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Arboreal Diversity of the Atlantic Forest of Southern Brazil: From the Beach Ridges to the Paraná River

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1. Introduction

The Atlantic Forest (a hotspot for conservation) used to be the second largest tropical moist forest of South America (Oliveira-Filho & Fontes, 2000). It originally covered 20% (around 1.5 million km²) of the Brazilian territory and occupied highly heterogeneous environmental conditions (Ribeiro et al., 2009). Nowadays, however, the Atlantic Forest covers less than 1% of the country or 7.5% of remnants (Myers et al., 2000). When intermediate secondary forests and small fragments (< 100 ha) are included, this contribution increases, ranging from 11.4 to 16% (Ribeiro et al. 2009). The Atlantic Forest still comprises 20000 plant species, 8000 being endemic (Myers, 2000).

For instance, in the 1950s, 40% of the Atlantic Forest still covered almost all the state of Paraná in Southern Brazil (Fundação SOS Mata Atlântica et al., 1998). During the following three decades, habitats that took thousands of years to evolve continued to be destroyed. What remains today covers an area 9.5 times smaller (10.58%) than the original area (Fundação SOS Mata Atlântica & INPE, 2010). This coincided with a period when the government aimed at an "economic development". However, this erroneous decision caused an irreparable loss of ecosystem functions (e.g. amount and quality of water, soil, carbon stocks, biodiversity, etc). Once more, immediate "development" led to the loss of a valuable ecosystem that had potential to bring true and sustainable development. The respect for the natural dynamics of ecosystems and species evolution is rarely presented in environmental discussions. Therefore it is timely to study biodiversity and to promote its management and restoration.

This chapter aims at discussing tree diversity of different formations of the Atlantic Forest in Southern Brazil, using data from phytosociological studies carried out in the state of Paraná. This study attempts to assess the following questions:

What ecosystems are understudied in terms of phytosociological surveys? Are the tree species richness and diversity of the different formations of these Atlantic Forests sufficiently known? What are the tree species richness and the diversity when considering only individuals found in phytosociological surveys? What species are the most abundant in each ecosystem evaluated? What are the differences and similarities among these formations?

2. Data analysis

Besides presenting a brief literature review, this study compiles abundance data and updated floristic information from the most representative tree phytosociological studies of the Atlantic Forest formations in the state of Paraná, Southern Brazil. The data were obtained from scientific papers, doctoral thesis, master dissertations and from our own surveys performed for at least 10 years in the region (Table 1). The floristic information from 39 studies encompassing 58 forest sites was included in the present study.

There was a difficulty in finding studies with same inclusion criteria (same diameter at breast height – DBH) for different formations. The minimum DBH value available in the original dataset ranged from 3.1 to 10.0 cm. This range was therefore considered in the present study. Additionally, the different sample sizes were not standardized among surveys.

The altitudes of the sites range from 5 to 1750 m a.s.l. The most distant sites (separated by 590 km) are located in the following geographic coordinates: 25°23′ S; 48°13′ W, near the Atlantic Ocean and 22°43′ S; 53°18′ W, near the Upper Paraná River (Figure 1).

