, with higher surface drainage, and consequently, greater hewing out of permanent channels, due to the hydrological deportment of rocks (2).

The quantification of roads, in relation to the entire area occupied by the watershed, facilitates diagnosing their density. Roads, on one hand, present a positive contribution when considering accessibility among properties. But, on the other hand, they expose natural areas to human presence through easy access, thereby compromising their preservation, both through favoring the entrance of toxic substances, as from the facility in collecting plants and the capture or running over of wild animals (10).

The watershed also presents low average altitude and hypsometric amplitude, factors which influence the amount of radiation received and, consequently, evapotranspiration, temperature and rainfall. According to Tonello *et al.* (2009), the greater the altitude, the less the amount of solar energy that the environment receives, thus resulting in less energy availability. In this sense, the amount of available energy in the watershed can be considered high.

Most of the watershed is considered as appropriate for agriculture, provided that simple steps for controlling erosion are taken. We considered those areas with an accentuated slope as apt for developing annual cultures. However, due to the considerably high susceptibility to erosion in this type of relief, the implantation of this type of culture is conditioned to the implementation of intensive soil conservation techniques. The few areas that present restriction to agriculture due to this high susceptibility, offer adequate conditions for the establishment of permanent cultures such as perennial agriculture and citrus.

Since declivity is intimately related to the distribution of water in a watershed (20), the average slope presented by the watershed plays a

significant role in the distribution of water between surface and subterranean drainage, thereby functioning positively in the natural conservation of the drainage system as a whole. Nevertheless, in the present case, signs of erosion in the watershed were observed. This was characterized by ravines in farming areas and gullies along the roads, mainly where there is higher declivity.

As regards land use classification in the study area, image classification was limited, due to low spatial resolution, thereby precluding identification with the same precision as that of some classes mapped with GPS approach. Nonetheless, the classification of this type of image can be an excellent tool when used for larger study areas.

The results obtained from the land use classification permit inferring that the matrix of land use is agriculture, represented by the corn, soybean and tobacco cultivation. These cultures are undertaken with no heed to conservation procedures, thus possibly giving rise to a high loss of soil by erosion.

The divergence among the percentages obtained for the class 'agriculture' in the different methodologies adopted, is possibly related to the period in which the LandSat image classification was obtained, viz., October, as this coincides with a critical period, in which the lowest indices of vegetal cover occur, and when there is a similarity between the coloration of agropastoral cultures and natural vegetation, whereby the spectral response makes identification difficult, especially the case of small forest fragments and secondary forests, which end up being incorporated into the local farming matrix. Besides this, in the GPS approach we could separate annual plantations from the perennial agriculture, eucalyptus and citrus classes.

We believe that roads/access routes, built-up areas, farms, secondary forest, groves, eucalyptus, and swamps, as identified through GPS mapping approach, as well as small forest fragments, were incorporated as agricultural areas in the interpretation of the satellite image. Thus, the difference between the two methodologies of land use classification was significantly increased regarding to the differentiation among distinct land use classes.

It is important to point out that high resolution images are more indicated for small study areas, since they permit the correct differentiation

of various land use classes. However, as the acquisition of this type of image is very costly (1 ha costs around R\$10.00 for Quickbird satellite images: spatial resolution = 0.60 m), this can compromise the feasibility of the projects with the required characteristics. Selection of the most adequate image is a preponderant factor in a research project, since there are images available in internet free of charge, as is the case of LandSat images.

GPS mapping approach makes a precise and correct diagnosis, and is also indicated in the study of small areas, due to the intense field work involved. For larger study areas, satellite images are once again recommended, in view of the cost-benefit factor and the rapid task execution, since the difference in results is more significant, regarding to the number of categories in the same class, than in relation to the differentiation between natural and anthropic areas.

Pastures occupy the third largest area, possibly due to the economic importance of dairy-cattle breeding for the region. It is importante to note that pastures, when well-managed, is a form of maintaining the surface of the soil covered throughout the year. This practice reduces the speed of surface drainage, contrary to agricultural activities, which leave the soil exposed during its preparation prior to planting (10). As a rule, animal breeding in the region is developed extensively, with pasture of low productivity. According to field observations, we visualize badly-managed compacted areas, having all the available forage used. The results of these actions let the soil exposed and without protection against the erosive action of rain and wind, and significantly diminishing infiltration and directly affecting the drainage of springs and watercourses.

The difference between the values observed in satellite-image classification and GPS mapping approach is explained by the presence of small areas with pasture, as well as pastures close to or inserted into agricultural areas that possess a similar spectral response, and thus, are not differentiated in satellite-image classification.

Field mapping differentiated vegetation in forest, secondary forest and groves. Forest, that originally occupied all the study area, are mainly located next to springs, accompanying river courses and in areas of high declivity. We considered

forest as of fundamental importance in the erosion control and to replenish phreatic water. Accelerated erosive processes prejudice both the environment and society through diminishing the fertility of the soil, and affecting plant growth. They also diminish the capacity of soil water retention, as in near and remote areas, through the drainage of water and sediments, local damage, negative changes in the environment related to floods, the fill-in of rivers, lakes and reservoirs, the contamination of bodies of water, etc.. In such cases, natural vegetation is a potential aid in minimizing these processes (6).

Nevertheless, the area of native forest shows that the watershed represents the conservation status equivalent to the region where it is located. Based on LandSat image classification, Tonial *et al.* (2005) encountered approximately 16% of forest areas in the five water basins located in the northeastern region of the state of Rio Grande do Sul, where the present study area is located. On the other hand, Cemin *et al.* (2009) found a higher coverage (51.96%) of natural vegetation, in a water basin located close to the same study area.

APPs present a large degree of deforestation, as a result of the urban expansion. Thereabouts, the execution of environmental projects should be intensified, as a way of preserving areas where springs occur. We believe this class needs special attention due to the negative impact which can be associated with areas covered by solid material, thereby hindering various physical and biological processes, such as the absorption of rainwater, which normally occur between the soil and the atmosphere. Furthermore, the production of residues and the conversion of areas with natural vegetation into lots constitute two serious recurring problems arising from urbanization (11). Urban expansion should be redirected to locations with more favorable physical conditions, avoiding negative environmental impacts, and so maintain the quality of hydric resources.

We do not identify small watercourses in the image classification due to its scale of 1:50.000, and the pixels size.

## CONCLUSIONS

The watershed is considered appropriate for agro-pastoral activities, through being on a

plain, and possesses high drainage efficiency, thereby favoring surface drainage and minimizing the aftermath of erosive processes.

Agriculture is the landscape matrix, and thus constitutes the main threat to the environmental quality of the watershed. Farming areas present a lack of adequate management, and require urgent conservation actions, as a means of mitigating the impacts arising from the intense exploitation of natural resources.

Forest recomposition in the study area is imperative, mainly in areas of permanent protection, with the aim of maintaining the ecological functions associated with natural ecosystems, especially the control of erosion and aid in replenishing phreatic water.

The methodologies used for diagnosing the distribution of land use mapping differed, mainly as regards the identification of the different land use classes. Although GPS mapping approach identified a larger number of categories of land use, more time was dedicated to undertaking the task, thereby conditioning the application of this method to small areas. Satellite images of mid-spatial resolution proved to be most indicated in the study of larger areas, due to the adequate relationship cost-benefits.

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## RESUMO

Este trabalho analisa o uso da terra e da estrutura da paisagem da sub-bacia hidrográfica do Lajeado Tunas, Frederico Westphalen, RS, Brasil. Sistemas de Informação Geográfica (SIG), imagens de Sensoriamento Remoto e Coordenadas de Global Positioning System (GPS) foram usadas para caracterizar a paisagem e para gerar dois mapas de cobertura da terra, que foram posteriormente comparados para avaliar as metodologias utilizadas. A sub-bacia do Lajeado possui cerca de 650 ha, e os resultados sugerem que o relevo possui declive suave (6,95%), estando orientado de leste a oeste. Devido ao terreno ser ligeiramente plano, a sub-

bacia possui condições favoráveis para atividades agropastoris, no entanto, práticas conservacionistas são necessárias a fim de controlar a erosão e proteger os recursos hídricos. O mapeamento dos usos da terra mostrou que a região é predominantemente ocupada por usos antrópicos, que desempenham efeitos negativos para a qualidade ambiental e a conservação da biodiversidade. Embora tenha sido usado um conjunto simples de ferramentas de SIG para analisar a paisagem focal, esses métodos auxiliaram o entendimento de características da paisagem estruturalmente importantes no contexto regional, e os resultados obtidos mostraram-se interessantes para entender quais ações de conservação devem ser usadas para melhorar a manutenção da biodiversidade local ou regional, para garantir a longo prazo a manutenção dos ecossistemas agrícolas, e que, em futuras análises, a compreensão de como fauna e flora locais respondem às características da paisagem regional são os pontos-chave para garantir a manutenção da biodiversidade.

**Palavras-chave:** Planejamento Ambiental, Estrutura da Paisagem, Manejo Sustentável, Sistemas de Informação Geográfica (SIG)

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## STRUCTURE OF AVIAN GUILDS IN A FRAGMENT-CORRIDOR IN LAVRAS, MINAS GERAIS, BRAZIL.

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### ABSTRACT

Analysis was centered on avian guild structure of a community of birds in a forest fragment|corridor|farming matrix in the Cerrado, in Lavras county, Minas Gerais, Brazil (21°14'45"S/44°59'51"W). Samples were collected from eight semideciduous forest fragments of 1,0 to 12,1 ha, connected by 5 hedgerow corridors bordered by an adjacent agricultural matrix. Whether the distribution of frequency, diversity and composition of the guilds was similar among the fragments, ecological corridors and matrix. 176 bird species belonging to 44 families were recorded. The main guilds recorded were insectivore, omnivore and granivore. The environments sampled statistically dissimilar guild distribution and composition. Insectivore (68 species) and omnivore (53 species) guilds were predominant. Nevertheless, the average number of species was higher in the matrix and corridors, than in forest fragments. The latter, through functioning more as an efficient way of facilitating the movement of generalist species can mask the reduction in regional species richness.

**Key words:** birds, forest fragments, avian guilds.

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### INTRODUCTION

Forest fragmentation, a historical process in the Cerrado biome, increased in the 20th century due to agricultural expansion in the Brazilian center-west. Among the outcomes of the consequential reduction in habitat, a decline in fauna and flora diversity could be observed. Even though there still are natural forest fragments in the Cerrado, it is not known whether the influence of ecological processes is similar to those observed in forest environments of the Atlantic Rain Forest and the Amazon Forest. The impact on tropical ecosystems originating from the fragmentation process has led to alterations in various parameters which, in turn, have given rise to the disappearance of insectivore guilds.(13).

Notably, the decline in these guilds in small forest fragments is more strongly related to the capacity for dispersion by way of anthropic matrices than to the low availability of food resources (29).

Research related to forest fragmentation involves the theory of biogeography and metapopulation dynamics (19). The former defines a diminishing in isle surface or as being associated to an exponential decrease in the number of species, and the reduction in relationships (17). The formation of metapopulations is favored by habitat fragmentation, with each species occurring in a fragment, even though these populations can also occur in continuous habitats. The theory of metapopulations has supplanted that of biogeography through its potential to explain the dynamics of populations in fragmented areas.

Forest mosaics or fragmentation can cause profound impacts on species that require large areas for survival. These, known as interior species, tend to quickly disappear in deforested or impacted areas. Meanwhile, under these circumstances, other species adapted to margin or conditions become dominant. Can be maintained through adequate management, to so guarantee immigration from larger contiguous areas (17). From studies dealing with fragmented environments, it can be inferred that parameters, such as area (3), and isolation, exert an influence on the distribution of the flora and the movement of wild fauna (28).

Other ecological aspects of structures, such as, vertical stratification and heterogeneity, comprise important parameters in the determination of environmental avian guild diversity (21).

## OBJECTIVE

In the present work, the response of the different avian guilds to the elements of a fragmented agricultural landscape was evaluated. The hypothesis to be tested was that the distribution of avian guild frequency, diversity and composition between forest fragments, ecological corridors and matrix remains unchanged.

## METHODOLOGY

### *Study site*

The corridor-fragment studied is located in Lavras county, the Alto Rio Grande region, in the south of Minas Gerais State ( $21^{\circ}17'15.1''\text{S}/44^{\circ}58'59.3''\text{W}$ ) (Figure 1).

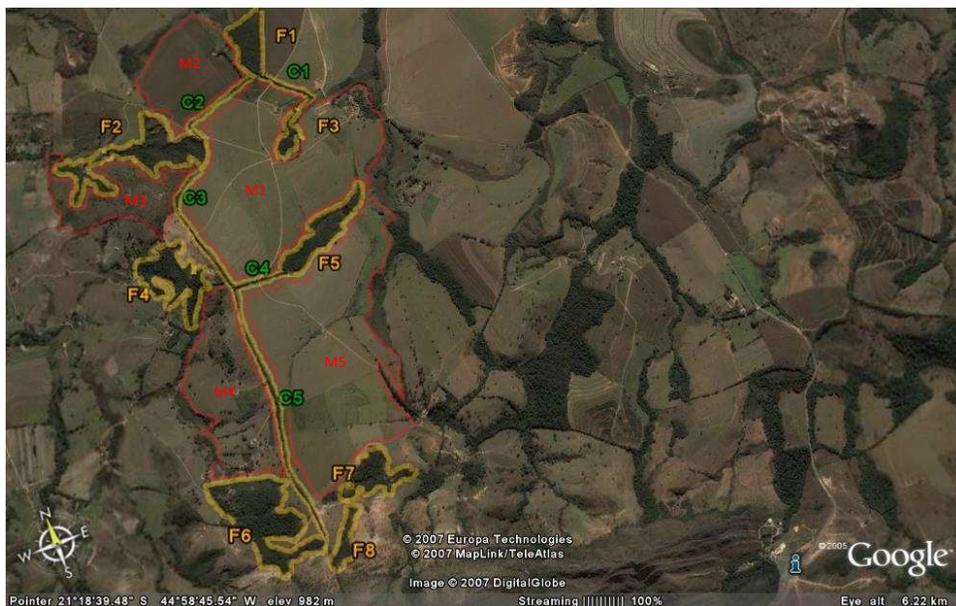


Figure 1. Map of the area studied, Lavras city/Minas Gerais State, at the base of the Serra do Carrapato (Source: <http://earth.google.com>).

Piratelli & Pereira (2002) emphasized the importance of studying avian guilds, as a source of relevant data on community trophic structures, as well as abiotic parameters. As regards small fragments, even though connected, they be poor, and, with the association of a reduced area. Fire, agricultural defensives, invading vegetal species, etc., the occurrence of populations could become unfeasible, or there might even be the exclusion of certain ecological groups (18).

The study site is located around 6 km from Lavras, on the slopes of the Serra do Carrapato. In all, there are eight fragments (F), interlinked by a vegetational corridor (C) composed of a main axis and four branches (Figure), in which seven of the fragments present an interior river course, within an agricultural matrix (old regional farming properties). The total area of the properties is 51,1624 ha, varying from 1,0302 ha ( $21^{\circ}17'51''\text{S}/44^{\circ}59'13''\text{W}$ ) to 12,40 ha ( $21^{\circ}19'01''\text{S}/44^{\circ}59'47''\text{W}$ ). The corridors dealt with in the present study are defined as lineal

vegetal structures of various origins, of reduced width (between 3 and 6 meters), which can be connected to various-sized fragments (6).

In the area studied, it was possible to identify: a) a farming matrix (M), comprising annual cultures, i.e., corn, soybean and beans, among others, planted pasture (*Brachiaria spp.*) for raising cattle, and natural farmland. Through dealing with a fragmented area, the matrix was defined as any farming area, without any form of forest formation, such as forest fragments or vegetal corridors, since, from the beginning of the 20<sup>th</sup> century, these phytophysiognomies have been gradually substituted by open areas, due to the regional expansion of agriculture; b) corridors of regenerating (30 years) arboreal vegetation occurring in hollows; c) portions of mosaic type habitat, consisting of secondary stage cerrado vegetation in the broad sense, secondary stage man-formed galleries and patches of secondary stage semideciduous forest (6).

The climate of the region can be defined as of the Köppen Cwa type, with an average annual rainfall of 1.529,7 mm, and an average annual temperature of 19,4°C (5). The minimum altitude is 920 meters and the maximum 1.180 meters.

a total of 132 days (924 hours) of field work. Work began at 5:30 a.m. and finished around 9:30 a.m. The visits took place twice a week, at twilight (4:00 p.m. to 7:00 p.m.). One and the same point was visited only once a day. The identification of species and the nomenclature used was according to basic references on the birds encountered in the Comitê Brasileiro de Registros Ornitológicos (2011).

One of the parameters used for studying bird communities in closed environments is the composition of avian guilds (24). Trophic category analysis was applied to understanding bird community composition patterns within the system fragment|corridor|matrix.

For guild characterization, information on the foraging form was used, whence, according to Pimm (1991), guilds could be defined as: Carnivores, Frugivores, Granivores, Insectivores, Nectarivores, Omnivores and Piscivores.