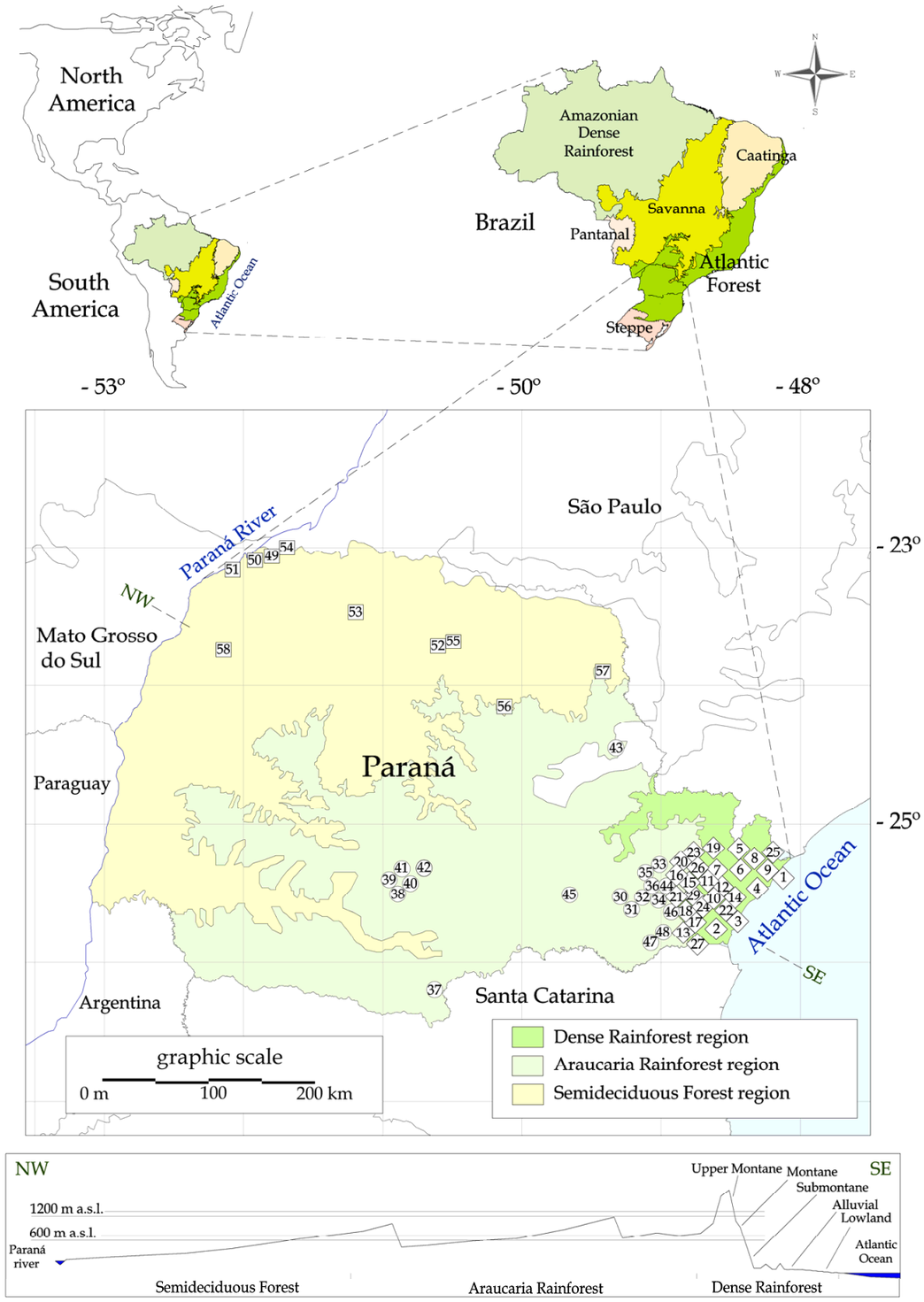
Sites in early and middle sucessional stages, as well as undetermined *taxa* and exotic species were not included. *Taxa* identified only to the family or genus level were grouped according to taxonomic hierarchy. For example: the Myrtaceae group included many undetermined *taxa* of this family, and the *Lonchocarpus* group comprised undetermined species of this genus. For the richness estimation, each taxonomic group of undetermined *taxa* was considered as a unique species. The data underwent a detailed review to check all accepted species names and synonymy according to the "Species List of the Brazilian Flora" (Forzza et al., 2010). The compilation of the surveys on forest structure comprised 29 hectares of sampled area and 36627 measured individuals. The diversity indexes were calculated according to Magurran (1988). Canonical correspondence analyses (CCA) processed by the program CANOCO 4.5 (Ter Braak & Smilauer, 2002) were used to assess the relationship between abundance of the tree species of 58 sites comprising nine Atlantic Forest formations, and geo-climatic variables. The matrix with abundances per forest site includes 631 species. The geo-climatic matrix includes the following variables: distance from the ocean, annual temperature, altitude and annual rainfall. Data not presented in the original studies were obtained from climatic maps of IAPAR (Caviglione et al., 2000). Major approximations of mean annual temperatures (decrease of 0.54 ^{o}C for every 100 m of increased altitude) were used following recommendations in Roderjan & Grodski (1999). The Brazilian official vegetation classification (Veloso et al., 1991; IBGE, 1992) was used to group the sites into each Atlantic Forest formation (see below).

3. Atlantic Forest Biome, environmental and vegetational features

The Atlantic Forest in the state of Paraná has three distinct types of forest ecosystems: the Dense Rainforest (Atlantic "Ombrophilous" Dense Forest), the Araucaria Rainforest (Mixed "Ombrophilous" Forest) and the Semideciduous Seasonal Forest (IBGE, 1992). Each one of these forests also comprises distinct formations and associated or ingrown ecosystems, resulting from geomorphological and climatological features (Figure 1). The five main categories of formations (IBGE, 1992) were included, namely: Lowland (Coastal Plain Forest), Alluvial (Floodplain Forest), Submontane and Montane (both can be also considered Lower Montane), and Upper Montane. The Dense Rainforest presents all of these categories, whilst the Araucaria Rainforest and the Semideciduous Seasonal Forest Comprise mainly the Alluvial and Montane and the Alluvial and Submontane formations, respectively.