In order to discern the differences in inter-environment guild composition, data was submitted to NMDS (nonmetric multi-dimensional scaling) analysis. Accordingly, the program is applied to calculating similarity among samples, by cartesian grouping of the more similar points, as to guild composition and abundance (7). This method was

Tabela 1. Areas studied within each environment, with the points shown.

Environments	Áreas (ha)	Physiognomy	Successional stage	Points shown	Sampling area (m <sup>2</sup> )	Altitude	Coordinates
<b>Fragment</b>							
<b>Forest</b>							
F1	7,19	Semid seas for	Secondary	8	2513 m <sup>2</sup>	965 m	21°17'28''S/44°59'13''W
F2	11,84	Semid seas for	Secondary	8	2513 m <sup>2</sup>	971 m	21°17'43''S/44°59'40''W
F3	1,03	Semid seas for	Secondary	8	2513 m <sup>2</sup>	977 m	21°17'51''S/44°59'13''W
F4	7,36	Semid seas for	Secondary	8	2513 m <sup>2</sup>	973 m	21°18'08''S/44°59'48''W
F5	7,80	Semid seas for	Secondary	8	2513 m <sup>2</sup>	977 m	21°18'13''S/44°59'16''W
F6	12,40	Semid seas for	Secondary	8	2513 m <sup>2</sup>	996 m	21°19'01''S/44°59'47''W
F7	2,25	Semid seas for	Secondary	8	2513 m <sup>2</sup>	990 m	21°19'01''S/44°59'47''W
F8	1,25	Semid seas for	Secondary	8	2513 m <sup>2</sup>	1044 m	21°19'13''S/44°59'32''W
<b>Corridors</b>							
C1	0,2	Semid seas for	Secondary	8	628 m <sup>2</sup>	960 m	21°17'39''S/44°59'10''W
C2	0,28	Semid seas for	Secondary	8	628 m <sup>2</sup>	985 m	21°17'38''S/44°59'24''W
C3	0,44	Semid seas for	Secondary	8	628 m <sup>2</sup>	996 m	21°17'58''S/44°59'41''W
C4	0,12	Semid seas for	Secondary	8	628 m <sup>2</sup>	991 m	21°18'17''S/44°59'29''W
C5	0,72	Semid seas for	Secondary	8	628 m <sup>2</sup>	1002 m	21°18'43''S/44°59'35''W
<b>Matrix</b>							
M1	71,0	Anthropized field	Secondary	8	10053 m <sup>2</sup>	985 m	21°17'46''S/44°59'23''W
M2	27,0	Agric cultivation	Secondary	8	10053 m <sup>2</sup>	980 m	21°17'33''S/44°59'28''W
M3	24,0	Cerrado	Secondary	8	10053 m <sup>2</sup>	997 m	21°17'50''S/44°59'43''W
M4	28,0	Cerrado	Secondary	8	10053 m <sup>2</sup>	934 m	21°18'33''S/44°59'53''W
M5	93,0	Anthropized field	Secondary	8	10053 m <sup>2</sup>	1022 m	21°18'49''S/44°59'19''W
<b>Total fragments</b>	51,16			64	20104 m <sup>2</sup>		
<b>Total corridors</b>	1,76			40	3140 m <sup>2</sup>		
<b>Total matrix</b>	243,0			40	50265 m <sup>2</sup>		
<b>Total</b>	295,92			144	73509 m <sup>2</sup>		

### Sampling Planning

The Point (32) Sampling Method, with 10 minutes per point, was used for qualitative and quantitative surveying.

Observations were carried out three times a week, between February and December, 2005, to

basically used to represent differences in guild composition in fragment, corridor and matrix environments. The Bray-Cutis similarity index was used for analysis.

One-way ANOSIM testing was used to statistically verify the differences among groups

formed by NMDS. This is a nonparametric test which, based on Bray-Curtis similarity (7), furnishes a way of testing whether there is a significant difference between two or more groups, according to the formula:

$$R = \frac{r_b - r_w}{N(N-1)/4}$$

$r_b$ : average of all the distances among the groups

$r_w$ : average of all the distances within the groups

N: samples

The SIMPER (Analysis of similarity of percentages) test was used for examining the inter-environment contribution of each group, according to Bray-Curtis dissimilarity, and to determine the contribution of each to intra-environment similarity (7).

## RESULTS

176 bird species belonging to 44 families were registered. The main guilds were comprised of insectivores, omnivores and granivores.

The insectivore guild presented the highest species richness with 68 species (38,0%) in fragment environments. Insectivore species richness was similar to that of omnivores in corridor environments (18 species each {10%}). As to the matrix environment, there was a reduction in insectivore species richness (21 species) in relation to omnivore (23 species). Behavior of the omnivore guild was the contrary to that of insectivores. There was a gradual rise in omnivore species richness matrixwise. In general, granivore species richness was inferior (22 species), followed by nectarivores (12 species), carnivores (11 species), frugivores (10 species) and piscivores (3 species). Distribution in the matrix was different from that of the other environments. In fragments and corridors distribution was more grouped (Figures 2 and 3). In axis 1, the omnivore guild contributed to the overall appearance of the fragment-corridor-matrix grid. In axis 2, there were differences in distribution among fragments, corridors and matrix. Once again, the greater contribution towards these differences came from the omnivores.

Analysis of similarity (ANOSIM) detected

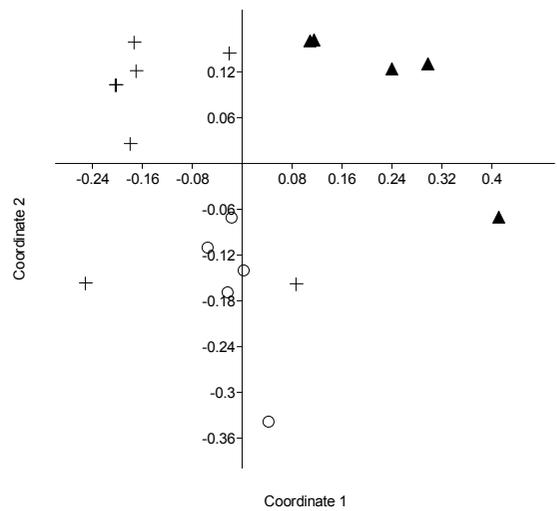


Figure 2. NMDS testing of inter-environment guilds (species diversity) (Symbols: + = fragment; o = corridor; ▲ = matrix).

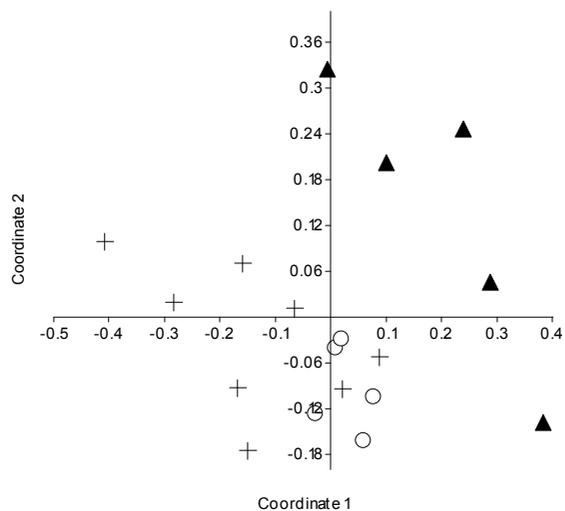


Figure 3. NMDS testing of inter-environment guilds (number of individuals) (Symbols: + = fragment; o = corridor; ▲ = matrix).

significant differences among the inter-environment guilds studied, both by species ( $r = 0.67$ ,  $P = 0.0001$ , average dissimilarity = 27.4), and individuals ( $r = 0.53$ ;  $P < 0.0001$ , average dissimilarity = 34.2). Significant differences of guilds among the components of the system were obvious: Fragment and Corridor by species ( $r = 0.46$ ,  $P < 0.012$ , average dissimilarity = 23.84); by individuals ( $r = 0.26$ ,  $P < 0.05$ , average dissimilarity = 26.02); Fragment and Matrix by species ( $r = 0.70$ ,  $P < 0.001$ , average dissimilarity = 29.83); by individuals ( $r = 0.76$ ,  $P < 0.008$ , average dissimilarity = 42.13); Corridor and Matrix by species

( $r = 0.91$ ,  $P < 0.007$ , average dissimilarity = 29.81); by individuals ( $r = 0.66$ ,  $P < 0.008$ , average dissimilarity = 35.81). The aim was to evaluate the importance of the guilds (Table 2).

among the three cited environments, with higher average abundance in corridors (106) than in matrices (93.6) and fragments (76.3) (Table 4).

Table 2. Analysis of Similarity (ANOSIM) and the percentage of dissimilarity (SIMPER) of guilds in the different environments.

Interactions	Species			Individuals		
	R	P	Average dissimilarity	R	P	Average dissimilarity
Fragment x Corridor	0.46	0.011	22.84	0.26	0.0448	26.02
Fragment x Matrix	0.70	0.001	29.83	0.76	0.0008	42.13
Corridor x Matrix	0.91	0.007	29.81	0.66	0.0079	35.81

On separating the 3 environments evaluated, viz., fragments, corridors and matrices, SIMPER species analysis showed that the insectivore guild presented the most expressive result, 10.98 (40.44% accumulated). The average abundance of insectivore species was greater in fragments (27.8) than in corridors (14) and matrices (13.6). Omnivores, as the second most abundant guild, contributed with 4.136 (15.23% accumulated). Average omnivore abundance was a little higher in the matrix (19.2) than in fragments (15.4) and corridors (13.2) (Table 3).

## DISCUSSION

Among the environments studied, the matrix was clearly dissimilar to fragments and corridors, as regards avian guild structure, frequency and diversity. The guilds with greatest relative importance in the matrix were the insectivore and omnivore, thus corroborating studies on avian guilds in tropical environments (23.9). The greater part of the insectivores registered presented preference for the matrix. In tropical forests, the high percentage of insectivore bird species is common (9,26).

Table 3. Results from similarity analysis (SIMPER) among and within the environments evaluated, using the number of species as an indicator of the importance of a guild.

Guilds	Contribution	% Accumulated	Average abundance in fragments	Average abundance in corridors	Average abundance in matrices
Insectivores	10.98	40.44	27.8	14	13.6
Omnivores	4.13	55.67	15.4	13.2	19.2
Frugivores	3.91	70.09	2.25	0.6	7.8
Granivores	3.01	81.18	7.63	7.8	12.8
Carnivores	2.68	91.06	2.25	1.4	6.4
Nectarivores	2.02	98.5	6.25	8.2	6
Piscivores	0.40	100	0	0	0.8

SIMPER analysis by individuals presented different results from those by species. The omnivore guild contributed with 13.19 (39.3% accumulated) towards distinction the 3 environments (fragments, corridors and matrices) evaluated. Average omnivore abundance was higher in matrices (191) than in corridors (107) and fragments (73.8). Granivores contributed with 9.83 (29.33%) towards distinction

Among insectivore guilds, most were Passeriformes (72.4%), with a predominance of species from the families Tyrannidae (21.7%) and Furnariidae (18.8%). With the exception of insectivores and omnivores, the matrix environment is normally associated to places which offer little attraction to birds in fragmented landscapes (12). There was a reduction in the relative importance

Table 4. Results of similarity analysis (SIMPER) among and within the environments evaluated, by using the number of individuals as an indicator of the importance of the guild

<b>Guilds</b>	<b>Contribution</b>	<b>% Accumulated</b>	<b>Average abundance in fragments</b>	<b>Average abundance in corridors</b>	<b>Average abundance in matrices</b>
Omnivores	13.19	39.35	73.8	107	191
Granivores	9.83	68.68	76.3	106	93.6
Nectarivores	3.31	78.57	21	43.4	21
Insectivores	3.29	88.40	40.5	50.2	23
Carnivores	2.09	94.66	12.1	4.2	22.6
Frugivores	1.69	99.72	6.88	5	16
Piscivores	0.09	100	0	0	1

of insectivore and omnivore guilds, in corridor environments. Corridors, besides contributing towards reducing the isolation of these and other guilds, makes the conservation of diversity in farming areas possible (1). The use of corridors, by way of perches, shelters and food resources (33), facilitates the slightly more efficient distribution of forest bird guilds (11, 14, 16)

Generally speaking, forest fragments presented low insectivore diversity, possibly related to variations in their structure (4). According to Ribon *et al.* (2003) and Devey & Metzger (2005), as habitat-specialist bird guilds are more sensitive to alterations in landscape elements, such as fragmentation, this could possibly account for local extinction. These aspects are thus relevant for enlightenment on the use of the most appropriate landscape elements for each guild.

As regards matrix environments, normally, omnivore guilds are the most relatively important, followed by granivores. In the present case, omnivore guilds were the most abundant (15.23%). This guild was mainly formed by Passeriformes (75.4%), predominantly by species of the family Thraupidae (24.5%). The greater omnivore density in relation to granivores presumes that alterations in a landscape are capable of inducing structural changes in the environment, which would reflect on local bird-guild abundance. Corroborating Willis (1976), the increase in omnivores is expected in small environments, since omnivorousness would have a buffer effect against fluctuations in the available food supply thereabouts. Habitat structure is a relevant factor in the composition of bird-guild communities in tropical environments (30). MacArthur & Whitmore

(1979) noted that, depending on its size, guild diversity in a forest fragment can endure distance from a source and the prevailing habitat structure. As regards the fragment environment, granivore guilds were relatively the most important, followed by the omnivores. Marini (2001) also registered the highest diversity of granivores in small forest patches of the cerrado. On the contrary, in the corridor environment, the omnivore guild presented the highest relative importance, followed by the granivores. In the highly man-formed environments, omnivore guilds were on the increase (23). In the matrix environments, granivore guilds presented the highest relative importance, followed by the omnivores. A guild distribution pattern in relation to the three environments sampled became apparent. This pattern indicated that guilds that are the most adaptable to an environment, and to establishing therein, are those capable of movement among landscape elements (31) (Figure 4). All the environments sampled appeared to undergo direct influence from the matrix. Through being reduced environments (1 to 12 ha), fragments functioned as islands, with the available resources limited to some, less sensitive, groups. Apparently, certain factors, such as original habitat loss and a reduction in remnants (2), are limiting factors to the presence of certain groups.

Guild distribution in the environments under study seemed to be linked to bird community composition and the physical structure of the vegetal mosaic. As to individuals, omnivore and granivore guilds were apparently predominant in corridors and matrices. The low frugivore density could be related to seasonal variation in the offer of fruits, and the dependency on fruits and insects (15). Semi-

dependent insectivore guilds were observed in several fragments and corridors. The capacity of dispersion of these groups was favored by the structure and availability of landscape elements.

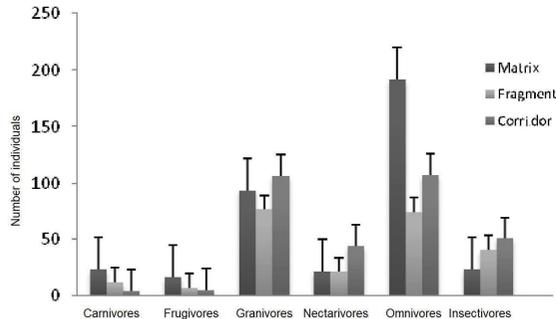


Figure 4. Relative abundance of bird guilds in the three environments.

## CONCLUSION

The response of the various avian guilds to the elements of a fragmented agricultural landscape showed the importance of insectivores in the separation of the three environments evaluated, viz., fragments, corridors and matrices. On considering species and individual analysis, it was noted that the distribution of frequency was not the same, the distribution of diversity remained the same, and avian guild composition was not maintained among the three.

## RESUMO

Foi analisada a estrutura de guildas alimentares na comunidade de aves num sistema fragmento-corredor-matriz em ambiente de Cerrado, no município de Lavras, Minas Gerais (21o14'45''S/44o59'51''W). Foram amostrados oito (8) fragmentos de floresta estacional semidecidual de 1,0 a 12,1 ha, conectados por 5 corredores ecológicos delimitados por uma matriz agrícola adjacente. A hipótese a ser testada é se a distribuição da frequência, diversidade e composição das guildas alimentares é similar entre os fragmentos, corredores ecológicos e matriz. Foram registradas 176 espécies de aves, pertencentes a 44 famílias. As principais guildas registradas foram insetívoros, onívoros, granívoros. Os ambientes amostrados são estatisticamente dissimilares para a distribuição e composição

das guildas. A composição das guildas é alterada pelos diferentes componentes da paisagem. Houve predomínio das guildas de insetívoros (68 espécies) e de onívoros (53 espécies), de maneira geral. Contudo, a média de espécies da guilda de onívoros e granívoros foi maior na matriz e nos corredores que nos fragmentos. Os corredores ecológicos funcionam de maneira eficiente para o deslocamento de espécies generalistas, fato que pode mascarar a redução da riqueza de espécies na área.

**Palavras chave:** aves, fragmentos florestais, guildas alimentares.

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## EMERGENCE AND GROWTH OF *ATELEIA GLAZIOVEANA* BAILL. SEEDLINGS IN DIRECT SOWING IN AN EARLY SECONDARY SUCCESSION STAGE

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### ABSTRACT

*Ateleia glazioveana* Baill. (Fabaceae), a pioneer tree species from south and southeastern Brazil, reaches a high population density in Seasonal Forests. The aim was to analyze the emergence, growth and survival of *A. glazioveana* seedlings under natural conditions. The experiment was installed in an eleven-year-old post-agricultural site, with herbaceous vegetation in an early stage of secondary succession. The plots measured 2 x 3 m, with four random replications in four blocks. The experimental design was factorial 2 x 2 x 2, in two different conditions of vegetation management (with and without the removal of herbaceous and shrubby plants), two levels of fertilizer (with and without the addition of 33 g/m<sup>2</sup> of NPK 4:20:12), and with and without seed sowing. Each plot received 200 seeds, i.e., 33 seeds/m<sup>2</sup>. Dates of emergence and survival were recorded at the second, fifth and twelfth months. Growth data (height and diameter) were obtained after 12 months. Spontaneous emergence was nil. Emergence from direct sowing reached a total of 48 (1.5%) seedlings after two months, and 77 (2.4%) after 12 months, from which 56 survived, viz. 5.833 per hectare. Although the removal of vegetation had no effect on seedling height and survival, diameters were increased. Moreover, differences with the addition of fertilizer were insignificant. The average height was 11.96 cm ( $\pm 4.08$ ). Direct sowing was viable. Even so, frost damage after the winter of 2010 was general, thus indicating the possibility of microclimate limitations to recruitment.

**Key words:** secondary succession, Forest restoration, Semideciduous Seasonal Forest.

### INTRODUCTION

Although pre-colonial cover by Subtropical Semideciduous Forest was 1,000,000 km<sup>2</sup>, including Brazil, Argentina and Paraguay, nowadays this has been reduced to only 6% of the original area (4). The remnants present high reduction and fragmentation, with an expressive degree of isolation (23).

Forest fragmentation leads to significant modifications in the composition, structure and

dynamics of local communities and populations, with a corresponding reduction in species habitat and ecological niche (19). Forest restoration could be helpful in reducing wild ecosystem fragmentation, promoting the improvement of degraded areas, and recovering environmental services. Seedling planting with a combination of tree species from different successional groups, is a frequently used method for restoring forest cover (16, 15, 24). Notwithstanding, direct sowing and spontaneous

regeneration are promising alternatives for minimizing costs, and making restoration feasible from a socioeconomic point of view (10). Direct sowing is particularly recommended for both pioneer and early secondary species, and for sites without vegetal cover. It is also recommended for late successional species in secondary forest enrichment (15).

Secondary succession is the transformation, over time, of the community structure, following a local disturbance (13). The first species to colonize a given site are denominated pioneers. Pioneers are capable of facilitating, hindering, or simply playing a neutral role, in the settlement and growth of other species (9).

Plant population renewal or recruitment presents a series of limitations. These limiting factors can be divided into three groups, namely source and fecundity, dispersion and establishment. The source and fecundity refers to limitations in seed production by adult plants. Such limitations could be related to climate variation (lack or excess of rain, late frosts, etc.) or biotic factors (lack of pollinators and flowers, or fruit predation). Moreover, seed availability, besides being variable year to year, is also affected by landscape structure and the size of neighboring, wild remnant vegetation. Dispersion efficiency depends on the available dispersion agents and propagule quality (8). *A. glazioveana* is wind-dispersed, so that the force, amount and direction of the winds are all determinant for dispersion efficiency.

Establishment factors refer to seedling survival and development. Losses throughout the process could be due to predation, competition or the inadaptability of seedlings to local ecological conditions. In the case of early succession stages in abandoned cropland (old-field succession), competition with herbs and climbing plants could be the most limiting factor for woody species (5). Herbaceous vegetation withdrawal or topsoil removal could improve the germination rates and early growth of woody species (25,12).

*Ateleia glazioveana* Baill. (Fabaceae), a pioneer tree species in Seasonal Subtropical Forest and secondary forest formations in south and southeastern Brazil, Argentina (Misiones) and Paraguay, is outstanding by its high-capacity to occupy sites with adverse conditions. The fruit is an

orbicular, samaroid, indehiscent legume with only one seed that reaches maturity between May and August. Dispersion is anemochoric (6). The species, through association with nitrogen fixative bacteria, provides an excellent green manure. The foliage in dry matter can reach 3.5 to 4.9 % of nitrogen (1). This species, dominant in the first stages of forest succession, remains as a canopy component in the late succession stages and frequently forms spontaneous monospecific stands denominated 'timbozais' in the vernacular (2). Thus, the presence and regeneration of *A. glazioveana* can play a key role in nutrient cycling processes and the recruitment of other species.

The aim was to evaluate spontaneous and induced recruitment through the direct sowing of *A. glazioveana* seeds under various management conditions. The experiment was carried out in an 11-year-old post-agricultural site with herbaceous vegetation in an early stage of secondary succession. The spontaneous emergence of other tree species was also quantified.

## METHODOLOGY

### *Study site*

The experiment was carried out in a forest remnant named 'Mato do Silva', in Chiapetta, State of Rio Grande do Sul, Brazil (27° 55' 02" S and 53° 53' 18" W). The climate is SL PU perhumid subtropical, with an average annual temperature of 19 °C, and annual rainfall of 1,800 mm (17). The altitude ranges between 400 and 472 m above mean sea level. The forest remnant comprises 240 ha of late successional semi-deciduous seasonal forest, and around 50 ha of areas of secondary herbaceous or secondary forest vegetation (2).

The area of the experiment was an abandoned cropland, which after 11 years has become dominated by Poaceae such as *Saccharum villosum* Steud. (dominant), *Schizachyrium microstachyum* (Ham.) Roseng. et al., *Leersia hexandra* Sw., and *Calamagrostis viridiflavescens* Steud. Sparse individuals of various woody species also occur, especially *Schinus terebinthifolius* Raddi and *Aegiphila brachiata* Vell. The topographic level ranges between 402 and 403 m above mean sea level (Figure 1). The late successional Semi-deciduous Seasonal Forest begins 100 meters from the 408 m

quota. Physicochemical soil data were provided by UNIJUÍ Soil Laboratory (Table 1).

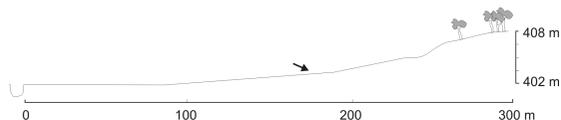


Figure 1. Topographic diagram in a northeast-southwest direction between the Inhacorá River, on the left, and the beginning of secondary forest dominated by *A. glazioveana*, on the right. The arrow indicates the location of the experiment, between the quotas 402 and 403 m above sea level.

Table 1. Soil physicochemical profile in an old-field with secondary vegetation, Mato do Silva, Chiapetta-RS, Brazil, 2009.

pH	P	K	S	Cu	Zn	Mn	Ca	Mg	Al	H + Al	CEC (pH = 7.0)	V %	M %	O.M. (%)
mg/dm <sup>3</sup>							cmol/dm <sup>3</sup>							
5.9	4.2	73.0	4.3	8.3	4.9	54.1	7.0	2.9	0.0	4.2	14.6	71.0	0.0	4.0

#### Experimental protocol

Seeds of *A. glazioveana*, gathered between July and September, 2009, were first cleaned and then stored at room temperature in sealed recipients. It was sowing by casting was in October, 2009, in plots measuring 2 x 3 m. Data on emergence, survival and growth were obtained between December, 2009 and October, 2010. The experimental design was factorial 2 x 2 x 2, under two different conditions of vegetation management, viz., with and without the removal of herbaceous and shrubby plants, with and without the addition of fertilizer, and with and without seed sowing.

The fertilizer used was 33 g/m<sup>2</sup> of NPK 4:20:12. Two hundred seeds, corresponding to 33 per m<sup>2</sup>, were sowed in each plot.

Each treatment consisted of four replications distributed at random, one per block. The blocks were located in transverse strips in relation to the slope of the site. The northward-sloping inclination of the site was 2%.

Emergence and survival were recorded after 60 days (December, 2009), 150 days (March, 2010) and one year (October, 2010). After one year, the maximum height and the diameter of the basal portion of the stem were measured with ruler and pachymeter.

Seed germination capacity, determined in a greenhouse in the IRDeR- Instituto Regional de Desenvolvimento Rural (UNIJUÍ), at ambient temperature and in a PLANTMAX ® substrate (a mixture of vermiculite and *Pinus* residues), was 55%.

#### Statistical Analysis

Considering as experimental factors vegetation removal and the addition of fertilizer, analysis of seedling emergence with direct sowing was by one-factor ANOVA, whereas comparative analysis of maximum height and diameter was by two-factor ANOVA. Seeing that emergence without seed sowing under the prescribed conditions was zero, these experiments were excluded from the analysis.

## RESULTS

Emergence only occurred in treatments with sowing (Table 2), thus spontaneous emergence was nil.

After one year, there was no significant difference among treatments as regards emergence or the number of remnant seedlings. The highest emergence rate occurred in the first 60 days, reaching 48 seedlings. After one year, 77 seedlings had emerged (Figure 2), corresponding to a density of 8.021 seedlings per ha.

Table 2. Survivor seedlings (% of seeds) of *Ateleia glazioveana* obtained through direct sowing, Mato do Silva, Chiapetta-RS, 2009-2010. There was no difference at any time among treatments ( $P > 0.05$ ).

	R	RF	NR	NRF	Total
December, 2009	2.1	1.4	0.9	1.6	1.5
March, 2010	0.9	1.4	4.6	0.4	1.8
October, 2010	0.5	1.4	4.9	0.3	1.8

R = removal of vegetation without fertilizer, RF = removal of vegetation with fertilizer, NR = without both vegetation removal and fertilizer, NRF = without vegetation removal, but with the addition of fertilizer

Between 150 days and one year, 21 seedlings (36% of the total emergence) had disappeared, the remaining 56 thus corresponding to a density of 5.833 seedlings per hectare.

As to average height, no difference was observed among treatments, the overall average height reaching 11.96 cm ( $\pm 4.08$ ).

The average diameter of seedlings in treatments with vegetation removal was higher than those without

removal. There was no significant difference with the addition of fertilizer (Table 3 and Figure 3).

On the 60<sup>th</sup> day, three seedlings of other species were observed, two of *Eugenia uniflora* L. and one of *Allophylus edulis* (A. St.-Hil.) Niederl. One *E. uniflora* seedling disappeared between 150 days and one year.

In October, 2010, all the seedlings presented signs of frost damage, which caused loss of the shoot apex and the absence of lateral bud expansion.

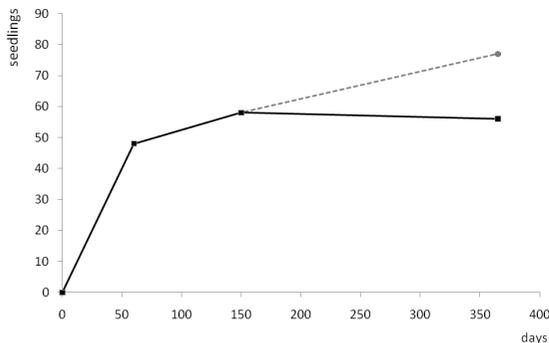


Figure 2. As a sum of all treatments, accumulated emergence (dashed line) and survival (solid line) of *A. glazioveana* seedlings in direct sowing, Mato do Silva, Chiapetta, State of Rio Grande do Sul, 2009-2010.

Table 3. Two-factor ANOVA results for the variable 'diameter'; comparison among treatments R, RF (with vegetation removal) and NR, NRF (without vegetation removal). \* indicates  $P < 0.05$ .

Source of Variation	Df	Mean square	F	P
Interaction	1	1.19	0.834	0.368
Vegetation removal	1	6.25 *	4.375	0.045 *
Fertilizer added	1	0.358	0.251	0.620
Residual	30	1.43		

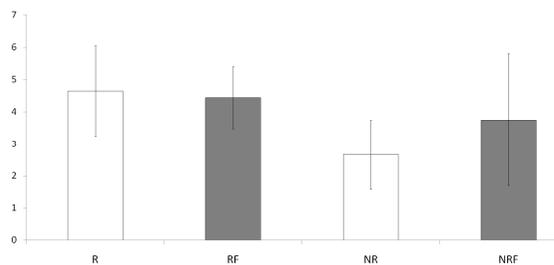


Figure 3. Stem basal diameter (mm) of *A. glazioveana* seedlings after one year of direct sowing in Mato do Silva, Chiapetta, State of Rio Grande do Sul, 2010. Treatments R and RF are with vegetation removal, treatments NR and NRF, without. The gray columns indicate the addition of fertilizer (33 g/m<sup>2</sup> of NPK 4:20:12). Vertical bars indicate standard error.

## DISCUSSION

Seedling emergence only occurred in treatments that received seeds. The absence of spontaneous emergence could be explained by insufficient seed dispersion or high predation prior to initiating the experiment. Furthermore, data on sowed plots showed that emergence continued after 150 days (after April, 2010), a sure indication that the winter of that year was not severe enough to hinder the course of seedling emergence.

Curiously, although local seed rain was apparently insufficient, the production of seeds was high during 2009 and *A. glazioveana* is abundant in the vicinity, reaching dominance above the quota 405 m. a. s. L., 70 m from the experiment (7).

The addition of fertilizer caused no increase in seedling growth during the first year. As a rule, pioneer tree species respond to fertilization with an increase in growth, whereas late successional species respond either weakly or insignificantly (21). To several species, with direct sowing, both in greenhouse (3), and in the field (14), the addition of fertilizers or organic soil increases seedling growth.

The removal of vegetation induced an increase in stem diameter, since the presence of herbaceous plants can reduce light intensity, a possible cause of thinner stems. In spite of such low-light-intensity conditions are capable of inducing an increase in height, damage to the shoot apex caused by the frosts of 2010 supposedly prevented differences among treatments.

Shoot-apex damage, which suggests sensitivity to frost in the seedling stage, could have been a limiting factor to species settlement. The experiment was located 150 meters from, and less than one meter above, the Inhacorá River, thus favorable to the occurrence of subzero temperatures, since cold air tends to move to lower topographic levels (20). The species is considered only moderately tolerant to cold, whereby it presents growth limitations when subjected to heavy frosts during experimental planting (6). Furthermore, as wind intensity can be low in the bottom of valleys, seed dispersion is less and consequently recruitment reduced.

Seedling height after one year of experimentation can be considered low when

compared with other experimental studies with direct sowing. For example: Soares & Rodrigues (2008) recorded a wide variation in the heights of Fabaceae tree species sowed in abandoned cropland, of 30 cm for *Bowdichia virgilioides* Kunth to 3 m for *Acacia polyphylla* DC, after 13 months; Mattei & Rosenthal (2002) registered heights between 29 and 66 cm for *Peltophorum dubium* (Spreng.) Taub., in secondary forest enrichment through direct sowing, after 18 months; Engel & Parrotta (2001) observed heights ranging from 20 cm (*Ceiba speciosa* [A. St.-Hil] Ravenna) to 170 cm for *Schizolobium parahyba* (Vell.) Blake, after two years of direct sowing in Botucatu, São Paulo; Camargo *et al.* (2002), noted heights ranging between 38 and 85 cm for *Caryocar villosum* Aubl., and 20 and 45 cm for *Parkia multijuga* Benth. in Amazonia, after one year of direct sowing; and finally, Ferreira *et al.* (2007) reported heights ranging from 200 to 250 cm after 15 months of direct sowing for *Trema micrantha* (L.) Blüme, *Senna multijuga* (L. C. Rich) Irwin & Barneby, *S. macranthera* (Collad.) Irwin & Barneby, and *Solanum mauritianum* Scopoli.

Data indicate that the regeneration of *A. glazioviana* through direct sowing is viable, even without vegetation removal. On the other hand, the occurrence of severe frosts can hamper species survival and recruitment. Direct sowing, though being a low-cost restoration method, requires a longer period of monitoring, in order to check whether plants can reach sufficient densities, to so establish a viable forest structure.

## ACKNOWLEDGEMENTS

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## RESUMO

Emergência e crescimento de plântulas de *Ateleia glazioviana* Baill. em sementeira direta em um estágio sucessional inicial. *Ateleia glazioviana* (Fabaceae) é uma espécie arbórea pioneira que ocorre no Sul e Sudeste do Brasil, alcançando grandes

densidades populacionais na Floresta Estacional. O objetivo deste trabalho foi analisar a emergência, crescimento e sobrevivência de plântulas de *A. glazioviana* em condições naturais. O ensaio foi instalado em uma área agrícola abandonada por 11 anos, com vegetação herbácea em fase inicial de sucessão secundária. As parcelas tinham 2 x 3 m, com 4 repetições, em 4 blocos casualizados. O desenho experimental foi um fatorial de 2 x 2 x 2, com duas diferentes condições de manejo da vegetação (com e sem remoção da vegetação herbácea e arbustiva), dois níveis de fertilização (adição de 33 g/m<sup>2</sup> de NPK 4:20:12 e sem adição de fertilizante) e com ou sem adição de sementes. As parcelas com sementeira receberam 200 sementes, o que corresponde a 33 sementes/m<sup>2</sup>. O registro de dados de emergência e sobrevivência foi feito aos dois, cinco e 12 meses. Os dados de crescimento (diâmetro do colo e altura) foram obtidos após 12 meses. A emergência espontânea de *A. glazioviana* foi nula. A emergência produzida pela sementeira direta atingiu um total de 48 (1,5%) plântulas após dois meses e 77 (2,4%) plântulas após 12 meses. Destas, 56 plântulas sobreviveram após 12 meses, o que corresponde 5.883 plântulas por hectare. Os tratamentos não diferiram quanto à altura e sobrevivência, entretanto os tratamentos submetidos à retirada da vegetação apresentaram plântulas com maior diâmetro do colo. A adição de fertilizante não gerou diferenças significativas. A altura média das plântulas após 12 meses foi de 11,96 cm ( $\pm$  4,08). A sementeira direta se mostrou viável, porém todas as mudas apresentaram danos causados pela geada após o inverno de 2010, indicando limitações microclimáticas ao recrutamento.