N	Forest formation	Municipality	Location (site)	Alt. (m a.s.l.)	Reference
1	Lowland DRF	Guaraqueçaba	Ilha do Superagui	12	Jaster (1995)
2	Lowland DRF	Guaratuba	Guaratuba	10	Galvão et al. (2002)
3	Lowland DRF	Matinhos	Matinhos	10	Galvão et al. (2002)
4	Lowland DRF	Paranáguá	Ilha do Mel	5	Menezes Silva (1990)
5	Alluvial DRF	Guaraqueçaba	Itaqui Reserve/site1	20	Zacarias (2008)
6	Alluvial DRF	Guaraqueçaba	Itaqui Reserve/site2	20	Zacarias (2008)
7	Submontane DRF	Antonina	Cachoeira Reserve	350	Liebsch et al. (2007)
8	Submontane DRF	Guaraqueçaba	Morro do Quitumbe	200	Athayde (1997)
9	Submontane DRF	Guaraqueçaba	Morro do Superagui	20-170	Jaster (1995)
10	Submontane DRF	Guaratuba	Rio Cubatãozinho	400	Guapyassu (1994)
11	Submontane DRF	Morretes	Morretes	485	Silva (1994)
12	Submontane DRF	Morretes	Serra da Prata/site1	400-600	Blum (2006)
13	Montane DRF	Guaratuba	Morro dos Perdidos	800	Blum et al. (2001)
14	Montane DRF	Morretes	Serra da Prata/site2	800-1100	Blum (2006)
15	Montane DRF	Piraquara	Mananciais da Serra	1030	Reginato & Goldenberg (2007)
16	Montane DRF	Quatro Barras	Morro Anhangava/site2	1150	Roderjan (1994)
17	Montane DRF	São José dos Pinhais	Guaricana/site1	500-700	Schorn (1992)
18	Montane DRF	São José dos Pinhais	Guaricana/site2	500-700	Schorn (1992)
19	Upper Montane DRF	Morretes	Pico Marumbi	1385	Rocha (1999)
20	Upper Montane DRF	Quatro Barras	Morro Anhangava/site3	1300	Portes et al. (2001)
21	Upper Montane DRF	Quatro Barras	Morro Anhangava/site1	1350	Roderjan (1994)
22	Upper Montane DRF	Morretes	Serra da Prata/site3	1400	Scheer et al. (in press a)
23	Upper Montane DRF	Antonina	Serra do Ibitiraquire	1700	Scheer et al. (in press a)
24	Upper Montane DRF	Morretes	Serra da Igreja	1300	Scheer et al. (in press a)
25	Upper Montane DRF	Guaraqueçaba	Serra Gigante	950	Scheer et al. (in press a)
26	Upper Montane DRF	Morretes	Morro Mãe Catira	1300	Koehler (2001)
27	Upper Montane DRF	Tijucas do Sul	Morro Araçatuba	1400	Koehler (2001)
28	Upper Montane DRF	São José dos Pinhais	Serra do Salto	1300	Koehler (2001)
29	Upper Montane DRF	Morretes	Morro Vigia	1300	Koehler (2001)
30	Alluvial ARF	Araucária	Distr.General Lúcio/site1	897	Pasdiora (2003)
31	Alluvial ARF	Araucária	Distr.General Lúcio/site2	897	Pasdiora (2003)
32	Alluvial ARF	Araucária	Rio Barigui	875	Barddal et al. (2004)
33	Alluvial ARF	Pinhais	Pinhais/site2	850	Seger et al. (2005)
34	Alluvial ARF	São José dos Pinhais	Rio Miringuava/site1	880	Jaster et al. (2002)
35	Montane ARF	Curitiba	Barigui Park	900	Kozera et al. (2006)
36	Montane ARF	Curitiba	Capão do Tigre	900	Rondon Neto et al. (2002)
37	Montane ARF	General Carneiro	Fazenda Pizzato	990	Watzlawick et al. (2005)
38	Montane ARF	Guarapuava	Fazenda 3 Capões/site1	950	Cordeiro (2010)
39	Montane ARF	Guarapuava	Fazenda 3 Capões/site2	950	Cordeiro (2010)
40	Montane ARF	Guarapuava	Fazenda 3 Capões/site3	950	Cordeiro (2010)
41	Montane ARF	Guarapuava	Fazenda 3 Capões/site4	950	Cordeiro (2010)
42	Montane ARF	Guarapuava	Araucárias Park	1070	Cordeiro & Rodrigues (2007)
43	Montane ARF	Jaguariaíva	Paredão da Santa	1195	Blum (ongoing study)
44	Montane ARF	Pinhais	Pinhais/site1	850	Seger et al. (2005)
45	Montane ARF	São João do Triunfo	São João do Triunfo	780	Durigan (1999)
46	Montane ARF	São José dos Pinhais	Rio Miringuava/site2	910	Jaster et al. (2002)
47	Montane ARF	Tijucas do Sul	Tijucas do Sul	850	Geraldi et al. (2005)
48	Montane ARF	Tijucas do Sul	Fazenda Bührer	850	Geraldi et al. (2005)
49	Alluvial SSF	Diamante do Norte	Caiuá Ecol.Station/site1	250	Borghi et al. (2004)
50	Alluvial SSF	Diamante do Norte	Caiuá Ecol.Station/site2	250	Costa Filho et al. (2006)
51	Alluvial SSF	Porto Rico	Alto Paraná	240	Campos et al. (2000)
52	Alluvial SSF	Londrina	Ribeirão dos Apertados	500	Bianchini et al. (2003)
53	Submontane SSF	Astorga	Ribeirão Aurora	550	Veiga et al. (2003)
54	Submontane SSF	Diamante do Norte	Caiuá Ecol.Station/site3	280	Del Quiqui et al. (2007)
55	Submontane SSF	Londrina	Mata dos Godoy Park	500	Soares-Silva et al. (1998)
56	Submontane SSF	Sapopema	Fazenda Bom Sucesso	780	Silva et al. (1995)
57	Submontane SSF	Tomazina	Rio das Cinzas	500	Blum et al. (2003)
58	Submontane SSF	Umuarama	Estrada Boiadeira	450	Blum & Petean (2008)