**Palavras chave:** sucessão secundária, restauração florestal, Floresta Estacional Semidecidual.

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## PLANT RICHNESS IN EXOTIC TREE PLANTATIONS IN RIO GRANDE MUNICIPALITY, RIO GRANDE DO SUL STATE, BRAZIL

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### ABSTRACT

The aim was to investigate vegetal richness inside two exotic tree-species plantations, as well as to analyze the influence of light and litter. One of the areas was a 30 ha plantation of *Eucalyptus tereticornis* Sm. and *E. robusta* Sm., and the other a 3 ha plantation of *Pinus elliottii* Engelm. In each, twenty-five 5x10 m plots were marked out, so as to investigate the structure of the vegetal community. The presence of tree, bush, epiphyte, climbing and herb species was registered. 25 samples of litter from each area were collected by way of square frames measuring 625 cm<sup>2</sup>. Light intensity was measured in all the plots. Spatial richness and the distribution of species were correlated with the distance from the plantation-edge, litter-disposal and light-intensity. Richness was measured and analyzed according to the number of species. The area of *Eucalyptus* spp. presented 18 species and that of *P. elliottii* 14. *Tillandsia aeranthos* Desf. ex Steud., the most frequent species in both areas, was registered in all the plots. In the *P. elliottii* plantation, richness diminished with the increase in distance from the edge and with the reduction in light-intensity. In both study-areas, the number of species decreased in accordance with the increase of litter. Concomitantly, richness presented a higher correlation with light intensity. The data indicate the need for monitoring and amplifying the intensity of light as a strategy for regenerating vegetal communities.

**Key-words:** richness, invasive tree species; exotic-species monoculture; *Pinus*; *Eucalyptus*.

### INTRODUCTION

The coastal regions of Rio Grande do Sul State, Brazil, through comprising a varied assortment of environments, such as swamps, salt marshes, dunes and prairies, facilitate the formation of distinct vegetal contions with high plant diversity, herbaceous plants and trees amongst others (15). Recent anthropic activities have caused negative impacts and disturbance. Exotic tree and rice cultivation, cattle raising and real estate expansion are among the human activities accountable for

degradation in the southern Rio Grande do Sul coastal region (6, 4). The introduction of exotic-tree species is one of the greatest threats to local biodiversity, through the introduction of pathogens, competition, allelopathy and the formation of physical barriers (19).

Exotic species are defined as those that occur outside the natural and historically known limits, as a result of accidental or intentional human dispersion. Invasive species are those which, once having been introduced and adapted to the new environment, begin spontaneous reproduction and

occupy the space of native species, thereby inducing modifications in ecological processes, reaching to dominance (26). Biological contamination is pointed out as being the second main cause of extinction worldwide, surpassed only by fragmentation and habitat loss (19).

*Pinus* species, natives of the Northern Hemisphere, are among those with the highest invasive potential worldwide. Around the 1950's, they were introduced into Brazil for pulp production, their culture being largely stimulated by tax incentives. *Pinus* spp. is cultivated in the coastal region of Rio Grande do Sul State for resin production. It is anemophilous and wind-dispersed, with a dispersal range of 25 km. The more than 90% seedling emergence facilitates its adaptation to any ecosystem. Furthermore, it is highly fire resistant. The slow degradation and accumulation of pine needles in layers more than 20 cm deep acidifies the soil (19, 25).

The genus *Eucalyptus*, native of Oceania, was introduced into Brazil at the end of the nineteenth century. *Eucalyptus* species were widely used for railroad sleepers, fence posts, lamp posts, the drainage of bogs and marshes, and as windbreaks. Besides the fast growth rate, their extensive cultivation was much favored by their innate capacity for adaptation to various soil types and fertility levels (13). Since the 1970's, they have been used for pulp production, recently with the inclusion of genetically modified species. In 2000, *Eucalyptus* cultivation occupied an area of 3.0 million hectares of the 4.8 million dedicated to forestry in Brazil (1).

Whereas some authors advocate the importance of planting exotic trees in the regeneration of native vegetation (8, 20, 23), little research has been carried out to measure the impact of *Pinus* or *Eucalyptus* homogeneous plantations on local biodiversity (26, 16, 21), with a complete lack along the Southern Brazilian coastal region.

The aim was to describe the richness and structure of the plant communities inside two exotic plantations, one of *Pinus elliottii* Engelm. and the other of *Eucalyptus tereticornis* Sm. and *E. robusta* Sm. The correlations among litter accumulation, light intensity and plant spatial patterns were also analyzed.

## METHODOLOGY

The sites are located on the coastal plains of Rio Grande municipality, Rio Grande do Sul State. According to the Köppen system, the climate is Cfa humid subtropical. The average temperatures are: annual 17.9 °C., in the hottest month 23.3 °C; and in the coldest month 12.7 °C. The average annual rainfall is 1,252 mm, and relative humidity around 80%. The predominant wind direction in all seasons is northeast (18).

Plantations were with 2x3m spacing and with no commercial exploitation. The study took place between April, 2008 and November, 2009.

The nearly 25-year-old *P. elliottii* plantation, within an area of three ha, was located in the campus of the Rio Grande Federal University (FURG), 2 meters above sea level, at the coordinates 32° 04' 58.67" S and 52° 09' 21.10" W. The adjacent areas were meadows, urban areas, and other *Pinus* and *Eucalyptus* cultivations.

The nearly 30-year-old *Eucalyptus* spp. plantation, comprising two species, *E. tereticornis* and *E. robusta*, was located in an area of 35 ha in the 6<sup>th</sup> Industrial District of Rio Grande, within the coordinates 32° 07' 40.54" S and 52° 08' 21.60" W, 19 meters above sea level. The adjacent areas consisted of meadows, woody fields, swamps, and a sandbank forest inside a conservation area.

Richness was measured and analyzed through species quantification. Frequency and the number of species were estimated using the fixed-plot method (14). Five demarked areas of 5x50m were each divided into five plots, to a total of 25 plots of 50 m<sup>2</sup> and 1250 m<sup>2</sup> of total sampled area in the two sites. Within each spot, two plots of 1 x 1 m were delimited for herbaceous sinusia sampling. The demarked areas were placed so that the first were situated on the border and those subsequent towards the interior (Figure 1). For herbaceous sinusia, plants smaller than 30 cm high were recorded. For tree sampling, plants with DBH (diameter breast height)  $\geq$  5.0 cm at a height of 1.30 m above ground level were included. All epiphytic plants observed in the plots were recorded, this including hemi-epiphytic species. Terrestrial plants that use others as support were included as climbing plants, together with woody lianas (10). The sample was evaluated through the sample sufficiency curve.

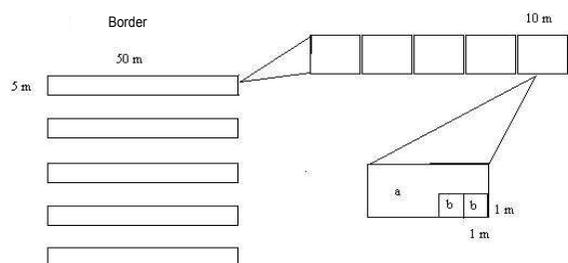


Figure 1 – Distribution of plots in the plantations, ‘b’ is the sampling spot used for herbs, and ‘a’ the spot for other sinusiae.

Other species observed inside the plantations, but not encountered in the plots, were registered to so complement the floristic survey.

Species were identified according to the literature, and by consulting herbaria (HURG), experts, the Digital Data Bank of the Brazilian Flora Species Checklist, Flora Brasiliensis, the New York Botanical Garden, and the Missouri Botanical

Garden. The delimitation of *taxa* at the family level is according to the proposition for the Angiosperm Phylogeny Group III (3).

Litter was estimated by way of 25 samples obtained by a square iron frame with 25 cm sides. Samples were dried in a stove at 70 °C, and weighed with a precision balance (15). Light intensity (expressed as  $\mu\text{mol s}^{-1}\text{m}^{-2}$ ) was estimated with a LI-COR Radiation Sensor in each sampling spot.

The Spearman rank correlation was determined for analyzing relationships between richness, litter and light intensity.

## RESULTS

In the *Eucalyptus* plantation, there were 18 species belonging to 15 families (Table 1), two species each from Cyperaceae, Poaceae and Polypodiaceae, and only one each from the others. Sixteen (88%) species were native, one exotic and one cosmopolitan (Table 1).

Tabela 1. Absolute (FA) and relative (FR) frequency of the species recorded in the *Eucalyptus* spp. plantation.

Species (Family)	Life form	Origin	FA	FR
<i>Eucalyptus</i> spp. (Myrtaceae)	AR	EX	100	26,32
<i>Tillandsia aeranthos</i> Desf. ex Steud. (Bromeliaceae)	E	N	100	26,32
<i>Axonopus fissifolius</i> (Raddi) Kuhl. (Poaceae)	H	N	76	20
<i>Microgramma vacciniifolia</i> (Langsd. & Fisch.) Copel. (Polypodiaceae)	E	N	40	10,53
<i>Eleocharis bicolor</i> Chapm. (Cyperaceae)	H	N	12	3,16
<i>Ficus cestrifolia</i> Schott ex Spreng. (Moraceae)	Eh	N	12	3,16
<i>Smilax campestris</i> Griseb. (Smilacaceae)	T	N	12	3,16
<i>Myrsine parvifolia</i> A.DC. (Primulaceae)	AR/AB	N	8	2,11
<i>Pycreus polystachyos</i> (Rottb.) P.Beauv. (Cyperaceae)	H	N	4	1,05
<i>Dichanthelium sabulorum</i> (Lam.) Gould & C.A. Clark (Poaceae)	H	N	4	1,05
<i>Pleopeltis pleopeltifolia</i> (Raddi) Alston (Polypodiaceae)	E	N	4	1,05
<i>Centella asiatica</i> (L.) Urb. (Apiaceae)	H	C	4	1,05
<i>Citharexylum montevidense</i> (Spreng.) Moldenke (Verbenaceae)	AR/AB	N	4	1,05
<i>Lithrea brasiliensis</i> Marchand (Anacardiaceae)	AB	N	-	-
<i>Hydrocotyle bonariensis</i> Lam. (Araliaceae)	H	N	-	-
<i>Senecio brasiliensis</i> (Spreng.) Less. (Asteraceae)	H	N	-	-
<i>Rhipsalis teres</i> (Vell.) Steud. (Cactaceae)	E	N	-	-
<i>Daphnopsis racemosa</i> Griseb. (Thymelaeaceae)	AR/AB	N	-	-

AB= tree; AR= shrub; E= epiphyte; H= herb; T= climbings; N= native; C= cosmopolitan; EX= exotic; Eh= hemiepiphyte; - = species observed out the sampling plots.

For *P. elliotii*, there were 14 species belonging to 12 families (Table 2), among which 11 (79%) were native and 3 (21%) exotic. There were two species each from Fabaceae and Myrtaceae, and only one each from the other 10 (Table 2).

Tabela 2. Absolute (FA) and relative (FR) frequency of the species recorded in the *Pinus elliotii* plantation.

Species (Family)	Life form	Origin	FA	FR
<i>Pinus elliotii</i> Engelm. (Pinaceae)	AB	EX	100	32,47
<i>Tillandsia aeranthos</i> Desf. ex Steud. (Bromeliaceae)	E	N	100	32,47
<i>Axonopus fissifolius</i> (Raddi) Kuhlm. (Poaceae)	H	N	40	12,99
<i>Acacia longifolia</i> (Andrews) Willd. (Fabaceae)	AR/AB	EX	16	5,18
<i>Schinus terebinthifolius</i> Raddi (Anacardiaceae)	AB	N	16	5,19
<i>Ipomoea cairica</i> (L.) Sweet (Convolvulaceae)	T	N	12	3,90
<i>Desmodium adscendens</i> (Sw.) DC. (Fabaceae)	H	N	8	2,60
<i>Hydrocotyle bonariensis</i> Lam. (Araliaceae)	H	N	4	1,30
<i>Rumohra adiantiformis</i> (G.Forst.) Ching (Dryopteridaceae)	H	N	4	1,30
<i>Sida rhombifolia</i> L. (Malvaceae)	H	N	4	1,30
<i>Syzygium cumini</i> (L.) Skeels (Myrtaceae)	AR/AB	EX	4	1,30
<i>Sapium glandulosum</i> (L.) Morong (Euphorbiaceae)	AB	N	-	-
<i>Myrsine parvifolia</i> A.DC. (Primulaceae)	AR/AB	N	-	-
<i>Eugenia uniflora</i> L. (Myrtaceae)	AB	N	-	-

AB= tree; AR= shrub; E= epiphyte; H= herb; T= climbing; N= native; C= cosmopolitan; EX= exotic; Eh = hemiepiphyte; - = species observed out the sampling plots.

The two sites contained four species in common: *Tillandsia aeranthos*, *Hydrocotyle bonariensis*, *Myrsine parvifolia*, *Axonopus fissifolius*. Seven woody species were recorded in the two sites, four in the *P. elliotii* (Table 2) and another three in the *Eucalyptus* (Table 1).

*Tillandsia aeranthos* was present in all the plots in both sites. *Axonopus fissifolius* was the second most common species (Table 1 and 2).

On considering only plots, the *Eucalyptus* and *Pinus* sites presented 13 and 11 species, respectively. All the sinusiae were represented in both areas, with the predominance of herbs (Table 3). Although epiphytes comprised the second richest sinusia in the *Eucalyptus* site, only one was observed in the *Pinus*.

Whereas in the *Eucalyptus* site sample sufficiency analysis indicated stabilization in the seventeenth spot (Figure 2), in the *Pinus* the absence of a clear stabilization (Figure 2) could be related to differences in richness between edge and interior plots.

In the *Eucalyptus* site, the lowest values for accumulated litter were in the edge plots and the highest in the intermediate (Figure 3), whereas species richness was inversely proportional to litter levels (Figure 3 on left), with  $r = -0.60$ .

Table 3 – Richness and sinusia in the sampling plots on each site

Sinusia	Eucalyptus	Pinus
Herbs	5 (38%)	5 (46%)
Trees	2 (15%)	2 (18%)
Shrubs	1 (8%)	2 (18%)
Epiphytes	4 (34%)	1 (9%)
Climbing	1 (8%)	1 (9%)
Total	13	11

Litter accumulation in the *Pinus* site was higher than in the *Eucalyptus*, and was inversely proportional to the distance from the edge (Figure 3). Furthermore, species richness was inversely proportional to accumulated litter (Figure 3 on the right), with  $r = -0.87$ .

In the *Eucalyptus* site, the lowest light intensity was registered in the intermediate plots. There was a significant correlation of richness with light intensity ( $r = 0.90$ ) (Figure 4 on the left).

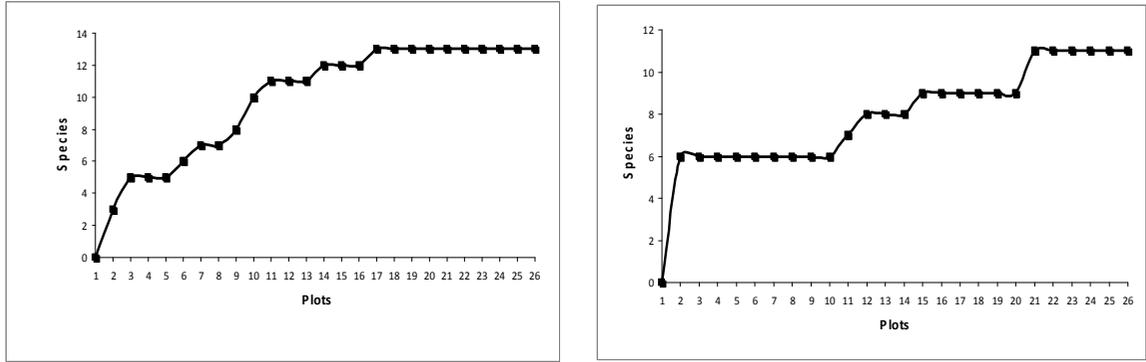


Figure 2 – Cumulative curve of species per spot in a monoculture *Eucalyptus* area (on the left) and a *Pinus* area (on the right).

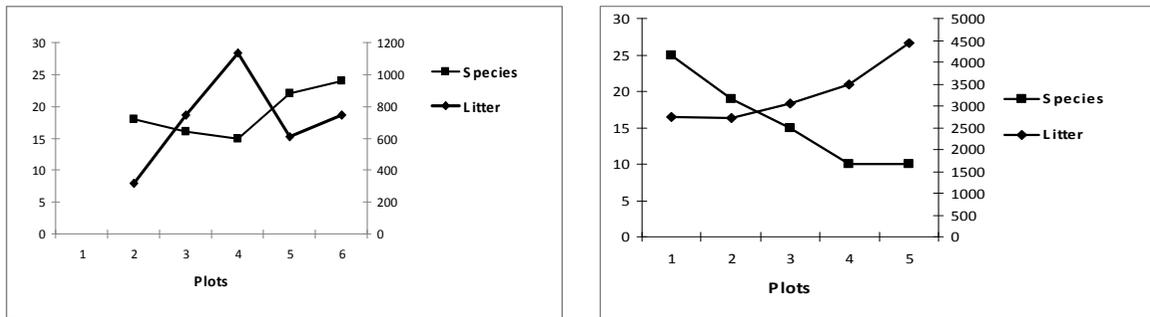


Figure 3 - Relationship between accumulated litter and richness in the *Eucalyptus* plantation (on the left) and in the *Pinus* (on the right).

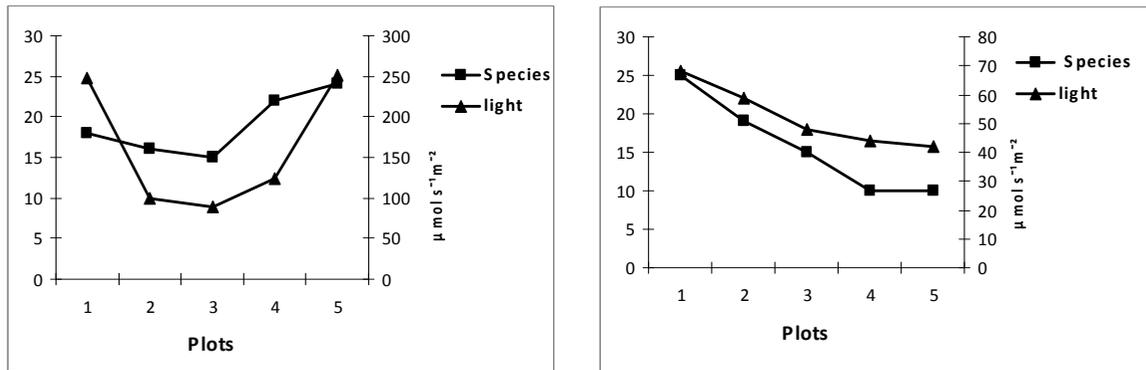


Figure 4 – Correlation between light intensity (triangles) and richness (squares) in the *Eucalyptus* site (on the left) and in the *Pinus* site (on the right).

In the *Pinus* site, light intensity was closely related to distance from the border. This pattern was accompanied by a significant correlation of richness with light intensity ( $r=0.97$ ) (Figure 4 on right).

### DISCUSSION

In spite of difficulties related to differences in method, the richness observed in our study could be considered low for both the *Eucalyptus* and *Pinus* sites, when compared to other inventories in

the same or other regions. It should be emphasized that, at the most, no more than one sinusia had been studied in those other inventories.

In native coastal ecosystems, plant richness is normally high, much more so than that noted in the present report. On recording the presence of 78 vascular plant species (including three endangered ones) in the Lagoa Verde Environmental Protection Area, Rio Grande municipality, Batista *et al.* (2007) used this to emphasize the extreme human disturbance in the area. Marangoni (2003) recorded 29 vascular

species in a site in the Lagoa dos Patos estuary. Porto & Dillenburg (1986) registered 151 vascular plants in two forest formations, one in a swamp and the other in sandy soil, located in the Taim Ecological Station. Kindel (2002) reported 158 vascular plants in a swampy forest in Torres municipality, Rio Grande do Sul State. In the Lagoa do Peixe National Park, Záchia (2006) recorded 100 plant species and Dorneles & Waechter (2004) 21 tree species.

Neri *et al.* (2005) recorded 47 species in a *Eucalyptus* site in the Brazilian Cerrado. The authors stressed that such low diversity, when compared to Cerrado diversity in general, could be attributed to shading.

In another similar study in the Cerrado, Saporetti *et al.* (2003) encountered 39 woody species. The authors, on pointing out that *Eucalypti* hinder the arrival of zoochoric and wind-dispersed native species, proposed *Eucalyptus* girdling and the permanence of dead trees to serve as perches.

Floristic studies of *Pinus* monocultures are few, in spite of species of this genus pointedly possessing high invasive potential and causing local diversity loss (26, 19). Even so, Andrae *et al.* (2005) reported understory establishment of 121 woody-plant species under 25-30-year-old pines in plantations in the Central Region of Rio Grande do Sul State.

Generally speaking, scientific papers refer to *Pinus*, *Eucalyptus* and other exotic tree species plantations as 'planted forest', 'commercial planted forest' (23) or 'reforestation' (2). Notwithstanding, a forest is a complex ecosystem, in which, not only one or two, but several species of plants, animals, fungi, protists and bacteria are involved.

Some studies indicate examples of *Pinus* and *Eucalyptus* as facilitating native forest regeneration (23). Nonetheless, the commercial management of such areas implies the use of agrochemicals to control plants, animals, fungi and bacteria, thereby hampering their complete development, whence the origin of the so-called "green deserts". The above mentioned studies were actually developed in non-commercial or abandoned areas of exotic tree plantations, thus where agrochemicals are no longer used, and where fallen trees generate gaps, thereby inducing native plant species development, beginning at the edges. According to light availability, native plant

regeneration could further expand to the interior, thus characterizing true restoration.

Nonetheless, even in noncommercial areas, the absence of patches of native forest, in regions with extensive *Pinus* and *Eucalyptus* plantations, could be a hinderance to native forest regeneration, since this requires seeds and propagules originating from other areas.

In the *Pinus* site, it was noted that the lowest plant richness was correlated to the highest litter accumulation, which, in turn, increased from the edges towards the interior. On the other hand, plant richness was positively correlated to light intensity. The scenario was similar in the *Eucalyptus* plantation. As plant richness was more highly correlated with light intensity than with litter accumulation and distance from the border, it can be deduced that a reduction in richness is strongly linked to the prevailing shade. However, the complementary contribution of litter to the decrease in richness cannot be discarded.

Although some authors point to the possibility of regeneration in homogeneous stands of exotic species through shading (2, 16, 21), this would be impossible in old plantations with trees of 30-meters or more in height. Hinderance would be especially stronger for tree species, when considering the observed predominance of herbs and epiphytes. In the *Eucalyptus* area only one tree species presented individuals with DBH  $\geq 5.0$  cm at 1.3 m above ground level, and in the *Pinus*, only one exotic woody species (*A. longifolia*) was observed, whence it is impossible to demonstrate regeneration in a plant community.

Considering the importance of biodiversity conservation, the adequate management of exotic-tree-species plantations, focusing native plant community restoration, requires top priority. This could be achieved through techniques that increase light intensity, such as tree girdling, as also proposed by previous authors (22).

However, the lower diversity found in exotic species monoculture may be due to other factors, such as allelopathy, a phenomenon in which substances released by the leaves and branches of tree species may hinder the development of other surrounding plants (9).

In Canada, Newmaster *et al.* (2006) proposed reforestation with native conifers, as the first step towards rehabilitating conifer forests that had been

converted to agriculture and then abandoned. However, in Brazil, *Pinus* may interfere in plant diversity, since its own regeneration is stimulated in detriment of native plants, insofar as light availability increases (5). On the other hand, abandoned non-commercial plantations that present well-developed understories, could serve as a source of seeds or seedlings for environmental restoration projects, an issue that needs further evaluation in the Atlantic Rain Forest Biome.

## CONCLUSION

Plant richness, reduced inside *Eucalyptus* and *Pinus* plantations, when compared to wild environments in the coastal ecoregion, is directly correlated to light intensity and inversely correlated to litter accumulation inside the plantations.

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## RESUMO

Este estudo teve como objetivo investigar a riqueza vegetal no interior de dois plantios de espécies arbóreas exóticas, analisando também as influências da luz e serrapilheira. Uma das áreas foi um plantio de *Eucalyptus tereticornis* Sm. e *E. robusta* Sm., com 30 ha. A outra área foi um plantio de *Pinus elliottii* Engelm. com três ha. Em cada área foram demarcadas 25 parcelas de 5 x 10 m para investigar a estrutura da comunidade vegetal. Registrou-se a presença de espécies arbóreas, arbustivas, epifíticas, trepadeiras e herbáceas. Foram coletadas 25 amostras de serrapilheira de cada área com o auxílio de uma moldura quadrada com 625 cm<sup>2</sup>. A intensidade de luz foi medida em todas as parcelas. A riqueza e a distribuição espacial das espécies foram correlacionadas com a distância da borda, a deposição da serrapilheira e a intensidade de luz. A riqueza foi mensurada e analisada através da quantidade de espécies. A área de *Eucalyptus* spp. apresentou 18 espécies e a área de *P. elliottii* 14 espécies. *Tillandsia aeranthos* Desf. ex Steud. foi a espécie mais freqüente em ambas as áreas, sendo registrada em todas as parcelas. Na plantação de *P. elliottii* a riqueza diminuiu com o aumento da distância da borda e com

a redução da intensidade de luz. O número de espécies diminuiu de acordo com o aumento de serrapilheira nas duas áreas. Em ambas as áreas a riqueza apresentou maior correlação com a intensidade luminosa. Os dados indicam a necessidade de monitorar e ampliar a intensidade luminosa como estratégia para a regeneração das comunidades vegetais.

**Palavras-chave:** riqueza, espécies arbóreas invasivas; monocultura de espécies exóticas; *Pinus*; *Eucalyptus*.

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## THE INFLUENCE OF FEEDING TREE SPATIAL DISTRIBUTION AND FRUIT ABUNDANCE IN THE LOCATION OF SLEEPING TREES IN THE COMMON MARMOSET, *CALLITRIX JACCHUS* (PRIMATES: CALLITRICHIDAE).

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### ABSTRACT

Security against predators, the proximity of food sources and cohesion within the group are factors which can have an influence on the localization of sleeping trees in primates. The aim was to investigate the influence of spatial distribution of gum and fruit trees, and the abundance of fruit in the localization of sleeping trees in the common marmoset. Two groups of marmosets living in the Parque das Natal, Rio Grande do Norte State were studied. Instantaneous scan sampling was used to register, at 5 minute intervals, their position on maps of the area, and to identify the localization of sleeping trees. Frequency of use of the same trees was also recorded. The species of trees used for fruit consumption, the extraction of gum and for sleeping were identified. Phenological data were collected monthly to determine the periods of fruit abundance. Sleeping trees were randomly distributed, without any apparent relationship to the aggregated distribution of gum and fruit trees. Nonetheless, the abundance of fruit seemed to be an important factor in the use of space and in the localization of sleeping trees. Both, the presence of potential predators and the nonconsecutive use of sleeping trees, seem to indicate protection against predators as being another important factor in the localization of sleeping trees in the study-area.

**Key words:** common marmoset; sleeping trees; food sources; predators

### INTRODUCTION

Arboreal primates typically sleep in trees. They use either the forks of branches, holes in the trunk (38, 43) the surface of leaves (23, 47, 5), nests they themselves build (26) or even bird's nests (29) in the process.

Predator risk has been defined as the main determinant in the location of sleeping trees (15, 25, 22, 1, 17, 7, 3, 37). Nevertheless, other variables, such as the proximity of food and water resources, ranging patterns and territoriality aspects, security from falls, physical comfort, hygiene, parasite avoidance, group cohesion, resource availability

and thermoregulation, are also important (16, 20, 44, 4, 23, 1, 3, 27, 14, 5).

Some species of primates (e.g. *Ateles geoffroyi* (11), *Colobus guereza* (46), *Hylobates pileatus* (36), *Saguinus fuscicollis* and *S. mystax* (40), *Trachypithecus leucocephalus* (28) prefer to sleep close to available food resources. The strategy to wake up close to food, decrease the time and energy spent in foraging. Apparently, in the case of these species, this factor is more important than sleeping in safety against predators.

The common marmoset (*Callitrix jacchus*) is a primate species endemic to the Brazilian northeast. Although its distribution was originally

restricted to this part, introduced populations can now be found in other regions of Brazil (43). It is now found in Atlantic Forest fragments, in the Caatinga (21), and in mangrove swamps (32). Through its adaptability to various environments, by living in the Atlantic Forest, this species inhabits one of the most threatened biomes in the world. This biome has been extensively transformed into a fragmented landscape (35), through conversion to alternative land usage, such as agriculture and pasture (45). Incidentally, several studies of small fragments of this forest have reported on the proximity of trees that serve for sleeping to feeding trees (1,8).

## OBJECTIVES

Under this perspective, the aim was to investigate the influence of gum and fruit tree spatial distribution, and fruit abundance in the location of sleeping trees.

## METHODOLOGY

### *Study area*

The study took place in a conservation area, in the Parque Estadual das Dunas (PED), in northeast Brazil ( $5^{\circ} 48' S - 35^{\circ} 12' W$ ). PED comprises a 1.175 ha fragment of the Atlantic Forest, 7 ha of which corresponding to a public area (24). There are large trees, extensive plant cover, a vast and continuous canopy, and high epiphyte density. With an idea to conservation, access is restricted to research and educational trails, with daily, though partial, monitoring.

The public area, with many exotic plants and gaps, harbors around a thousand tree species. There is also a touristic infrastructure for receiving more than 2.000 people daily. Each year, about 65.000 visitors find entertainment in the structure of the park itself, walking trails and picnicking, or simply by enjoying nature.

There are records of the presence of boa constrictors (*Boa constrictor*), black vultures (*Coragyps atratus*), turkey vultures (*Cathartes aura*), roadside hawks (*Buteo magnirostris*), great black hawks (*Buteogallus urubitinga*), white-tailed kites (*Elanus leucurus*), and the southern caracara

(*Polyborus plancus*) (24), all liable *Callithrix jacchus* predators.

### Data collection

From January to December, 2007, two groups of common marmosets (A and L) came under observation. Both inhabited the public area, and only used the forest area sporadically. In the former, there are trees conducting to fruit and gum consumption, and sleeping. Both groups were accustomed to the presence of researchers, and had already undergone capture and individual identification in previous years.

Instantaneous scan sampling (2), at 5-minute intervals, was chosen for recording the location of the marmosets on area maps containing alphanumeric system 20x20m quadrants, and for identifying the location of sleeping trees. These data also constituted the base for calculating the home range of each group, obtained as a sum of the quadrants visited. Frequency-of-use of sleeping trees was recorded, to so determine the proportion of use, by plant species.

The tree species turned to use for fruit consumption, gum extraction and sleeping, were identified taxonomically by on-the-spot floristic studies (18). Phenological data were collected monthly to determine the peak periods of fruit abundance. Fruiting was quantified using the semi-quantitative method (19), whence five classes of abundance are inferred, 0) absence of fruit; 1) 1-25% of fruit; 2) 26-50% of fruit; 3) 51-75% of fruit; and 4) 76-100% of fruit (19). Sleeping trees were identified, and measurements taken of height and diameter at breast height.

The distance from the nearest neighbor (R) was used to define spatial patterns of gum and fruit tree, and sleeping tree distribution.  $R=1$  indicates random distribution;  $R>1$  uniform distribution, and  $R<1$  aggregated distribution (12). The frequencies of monthly marmoset visits recorded for each quadrant in the home range were compared through one-way ANOVA (5%) and Tukey testing (5%). Spearman correlation analysis was used to investigate the relationship between frequency of use for sleeping and tree-height, frequency of use for sleeping and diameter of sleeping trees, and sleeping-tree height and diameter.

## RESULTS

Eight different trees belonging to five species were used for sleeping. *Coccoloba* sp. (Polygonaceae); *Bowdichia virgilioides* HBK, (Fabaceae); *Cassia apoucoita* Aubl. (Leg. Caesalpinoideae) and *Pouteria grandiflora* (Sapotaceae) were used by group L, and *Coccoloba* sp.; *Buchenavia capitata* (Combretaceae) and *Pouteria grandiflora* by group A. Diameters at breast height (DBH) ranged from 28.3 to 236.82 cm, and heights from 12 to 24 m (Table I).

No significant correlations were found between DBH and height of sleeping trees ( $r=0,02$ ;  $p=0,95$   $N=16$ ), DBH and frequency of use of sleeping trees ( $r=-0,09$ ;  $p=0,82$ ;  $N=16$ ), and height and frequency of use of sleeping trees ( $r=0,59$ ;  $p=0,12$ ;  $N=16$ ), whereby the inference of other variables influencing choice.

Gum trees were located between 10 and 42 meters from sleeping trees, whereas fruit trees were between 8 and 27 meters away. Of the eight trees used by groups for sleeping, two were located at the edge of the main forest ( $n=3$ ) and six in the

Tabela 1. Identification of species, height and location of sleeping trees by groups of common marmosets.

Species	N°	Height	Records of use as sleeping trees (n)	Location
<i>Coccoloba</i> sp.	1	12 m	3	Public area
<i>Coccoloba</i> sp.	2	14 m	5	Public area
<i>Bowdichia virgilioides</i>	3	17,5 m	4	Public area
<i>Bowdichia virgilioides</i>	4	24 m	6	Public area
<i>Cassia apoucoita</i> Aubl.	5	20 m	1	Edge of remnant
<i>Coccoloba</i> sp.	6	18 m	3	Public area
<i>Buchenavia capitata</i> Eichl.	7	17 m	2	Edge of remnant
<i>Pouteria grandiflora</i>	8	22 m	5	Public area

For sleeping purposes, Group L showed a preference (50)% for *Bowdichia virgilioides*, whereas Group A preferred (75%) *Coccoloba* sp.. Although re-use of sleeping trees was detected on several occasions, this did not occur on consecutive days.

public area ( $n=26$ ) between 20 and 80 meters from the main forest edge (Table I). Sources of fruit, gum and sleeping trees were distributed over the  $0.94 \text{ ha} \pm 0.4$  ( $\pm$  standard deviation) and  $1.3 \text{ ha} \pm 0.7$  ( $\pm$  standard deviation) areas, corresponding to the

Table 2. Fruiting periods and location of trees used by groups L and A for fruit consumption. Where PA = Public area and F = Forest

Family	Species	Fruiting	Group	Location of fruit trees
Cecropiaceae	<i>Cecropia adenopus</i>	February to March	L	PA/F
Myrtaceae	<i>Campomanesia dichotoma</i>	March and April	L/A	PA/F
Myrtaceae	<i>Hexaclamys itatiaiae</i>	January, February and March	L/R	PA/F
Poligonaceae	<i>Coccoloba</i> sp.	February and March	L/A	PA/F
Boraginaceae	<i>Cordia superba</i>	January	A	PA
Rhamnaceae	<i>Zizyphus joazeiro</i>	December and January	A	PA/F
Myrtaceae	<i>Syzygium jambolanum</i>	January, February, March and April	A	PA
Anacardiaceae	<i>Anacardium occidentale</i>	November, January	L/A	PA
Anacardiaceae	<i>Mangifera indica</i>	December, January and February	A	PA
Myrtaceae	<i>Eugenia malaccensis</i>	December	A	PA

home ranges of groups A and L, respectively.

The fruit consumed by both groups came from ten tree-species with overlapping fruiting periods (Table II). There were significant differences in the frequency of monthly visits to the various quadrants, mainly as regards group A ( $F=3.48$   $df=4$ ;  $p=0.01$ ). Visits were significantly higher in January, February and March, when a higher number of fruiting species was recorded. Most visited quadrants were those containing fruiting trees, with overlapping where at least one sleeping site was located. Trees for fruit consumption and gum extraction were distributed in the aggregate ( $R_A=0.78$  and  $R_L=0.71$ ), and sleeping trees randomly ( $R_A=1.27$  and  $R_L=1.23$ ).

Despite the presence of marmoset predators, no actual predation was recorded in the study area. Nonetheless, marmosets were vigilant on a number of occasions. Upon perceiving a great black hawk (*Buteogallus urubitinga*) in flight, they vocally warned other members of the group, before hiding behind branches and foliage.

## DISCUSSION

In the present study, gum and fruit trees were distributed in the aggregate and sleeping trees randomly. Aggregate distribution signifies the individual tendency to stay together at particular sites in the environment, whereas in random distribution, there is the likelihood of individual disposition at any point whatsoever (13). On the other hand, distances between gum, sleeping and fruit trees were short, to so facilitate marmoset locomotion to neighboring areas when searching for food, thereby reducing overall travel costs. A similar pattern has already been noted in several primates, such as *Ateles geoffroyi* (11), *Saguinus mystax* and *Saguinus fuscicollis* (23) and *Callithrix jacchus* (33).

The home range of primates from the *Callitrix* genus varies from 0.5 to 5 ha, with *C. jacchus* presenting the smallest ever recorded. The home range in this case is closely related to the distribution pattern of gum and fruit trees (38). The aggregate-type pattern of both justifies the establishment of two small territories wherever they occur. Above all, even though *C. jacchus* requires a minimum area to survive, the adequate availability of gum trees is essential (39).

Differences in visit-frequency to quadrants in the home range, clearly shows the influence of fruit abundance on space-use patterns and sleeping-tree location. The strong influence of gum trees and fruit abundance on the use of space, is especially manifest in groups of marmosets living in forest remnants or orchards (9)

Common marmosets may sleep in trees with or without dense foliage or epiphyte cover (1, 33), high up in palm trees (30), or much lower in the canopy (8, 33). The sleeping trees used by marmosets in the PED area were robust, with DBH ranging between 28.3 and 236.82 cm, and heights ranging from 12 to 22 m. They slept in the forks of branches, where group members aggregated in a ball-like formation. This behavior probably serves to confuse possible predators through taking on the appearance of either a much larger animal or even a termite nest (16). According to an early study, the sleeping trees used by *Callitrix flaviceps* varied in height from 8 to more than 20 m. Through being densely overgrown with climbers, they were relatively isolated from the surrounding vegetation, thus offering safe sleeping-quarters for the group members huddled together in a large ball (17).

There are many potential marmoset predators in the PED. A study of an area where predators had been eradicated demonstrated that sleeping trees were located in the sites of highest feeding-tree concentration (33). Regardless of its structure, the authors considered that the key variable defining sleeping-site location was the availability and location of immediate food sources. In the present study the availability of food, especially fruits, was more important than the location of their sources.

Although there are no records of common marmoset predation in PED, their response to potential aerial predators, such as the black hawk (*Buteogallus urubitinga*), presupposes that marmosets are capable of recognizing the characteristic flight profile of falconiforms, with the consequential and immediate reaction through avoidance. This response to potential aerial predators has been recorded in *Callitrix jacchus* (29), and *C. flaviceps* (17). The loud alarm call sometimes elicits a response from other group members, while in the act of taking cover and remaining completely

motionless. On taking cover at relatively low levels in the forest, the animals normally move to the underside of the supporting branch by way of a rapid lateral movement. Other studies have recorded a collared forest-falcon (*Micrastur semitorquatus*) predated an adult marmoset (1), a roadside hawk (*Rupornis magnirostris*) predated an infant (29), and an unsuccessful attempt on a group (8).

Earlier studies identified aspects related to the structure and location of sleeping trees in areas where predators were present. Totally hidden by a dense entangled mass of lianas, climbers and epiphytes (1, 43, 6,17), and located at the edge of the forest, bordering open fields (42, 41), they were distributed throughout the home range, and remained without use for several successive nights (41). This is in accordance with the present findings, in that the sleeping trees used by both groups in PED were close to the forest edge and not used on consecutive days.

Sleeping tree location is crucial for survival where predation risk is high, albeit less so, where predators are extinct (33). In the latter case, daily-food acquisition, rather than predators, would be the limiting factor. In the case of PED, and in spite of the importance of fruit abundance in space-usage and sleeping-tree location, the local presence of predators, and the non-consecutive use of sleeping trees, point to protection as an important factor in the location of sleeping trees among marmosets.

Differences in these results and those obtained in earlier studies (31, 8, 34, 33) reveal diversity in the strategies adopted by the common marmoset to selectively locate sleeping trees under the prevailing circumstances.

## CONCLUSION

This study offers important contributions to an understanding of the prevailing strategies among primates, when selectively locating sleeping trees. Location, as employed by two groups of marmosets in the Parque das Dunas, was not influenced by the distribution pattern of gum and fruit trees, but by fruit abundance and the presence of potential predators, thereby showing the relationship between the strategy adopted and the type of pressure encountered. Finally, the understanding of resource distribution and sleeping tree location, perceptibly

furnishes relevant factors towards the conservation of primates, in that their correct management could contribute to primate population viability.

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## RESUMO

A segurança contra os predadores, a proximidade das fontes de alimento e a coesão do grupo são fatores que podem influenciar a localização de árvores de dormir em primatas. Este estudo objetivou investigar a influência da distribuição de árvores de goma e de frutos e a abundância de frutos na localização das árvores de dormir dos sagüis. Dois grupos de sagüis que vivem no Parque Estadual das Dunas, em Natal, RN, foram estudados. A varredura instantânea de amostragem foi utilizada para registrar a cada 5 min a localização dos sagüis nos mapas da área e para identificar a localização das árvores para dormir. A frequência de uso de árvores para dormir foi registrada. As espécies das árvores utilizadas para o consumo de frutas, extração de goma e dormitório foram identificadas, e os dados fenológicos foram coletados mensalmente para determinar os períodos de abundância de frutos. As árvores de dormir estavam distribuídas aleatoriamente, aparentemente não possuindo relação com a distribuição agregada das árvores de goma e de frutos. No entanto, a abundância de frutos se apresentou como um fator importante na utilização do espaço e na localização das árvores para dormir. A presença de potenciais predadores do sagüi, e o uso não-consecutivo de árvores de dormir apontam a proteção contra os predadores como um outro fator importante na localização das árvores de dormir na área do estudo.

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## ENVIRONMENTAL IMPACTS CAUSED BY ROADS AND TRAILS IN THE ALTOMONTANA PRIVATE RESERVE, ITAMONTE, MINAS GERAIS.

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### ABSTRACT

The adequate planning and management of highways contribute to reducing environmental impacts. In conservation units, the evaluation of possible environmental impacts caused by roads has facilitated the adoption of preventive action, with a view to avoiding biodiversity loss. In this sense, impacts caused by roads and trails in the Altomontana Private Reserve, Itamonte, Minas Gerais State, Brazil, were assessed, as a means of obtaining information for improving road and trail management in the unit, as well as mitigating those impacts that generate local environmental degradation. Internal roadways of the property were scoured, and points along the altitude gradient marked. A grading impact array was used for standardizing observations. Marks of 0 to 3 were attributed to characterizing the intensity of impacts, with positive or negative signs added, according to the type of impact. Among the observed environmental impacts caused by roads, erosion, the most outstanding variable, occurred at all altitudes, with discarded waste as runner up. All told, local vegetation appeared to be well-conserved, with the variation in altitude favoring the formation of various physiognomies, thereby constituting an appropriate environment for developing local community activities as part of environmental education programs.

**Key words:** Environmental impact assessment; roads; conservation unit.

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### INTRODUCTION

The divulgation of environmental damage by organizations dedicated to the protection of the environment has contributed decisively towards consolidating the Evaluation of Environmental Impacts (EEI), as a tool for registering data applied to measuring the consequences arising from anthropic activities in natural ecosystems, and as a forerunner of means for taking the necessary steps towards maintaining

the quality of the environment (22). Following the United Nations Conference on the Environment, in 1972, there have been modifications in the policies for development and economic intervention, which are no longer exclusively orientated by economic-financial parameters. From there on, environmental and socio-economic questions have also been inserted (9), thereby leading to the publication of literature specialized in evaluation and reports on environmental impacts (25, 23, 17).

Around this time, the EEI turned up in Brazil, as a prerequisite for financial research by international organizations (24). Subsequently, this was inserted into the National Policy for the Environment (NPE), regulated according to the Federal Law 6.938/81. This later became obligatory on licensing processes involving polluting activities or those modifying the natural environment (22). The advance in the protection of Brazilian ecosystems continued with the Federal Law 9.605/98. Law of Environmental Crimes (5), and the Federal Law 9.985/00, which instituted the National System of Nature Conservation Units (6) thereby establishing criteria and norms for the creation, implantation and management of Conservation Units (CU). Among these, and within the group Sustainable Use, the Private Reserve of Natural Patrimony (PRNP) is a private area which aims at perpetually conserving biodiversity, and, according to article 21, permits scientific research, as well as tourism, recreation and educational visits.

The evaluation of impacts caused by roads is a recent line of research, and over the past few years, studies have been developed with the aim of acquiring knowledge on the possible effects on ecosystems (4, 8, 15, 18, 7). According to Gumier-Costa & Sperber (200), some of these have emphasized the impact of routes inside CUs, when considering that trails and roads possibly induce the isolation and fragmentation of environments, besides animal-hits when crossing. The impacts pointed out by Forman & Alexander (1998) include difficulty in dispersion by native plants, the introduction of exotic species, noise, changes in the levels of lighting, the attraction and repulsion of fauna, problems with drainage, erosion, atmospheric pollution through the emission of gases from fuel combustion, and the increase of dust in the air. The evaluation of environmental impacts caused by roads in CUs would effectively contribute towards the improvement of management planning, thereby facilitating the adoption of preventive and corrective action.

The aim was to assay and analyze environmental impacts caused by roads and trails inside the Altomontana PRNP, in Itamonte, Minas Gerais State, Brazil. As this unit is in the initial creation phase, this study will contribute with relevant information towards the elaboration of management planning. The specific aims were: a)

describe environmental impacts caused by roads; b) analyze and systematize data referring to road impacts, to so improve CU management; and c) propose mitigating solutions for degraded areas.

## METHODOLOGY

### *Study Area*

The study took place in the Altomontana PRNP, in Itamonte county, Minas Gerais State (22°21'51"S and 44°48'29"W). The steep altitude gradient varies from 1.450 to 2.400 meters. An inner road gives access to water slides, where the altitude reaches 2.140 meters. Close to the buildings at the entrance of the unit, trails lead away to the waterfalls. The total CU area is 672 hectares, comprising a mosaic of phytophysionomies, that of semi deciduous seasonal forest being the most representative (*sensu* 27). The climate is of the Köppen Cwb type, and mesothermic, with dry winters and mild, rainy summers. The average annual temperature varies from 17.4°C to 19.8°C. The dry season extends from May to September, with the driest period occurring in June and July, and the rainiest during December and January (21). The PRNP, a private property inserted within the Area of Environmental Protection (AEP) of the Serra da Mantiqueira, contains a large area with remnant Atlantic Rain Forest.

### *Sampling*

The inner roads (main and adjacent, as well as trails) were scoured and points marked at the extremities and along the altitude gradient, by means of GPS Garmin GPSMAP® 76Csx apparatus. Collected data was systematized in an impact grading matrix, adapted from Leopold *et al.* (1971), for standardizing observations and analyzing impacts. Impacts were characterized and analyzed by way of spot road-width measurements and respective intervention on roadside vegetation. The height of the embankment was evaluated in accordance with the roadside-presence of developed and adult native tree species, and vegetal soil cover. Visual and risk characterization of the occurrence of impacts, such as fire, erosion and waste, as well as other anthropic activities, were also investigated. The impacts were quantitatively classified as to magnitude; points from zero to

three were attributed for characterization, and qualitatively as to intrinsic value, to which were added positive and negative signs, according to the type of impact. Summation indicated the most impacted sights. Employees were interviewed as to outstanding natural events prior to the study period, with visual documentation (photographs) of the impact.

## RESULTS

Impacts caused by anthropic activity, such as visits, animal raising, the traffic of vehicles, and the points of erosion arising from these activities, were the most marked negative environmental impacts encountered along the road crossing the property. Vegetal conservation and soil cover were the most relevant positive aspects, these acquiring the highest marks. Environmental impacts analyzed on the inner road of the CU appear in Table 1. According to summation, the most impacted environment was located at point 1, close to the entrance of the PRNP. As informed, the largest area of erosion (Point 1), acquired its present form due to a land-slide that occurred in 2005, thereby starting the formation of a roadside ravine, at the moment 30 meters wide at the northern end, and with a 13-meter-wide crater in the south (Figures 1A and 1B). Points of erosion

were also noted at higher altitudes, this type of visual impact being the most remarkable. In some spots of the road, the incorrect drainage of rainwater has given rise to large natural ruts, thereby indicating the formation of fresh points of erosion (Figure 1C). Artificial ditches for better rainwater drainage were also seen.

Although small areas of erosion were noted in points 2 and 3, generally speaking, final summation of positive and negative impacts indicated adequate conservation of the stretch of road, roadside vegetation and height of embankments. A large clump of bamboo was noted at a higher level

(Point 4). Its origin is unknown, and further studies are required, as it was impossible to relate it to the presence of a road (Figure 1D).

The highest negative impact caused by anthropic activities along the road was in point 6, where an artificial clearing had been made for the installation of a telecommunication antenna. At this point, besides complete soil exposure, there was a considerable amount of remnant material. At the highest point, 2.140 meters (Point 7), vestiges of unauthorized camping were found, clear evidence of area vulnerability. This included signs of a bonfire (Figure 3), non-biodegradable packaging, and the opening of a trail in the vegetation. Old scrawls on the rocks were noted as a main negative visual impact (Figure 3).

Table 1: Environmental impacts on the road inside the Altomontana PRNP, Itamonte/MG.

	Sampling points							Summation
	1	2	3	4	5	6	7	
Altitude (m)	1.533	1.560	1.645	1.800	1.960	2.130	2.140	
Erosion	-3	-1	-1	-1	0	-1*	0	-7
Fire	0	0	0	0*	0	0	-2*	-2
Waste	-1	-1	0	0	0	-3	-3*	-8
Anthropic activity	-2	-1	-1	0	0	-3	-1*	-8
Preservation of vegetation	+1	+2	+2	+1	+3	+1	+2*	+12
Height of canopy	+3	+2	+1	+1	+3	0	0	+10
Soil vegetation cover	+1	+2	+2	0	+3	0	+3	+11
Visual impact	-3	-1	+2	-1	+3	-3	+2	-1
Total impact at the point	-4	+2	+5	0	+12	-9	+1	+7
Extent of roadside vegetation (m)	10,20	9,50	6,50	8,00	7,70	**	**	41,90
Road-width (m)	5,40	5,30	4,30	5,00	4,40	**	**	24,40

Legend:

Types of impact: [-] Negative impact; [+] Positive impact

Intensity of the impact: [0] None; [1] Low; [2] Medium; [3] High

\*Vulnerable; \*\*Artificial clearing

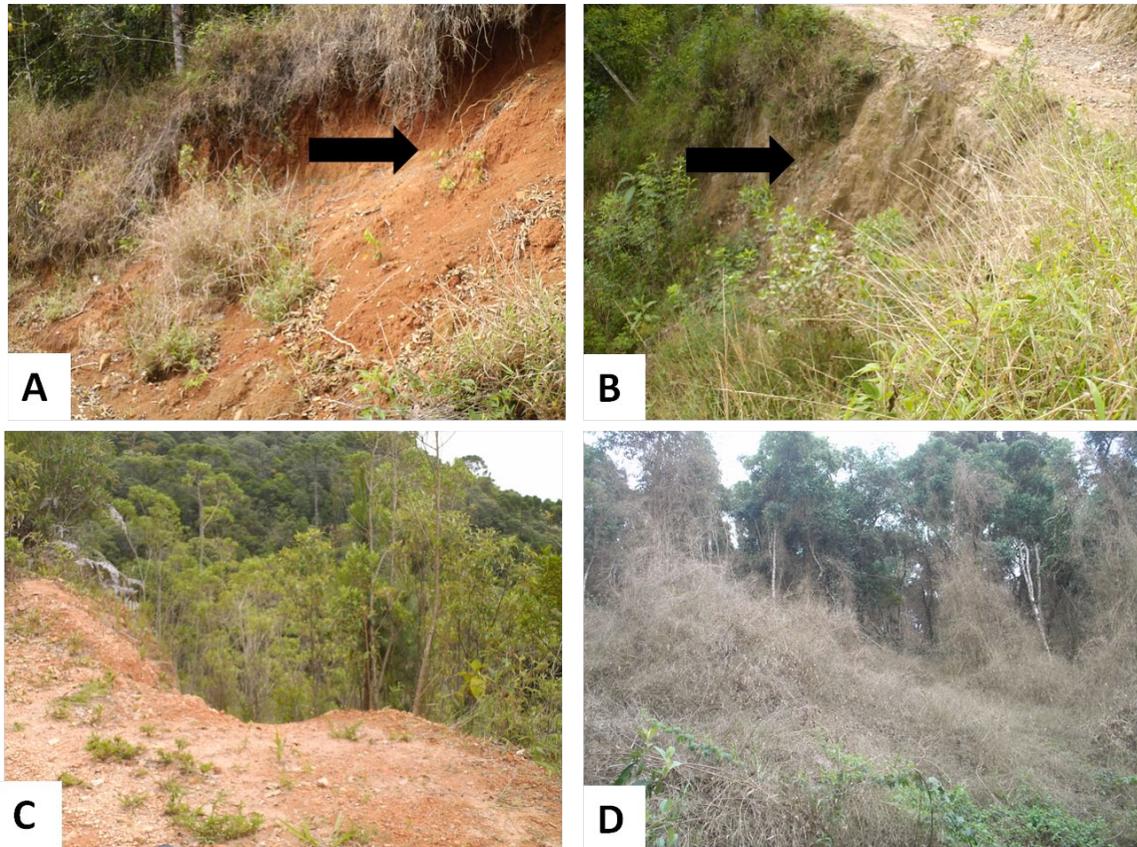


Figure 1: Heavy erosion at the edge of the main road. A) Northern part: 30m long. B) Southern part: crater 13 meters wide. Arrows: recent land-slides. Altitude: 1530 m. C) Natural ravine caused by hydro-erosion. Altitude: 1640 m. D) Long bamboo grove close to the road-side. Altitude: 1800 m.



Figure 2: Diversity of species as indicators of the satisfactory quality of the environment. Bromeliaceae and Orchidaceae families, respectively.

Apart from the main road, there are two trails, the Trail to the Waterfall (Points 10, 11 and 12) and to the Forest of the Elves (Points 14,15 and 16). Both were scoured for signs of impacts (Table 2). The main vestiges found were the residues of a bonfire, discarded non-biodegraded objects and small points of erosion. Around the higher-placed waterfall, the visual impact was great, due to stone

arches built by the former proprietor (Figure 4B). This did not occur at the better conserved, lower-placed waterfall. Positive points were the presence of alcoves appropriate for leisure, with well-installed grills. Nonetheless, the wrongly placed bonfire residues close to the waterfall was a clear indication of the need for dedicating more attention to visitor orientation on the best use of the area.



Figure 3: Visual and environmental impacts caused by unauthorized camping. The remains of a bonfire and scrawls.

All along the trail, the well-preserved vegetation (Figures 4C and 4D) with enclosing canopy, and the appearance of pioneer plants along the edges, were clear indications of initial regeneration processes (Figure 4A). Nowhere on the trails or around the waterfalls were there garbage cans for the selective collection of waste.

In point 9, 1.563 meters high, there is an 8-meter-wide road, adjacent to the main one and leading to an abandoned building. The road is around 800 meters long, and has been out of use for more than 5 years. It is in the regeneration stage, with the beginning of soil coverage by creepers. Several points of erosion were also observed, with

Tabela 1. Environmental impacts on the road inside the Altomontana PRNP, Itamonte/MG.

	Sampling points									
	8	9	10	11	12	13	14	15	16	Summation
Altitude (m)	2.110	1.563	1.490	1.465	1.455	1.475	1.490	1.445	1.435	
Erosion	0	-3	0	-1	0	-2	0	-1	-1	-8
Fire	0*	0	0	0	-3	0	0	0	0	-3
Waste	0	-2	0	0	-3	-2	0	0	0	-7
Anthropic activity	0	-2	0	0	-3	-3	0	-3	-3	-17
Preservation of vegetation	+3	+3	+3	+3	+3	+1	+3	+1	+1	+21
Height of canopy	+1	+3	+3	+3	+3	0	+3	0	0	+16
Vegetation soil cover	+3	+3	+3	+2	+2	0	+3	+1	+1	+18
Visual impact	+1	-2	+3	-1	-2	-2	+1	-2	-2	-6
Point total impact	+8	0	+12	+6	-3	-8	+10	-4	-4	+17
Extent of roadside vegetation (m)	5,80	4,50	4,40	2,80	2,00	**	3,00	6,00	6,00	34,50
Road-width (m)	3,00	4,00	2,40	2,00	2,00	**	3,00	6,00	6,00	28,40

Legend:

Types of impact: [-] Negative impact; [+] Positive impact  
 Impact Intensity: [0] None; [1] Low; [2] Medium; [3] High  
 \*Vulnerable; \*\*Artificial clearing





Figure 4: Trails on the property. A) Trail to the waterfall. B) Upper waterfall: Visual impact caused by construction. C) Entrance to the Trail to the Forest of the Elves. D) Trail of the Elves. – Out-of-use. E) Exposal of roots through erosion 1,80m high. F) Inclined trees due to erosion.

heights varying between 1,80 and 3 meters on the northern edge. In some points inclined trees and marked root exposure were apparent (Figure 4E). The vegetation in this area is well-preserved with an estimated 15-meter canopy (Figure 4F). The negative points for visual impact were the occurrence of non-biodegradable waste, mainly around the abandoned building. Tires, cans of oil and several types of plastic packaging were also found. No indicative signs or indications of strategic planning, to facilitate animal crossing or avoid accidents with the local fauna, were observed in any of the points evaluated.

## DISCUSSION

The most impacted areas are located at either end of the main road, the outstanding points being the presence of erosion, discarded material and the remains of fire. This could be related to the permanence of people, seeing that the road is used

only for passage between the lower part and the gliding ramps. One factor that may have contributed to the advance of erosion on the main road could be the recent entrance of heavy vehicles, for the installation of telecommunication antennas. This occurred before the present assaying. The crater cause by the landslide in 2005 presented visible signs of instability. Moreover, before this, the road was 10 meters wide, whereas now it is only 5,40m. Small landslides were noted and it is interesting to point out the possibility of the crater increasing in size, since vegetation is not in the process of regeneration. The slope of the land could be the main cause of erosion, thus corroborating Oliveira *et al.* (2010a), and Antonangelo & Fenner (2005), who pointed out declivity as being one of the generating factors of erosion. Further studies are required, with specific methodologies on declivity and erosion, to evaluate local vulnerability and instability.

Concrete gutters were built along the road to improve rainwater drainage. However, their inefficiency was apparent, seeing that incorrect

drainage was the means of accelerating erosion in some points. Surface drainage of rainwater is a preponderant factor in the formation of erosive processes, according to WEPP (Water Erosion Prediction Project), and as cited by Machado *et al.* (2003) and Garcia (2001). The adoption of preventive measures and the subsequent monitoring are attitudes which are simple, efficient and financially cheaper, when compared to corrective measures (20) Certain measures can be taken, such as the recuperation and contentment of canopy, the maintenance of adequate gutters, planting seedlings of native plants where erosion is in an advanced stage (20), programs of environmental education, supervision in areas of easy access, and studies on the influence of vehicle traffic on vertebrate communities, as suggested by Bager & Rosa (2010), who proposed specific studies and the use of an index for implanting mitigating measures against wild-fauna hits.

The presence of discarded non-biodegraded material, such as tires, oil cans, glass bottles and plastic packaging, was observed in isolated points. Even though it was impossible to estimate the time this material has been in the area, their very presence is a sign of vulnerability. The withdrawal of this material is indispensable, since these residues are prejudicial, both visually and to the native fauna. Although roads are necessary structures for the flow of material and people, their very existence can negatively affect the fauna (4, 7, 15, 26). Some studies, besides outlining the high diversity and abundance of biota, demonstrate their fragility in the face of anthropic impacts caused in their environment. Thus, it can be perceived that the Altomontana PRNP does not present the necessary structure or the required preventive measures against the loss of biodiversity through the ingestion of residues, the isolation of subpopulations, or road-hits, whence the need for undertaking appropriate studies in this field.

The presence of well-preserved vegetation, the various phytophysiognomies encountered on the altitudinal gradient and the wide expanse of the CU, go well towards affirming that the PRNP had reached a high level of environmental heterogeneity and complexity. Similar situations have been the focus of a series of studies, such as by August (1983) and Vera Y Conde & Rocha (2006). Heterogeneity in any environment is represented by the vertical

stratum developed. Apart from the characteristics of woody plants, the presence of epiphytes is considered a positive factor as it concerns environmental heterogeneity. According to Gatti (2000), they are extremely important as indicators of the maintenance of biological diversity and the interactive equilibrium among species, since their successful establishment and diversity is highly dependent on environmental conditions (13). Through their sensitivity to anthropic impacts, their role as indicators of environmental quality is further enhanced. Thus, the presence of epiphytic plants was a clear indication of preservation along roads and trails.

The presence of a bamboo grove at a fixed altitude caused a visual impact. As it extended over the areas of other properties, always at the same variations in altitude, its origin can probably be associated to a natural occurrence. Even so, additional more detailed studies are required to better understand the occurrence.

As the management plan for the CU is in the elaboration phase, and together with the results of this evaluation of impacts, the proposal is to charge an entrance fee for recreational visits and access to water slides, as a form of maintaining the roads and trails on the property, since, through being a CU of sustainable use, the use of areas for recreation and environmental education is permitted. Nevertheless, it is recommended that the entrance of visitors be limited, and selective garbage cans installed in the entrance of the reserve, in the areas of recreation at the waterfalls, and alongside water slides.

The elaboration of environmental education programs should also become an alternative for the better enlightenment of visitors, as to the preservation of the area.

## CONCLUSION

Among the various environmental impacts caused by the road, erosion at all altitudes is extremely prominent, with the presence of discarded waste as a close runner up. The vegetation on the edges of trails and roads was found to be well-preserved, thus comprising a propitious environment for the development of insertion activities among the local community, as part of programs on environmental education. The most impacted strips are the extremities of roads

and trails, where preventive supervision is required. The proposal is the adoption of a series of measures, such as the control of visitor entrance, the creation of educational activities on environmental conservation for PRPN-user enlightenment, the supervision of critical points, the restoration of unstable points of erosion with native plants, signs at various points on the road, with emphasis on the existence of fauna, and the need to reduce speed, as administrative tools to better conserve the area.

### ACKNOWLEDGEMENT

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### RESUMO

Planejamento e gestão adequada de estradas contribuem para a redução dos impactos ambientais. Em Unidades de Conservação, a avaliação de possíveis impactos ambientais causados pelas estradas permite a adoção de ações preventivas, visando evitar a perda de biodiversidade. Nesse intuito, foi realizado um levantamento de impactos causados pelas estradas e trilhas da RPPN Altomontana, Itamonte (MG/Brasil), objetivando fornecer informações para um melhor manejo das estradas e trilhas da unidade de conservação, bem como mitigar impactos que geraram degradação ambiental da área. As extensões das estradas internas da propriedade foram percorridas, sendo marcados pontos nos extremos e ao longo do gradiente altitudinal. Uma matriz de gradação de impactos foi utilizada para padronizar as observações. Foram atribuídas notas de zero a três para caracterizar a intensidade dos impactos, acrescidos dos sinais positivo e negativo conforme o tipo de impacto. Dentre os impactos ambientais observados causados pelas estradas, a erosão foi a variável de maior destaque, ocorrendo em todas as faixas de altitude da propriedade, seguida da presença de lixo descartado. De modo geral, a vegetação da área encontra-se bem conservada e a variação de altitude favorece a formação de diferentes fitofisionomias, sendo um ambiente propício ao desenvolvimento de atividades de inserção da comunidade local em

programas de educação ambiental.

**Palavras-chave:** avaliação de impacto ambiental, estradas, Unidade de conservação.

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## FLORISTIC AND SPATIAL DISTRIBUTION OF ORCHIDACEAE SPECIES IN THE SERRA DO MUCAMBO, CONCEIÇÃO DO COITÉ, BAHIA, BRAZIL

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### ABSTRACT

The aim of the present study was to evaluate the Orchidaceae family in the Serra do Mucambo, Conceição do Coité, Bahia and to describe the local population distribution patterns, as well as discuss local factors that influenced species distribution. Sixteen species in 14 genera were found. The genera *Trichocentrum* and *Vanilla* presented the highest number of species, with two each. All species displayed aggregated distribution. The highest abundance and species richness were found at higher altitudes. Availability of resources is possibly the main factor influencing species distribution.

**Key-words:** resources, elevation, abundance

### INTRODUCTION

The Orchidaceae family contains around 850 genera and 20,000 species, amongst which, 235 genera and 2.419 species have been registered in Brazil (6). Distribution of the family is cosmopolitan, Pantropical, and probably the second largest among the angiosperms (5), with the main centers of diversity in the tropical regions of America and Asia (9). Besides taxonomic representability, the family is valued by the ornamental potential of the flowers (16).

The use of the flowers for ornamentation purposes represents one of the threats to orchid species diversity, through removal from their natural habitats. Another ominous factor is the constant destruction of habitats through the advance of agriculture (16, 22). Thus, extinction could also be a consequence of the reduction in area of occupancy, since only larger areas sustain large populations. (18)

In a plant community, plants are aggregated according to the various intra and interspecific associations throughout their natural distribution

(14). Besides anthropic alterations, which incur vegetal impacts, there are also natural alterations arising from differences in the soil, and variations in humidity and altitude, which contribute to floristically characterizing certain areas of the mountain range (34). Altitude, a possible relevant factor, can induce a soil and climate grid, an important aspect in the repartition of the various floristic aggregates, thereby contributing to the different vegetation patterns in the landscape (24, 10). The distribution of the different ecological substrata and refuges is related to the degree of local shade or illumination, whence the selective process of appropriate environments for the development of certain types of vegetation in detriment of others (10). Through humidity, as well as the presence of a substratum, being limiting factors in the distribution of epiphytic orchids (7), epiphyte diversity can be used as an ecological indicator of the quality and conservation of humid forests (22).

On the whole, in Bahia, botanical studies in the field are concentrated in the Chapada Diamantina (3, 4, 12, 19, 20, 32, 36, 40, 37), with only a few studies having been undertaken in the

center-western part of the state (15). Further on, the findings will be commented on, since a list of citations without contents would not be informative. Studies on Orchidaceae spatial distribution are still scarce, especially in northeast Brazil.

On considering the work done on orchid spatial distribution, the importance of the family, the threats to its diversity, the scarcity of studies of northeast Bahia, and the need for a better understanding of the factors that influence the distribution of these species, the aim of the present study was to undertake a floristic survey of orchid species in the Serra do Mucambo, thereby identifying the spatial distribution of populations and investigating factors defining their occurrence and distribution.

## METHODOLOGY

Characterization of the study area – Conceição do Coité is located in the northeastern part of Bahia State (11°31' S and 39°19' W). The study area was at the highest point of the municipality, at an altitude of 575 meters. The surroundings and some parts of the Serra have already been deforested for sisal (*Agave sisalana* Perrine) hemp production and cattle raising.

The climate is semiarid, with temperatures ranging from 16.1 to 33°C, and an average rainfall of 500 to 800 mm. Vegetation is mixed, with elements from the arboreal Caatinga and arboreal-bushy Caatinga, and with the presence of palm trees (Arecaceae) of the species *Syagrus coronata* (Mart.) Becc.

Collection of data – 20 fixed and noncontiguous quadrats measuring 10×10m, in total 2.000m<sup>2</sup>, were marked out according to methodology developed by Almeida *et al.* (2007), but with modifications, with random distribution at various altitudes, an irregular number at each, along a sloping gradient of 449 to 575m, with no fixed difference between. Elevation and coordinates were obtained with a GPS Garmin eTrex Vista HCx, Personal Navigator. The fertile orchids in each quadrant were collected, pressed, identified and quantified. The amount of available resources was also measured, taking into account, trees, lianas, soil and palm trees. Rock, as a source,

was eliminated. Trees and lianas were measured as to the percentage of cover, and soil, as to the available area. Palm trees were counted. The total of available resources was obtained by substituting scarce, abundant and very abundant by the numbers 2, 3 and 4, respectively, and with the summation of values attributed to soil, trees and lianas, and the number of palm trees. As regards epiphyte species, even individuals that had accidentally fallen, and were still alive on the soil and remained fixed to dry branches, were included. Collections took place from January to December, 2010, thus twelve in total. Specimens were deposited in the herbarium of the Universidade Estadual de Feira de Santana (HUEFS).

Analysis of data – species identification was from specialized literature by Pabst & Dungs (1975, 1977). When necessary, the material was compared to specimens from the collection of HUEFS. Species binomials were standardized in accordance with the World Check List of Selected Plant Families, the Royal Botanic Gardens, Kew (<http://apps.kew.org/wcsp/qsearch.do>).

The Morisita index (27) was used for identifying species distribution patterns. Absolute taxon frequency was calculated by the formula described by Maracajá *et al.* (2003):

$$Fat = \frac{100 \cdot P_i}{20}$$

where  $F_{At}$  is the absolute taxon frequency,  $P_i$  the number of plots where the taxa occurred, and  $P$  the number of sampled plots.

Analysis of correlations between the amount of resources and orchid frequency was performed to evaluate the influence of resource availability. Cluster analysis of qualitative and quantitative data with the UPGMA method in the PCORD 4.0 software, using the Sorensen Index for qualitative, and the Morisita-Horn Index for quantitative, was used to evaluate whether more similar quadrants, in terms of resources, would be more similar as to floristic composition. Correlation analysis with SPSS for Windows was to evaluate the relationships between abundance and richness among species at different altitudes.

## RESULTS

Sampling involved 821 individuals belonging to 14 genera and 16 species (Table 1). On considering the two habits, epiphytes were found to be the most common. There were only five terrestrial species and one facultative.

Average abundance among quadrants was 41.5, with standard deviation of  $\pm 44.56$  individuals each. Richness varied from 1 to 10 species per quadrant; the most frequent was two species each.

patterns, respectively.

Individuals of *G. barbata*, *C. micranthum* and *Notylia* sp. represented 67% of those sampled (Table 1), whereas individuals of *O. maculata*, *V. palmarum* and *T. cebolleta* together represented 22%, and the remaining 10 species 11%. The most abundant species were also the most frequent (Table 1).

Groups of qualitative (Figure 2) and quantitative (Figure 3) similarity were formed in the same quadrants in both dendrograms. Whereas the first group was formed by quadrants without the

Tabela 1. List of the species from the family Orchidaceae found in the Serra do Mucambo, Conceição do Coité, Bahia, Brazil. Legend: N. IND = number of individuals sampled, MI= Morisita Index, AF= absolute frequency, Epi. = epiphyte, Ter.= terrestrial, Fa.Epi= facultative epiphyte. Species

	N. IND.	M.I	A.F. %	Habit	Voucher
<i>Campylocentrum micranthum</i> (Lindl.) Rolfe	191	22,5	55	Epi.	Carvalho, D. N. 19
<i>Catasetum luridum</i> Lindl.	27	4,2	35	Epi.	Carvalho, D. N. 7
<i>Cyrtopodium saintlegerianum</i> Rchb.f.	5	3,3	10	Epi.	Carvalho, D. N. 15
<i>Eltroplectris triloba</i> (Lindl.) Pabst	4	3,3	15	Ter.	Carvalho, D. N. 17
<i>Encyclia oncioides</i> (Lindl.) Schltr.	17	4,9	20	Epi.	Carvalho, D. N. 20
<i>Gomesa barbata</i> (Lindl.) M.W.Chase & N.H.Williams	272	33,6	60	Epi.	Carvalho, D. N. 4
<i>Notylia</i> sp.	109	27,8	45	Epi.	Carvalho, D. N. 2
<i>Oeceoclades maculata</i> (Lindl.) Lindl.	74	9,3	55	Ter.	Carvalho, D. N. 3
<i>Pelexia trachyglossa</i> (Kraenzl.) Pabst.	13	4,2	15	Ter.	Carvalho, D. N. 12
<i>Polystachya concreta</i> (Jacq.) Garay & H. R.-Sweet	2	2	5	Epi.	Carvalho, D. N. 9
<i>Prescottia</i> sp.	1	1	5	Ter.	
<i>Sarcoglottis</i> sp.	14	4,5	20	Ter.	
<i>Trichocentrum cebolleta</i> (Jacq.) M.-W.-Chase & N.-H.-Williams	51	8,8	60	Epi.	Carvalho, D. N. 18
<i>Trichocentrum pumilum</i> (Jacq.) M.-W.-Chase & N.-H.-Williams	3	0,9	15	Epi.	Carvalho, D. N. 16
<i>Vanilla bahiana</i> Hoehne	10	4,9	10	Epi. Fa.	
<i>Vanilla palmarum</i> (Salzm ex. Lindl.) Lindl.	60	14	30	Epi.	Carvalho, D. N. 6

No species occurred in all the quadrants, and only four occurred in more than half, viz., *G. barbata* and *T. cebolleta* (60%), and *C. micranthum* and *O. maculata* (55%). In relative abundance among the total of individuals studied, *G. barbata* 32.3%, *C. micranthum* 22.3%, *O. maculata* 8.8%, *T. cebolleta* 2.3%, and the remaining 10 species 11.7% were noteworthy.

Although the quadrants at higher altitudes presented a significantly higher abundance of individuals ( $r = 0.547$ ;  $p < 0.05$ ), no significant correlation between species richness and elevation could be found ( $r = 0.419$ ;  $p > 0.05$ ).

Most of the species presented aggregated distribution (14 species), and only two, *T. pumilum* and *Prescottia* sp., presented random and uniform

presence of *C. luridum*, in the second, this species was present in all, together with *S. coronata*, the only phorophyte to be used by this species. This phorophyte was also the only one on which *V. palmarum* and *C. saintlegerianum* occurred. According to the Sorensen Index, the most similar quadrants were P6 and P7 (Figure. 2), with 100% similarity in floristic composition, followed by P1 and P20 with more than 90%. As regards qualitative-quantitative similarity, and as indicated by the Morisita-Hom Index, the most similar quadrants were P3, P6 and P7, with 100% similarity.

Resource and orchid abundance ( $r = 0.223$ ;  $p > 0.05$ ), and resource and orchid-species richness ( $r = -0.317$ ;  $p > 0.05$ ) were not correlated.

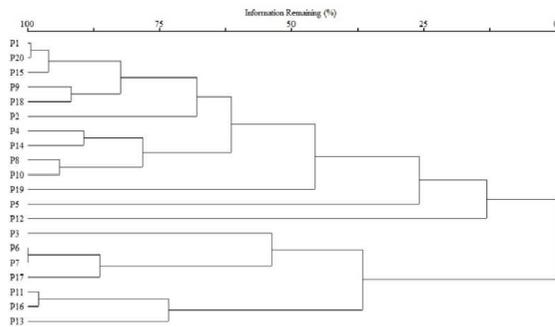


Figure 2. Floristic similarity dendrogram, by the UPGMA method and using the Sorensen Index, based on data on the presence or absence of Orchidaceae in quadrants in the Serra do Mucambo, Conceição do Coité, Bahia, Brazil.

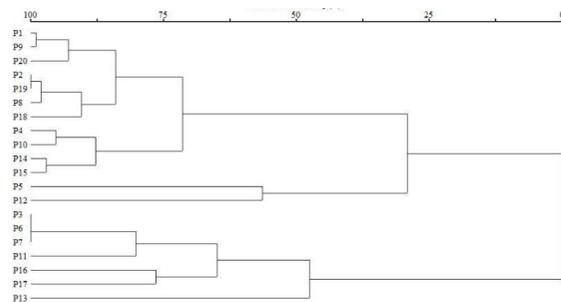


Figure 3. Floristic similarity dendrogram by the UPGMA method and using the Morisita-Index, based on data on Orchidaceae species abundance in quadrants on the Serra do Mucambo, Conceição do Coité, Bahia, Brazil.

## DISCUSSION

Most of the sampled orchids are widely distributed geographically, some of them even occurring in other countries, as well as in various biomes, such as *restingas*, rocky outcrops, mountain forests, ecotone areas, semideciduous forests and dense ombrophilous forests.

The species *C. micranthum*, *C. luridum*, *E. triloba*, *O. maculata*, *P. concreta* and *V. bahiana* are to be found in the 'restingas' of Espírito Santo State (23). *Campylocentrum micranthum* also occurs in the same ecosystem in the state of São Paulo (28) as well as in rocky ground in Mucugê, Bahia State (3). The species *E. oncioides*, *V. bahiana* and *P. concreta* are incidental in the ecotonal area between the Atlantic Rain Forest and the 'Cerrado' in São Paulo (22). *Vanilla palmarum* occurs in remnants of the Atlantic Rain Forest in the south of Bahia (21).

*Gomesa barbata* occurs in semiarid

regions in Pernambuco State (38). *Cyrtopodium saintlegerianum*, *O. maculata*, *P. concreta*, *T. cebolleta*, *Trichocentrum pumilum* and *V. bahiana* have been registered by Batista and Bianchetti (2003) among species occurring in the Brazilian Federal District. *T. pumilum* is also encountered in areas of the 'Cerrado' in São Paulo (16). *Campylocentrum micranthum*, *O. maculata*, *P. concreta* and *T. pumilum* have been registered in the Serra de São José, Minas Gerais State (2) as well as in riverine forests in Rio Grande do Sul State (39).

Species richness observed in the present study can be considered small when compared to that in plant corridors in the Cerrado, where 100 species were registered (9), and the 226 species registered in the Parque Nacional do Itatiaia, in the Serra da Mantiqueira (5). Nonetheless, many studies presented richness values close to those encountered herein, such as the 25 species found in an area undergoing regeneration in the Montane Dense Ombrophilous Forest (34), or the nine, even 10, species found in vegetal isles in parts of the Morro do Pai Inácio Plateau, also in Bahia (1, 20). Indeed, although Orchidaceae species richness is high in humid and montane regions, it is much lower in dry and seasonal areas.

*Cyrtopodium saintlegerianum* was registered as a rare species in dry forests, *O. maculata* as common in both dry and humid forests, *T. cebolleta* occasional in dry forests, *T. pumilum* rare in dry forests, *P. concreta* occasional in dry forests, and *V. bahiana* occasional in both dry and humid forests (8).

The species *O. maculata* was very frequent in shady or well-illuminated spots in areas with bushy and arboreal vegetation. The high frequency indices of this species have been associated to efficient reproductive organisms, such as autogamy and anemochorous dispersion (40). *O. maculata* and *E. triloba* were encountered in sheltered spots inside closed formations and in open areas (23), thereby corroborating their occurrence in both 'restinga' as well as dry forests, as was the case in the present study. This indicates the capacity of these species to inhabit areas with various grades of luminosity. Species that occur in the lower and upper part of trunks possibly prefer or tolerate more humid and shadier environments (39).

Rogalski and Zanin (2002) noted the existence of two groups, those that required less luminosity and more humidity, and those that tolerate higher luminosity and less humidity. Some species, such as *E. oncidoides*, were more present in tree canopies than in the lower part of the trunks where vegetation was more closed and large-sized. The species *C. luridum*, *V. palmarum*, and *C. saintlegerianum* always occurred associated with *S. coronata*, in quadrants with more open vegetation and higher solar radiation. Species requirements limit their distribution. A possible motive for this association could be the substratum conditions that this phorophyte offers, this favoring the growth and maintenance of symbiotic mycorrhizic fungi, and self maintenance as a microecosystem with the adequate luminosity and humidity for the development of these species. It was confirmed that, as cover becomes more open, other species begin to appear, especially those which are more tolerant to luminosity (23). Gonçalves & Waechter (2002) attributed high diaspore production and resistance against isolation to the outstanding capacity for colonizing and high abundance of vascular epiphytes. Lower species richness could be related to environments with microclimatic instability (higher solar radiation and wind exposure), and to the lower exposal of phorophytes to epiphyte diaspores (13). In other words, where there are more aged phorophytes, species richness is generally higher in the regions closer to the climax. Higher abundance, density and diversity is expected in canopy epiphytic orchids in mature forest fragments (35).

Cavatti (2007) related distribution of the terrestrial species *Epidendrum* sp. to the abundance of litter in the soil. This factor could also be related to the distribution of other terrestrial orchid species. In the 'Caatinga', the production of litter is not high, as it is in other ecosystems. Even so, in the present study, some areas notably accumulated a large amount of substratum in the soil, appropriate for the establishment of terrestrial species, such as *E. triloba*, *P. trachyglossa*, *Prescottia* sp., *Sarcoglottis* sp. and *O. maculata*.

Although no relationship between elevation and species richness was found, there was a positive relationship between elevation and abundance.

Jacquemyn (2005) encountered higher diversity between 400 and 800 meters, presumably due to the presence of an altitudinal distribution zone with many overlapping species. The high diversity between 500 and 2.000 meters is supposedly a result of high habitat diversity (41). In the present study, no relationship was found between habitat availability (resources) and species richness abundance.

High richness and diversity can be characterized as effected by climate (25). Temperature can be a limiting factor, whereas climate changes can contribute to changes in distribution and abundance in orchid populations (17). Thus, less richness and abundance in quadrants where temperature and humidity have been modified by human action, can be expected, as is the case of those near the edges in lower areas, where there is less humidity, and variations in the temperature, besides being greater during the day, are seasonal. This interference of the edge-effect was aggregated to the grid of elevation-labile humidity. Possibly, these two factors are directly linked with less abundance at lower placed areas undergoing the edge effect.

As observed by Pereira and Ribeiro (2004), members of Orchidaceae maintained aggregate distribution in three areas in the process of regeneration, as also occurred with young and old individuals of the species *Mesadenella cuspidata* (Lindl.) Garay (14). Thus, the present study confirms a tendency which has already been observed in orchids. The aggregation of these populations could be due to the incidence of light, or characteristics of the substratum, such as trunk texture and specificity in arboreal species (35). Some phorophytes harbored numerous epiphytes in a few quadrants, whereas others harbored very few.

Among the factors that exert an influence on orchid spatial distribution, two are of extreme importance, seed dispersion and an adequate substratum for germination and growth. Seed dispersion is a critical process in plant life, since these need to arrive at adequate substrata (31) in forest areas, protected from wind dispersal, and where young seedlings are always capable of germinating and growing close to the mother plant, thereby forming groups. This is especially the case of terrestrial orchids that form large groups on the

soil. Furthermore, infection and colonization of the habitat by compatible micorrhizic fungi is obligatory for supplying the necessary carbohydrates for seedling germination, initial growth, and nutrition on the substratum (11). Thus, only seeds which have fallen onto the adequate substratum are viable.

Even though Orchidaceae populations, on the whole, give evidence of being sensitive to human environmental interference, it cannot be said that this is the only factor influencing the distribution of individuals. Environmental alterations in the Serra do Mucambo still need to be studied, through the monitoring of other local populations and communities.

## RESUMO

O presente estudo objetivou inventariar a família Orchidaceae na Serra do Mucambo, Conceição do Coité, Bahia e descrever a distribuição das populações na área, discutindo os fatores que influencia na distribuição das espécies. Foram encontradas 16 espécies e 14 gêneros. Os gêneros com maior número de espécies foram *Trichocentrum* e *Vanilla*, com duas espécies cada. As espécies distribuíram-se de forma agregada. As maiores abundâncias e riqueza específica foram encontradas nas maiores elevações. A disponibilidade de recursos pode ser o fator que influencia na distribuição destas espécies.

**Palavras-chave:** recursos, elevação, abundância

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