Table 1. List of the analyzed fores sites in Atlantic Forest formations in the state of Paraná, Brazil. (N - site number used in this study; DRF – Dense Rainforest; ARF – Araucaria Rainforest; SSF – Semidecidual Seasonal Forest).



Adapted from: MMA (2011) and Roderjan et al. (2002).

Fig. 1. Location of the 58 sites in the Atlantic Forest types in the state of Paraná, Southern Brazil. Numbers are related to sites presented in Table 1.

3.1 Dense Rainforest

The Dense Rainforest, or Atlantic Forest *sensu stricto* (Oliveira-Filho & Fontes, 2000), is characterized by the dominance of large trees (25-30 m height) associated with many other biological forms, mainly epiphytes and woody lianas, that gives it its tropical appearance (Klein, 1979). Evergreen trees dominate the dense canopy (Veloso et al., 1991; IBGE, 1992).

Different plant communities of this forest type are found from the beach ridges near the Atlantic Ocean to the upper montane ridges of the Serra do Mar (Sea Mountain Range) and its western slopes towards the ecotone with Araucaria Rainforest (Figure 1). The altitudinal gradient ranges from 1 to 1887 m a.s.l., resulting in this region in a decrease of 0.54 °C for every 100 m increase in altitude (Roderjan & Grodski, 1999). While the coastal plain formations are in soils derived from Cenozoic (mainly Quaternary) marine sediments, alkali granites, embedded in high-grade metamorphic terrains, form the mineral soil horizons of the upper portions of the landscape. According to Mineropar (2001), intrusive igneous rocks from Serra do Mar were originated nearly 550 million years ago in the Upper Proterozoic to Cambrian. Faults from the Brasiliano (or Pan African) Cycle (events of the end of the late Proterozoic) and the Ponta Grossa Arch, cut the landscape in the NE-SW and NW-SE axes, respectively. Therefore, the soils of the Dense Rainforest have a high variety in parent material, genesis, depth, horizons, layers, structure, texture and organic matter.

The climate of the lower portions of the Dense Rainforest gradient, up to the transition between the Submontane and Montane formations, 600 - 800 m a.s.l. (Blum, 2010), can be classified as Cfa, or meso-thermic, according to the Köppen classification system. Daily mean annual temperature is 21 ºC, the mean temperature in the coldest month is about 16 ºC and, in the warmest month is higher than 22 ºC, with hot and wet summers (December-March), and a no-pronounced dry season. Maack (2002) considered the region as having a transitional tropical climate (Af). The climate of upper portions, above 700 m a.s.l., is classified as Cfb (humid subtropical, meso-thermic, with cool summers, frequent frosts and no pronounced dry season). The mean temperature of the coldest month (July) in the region is less than 16 ºC (reaching 12.5 ºC) and of the warmest month (February) is less than 22 ºC (20.5 ºC). Measurements in the coastal region exceed 2000 mm of rain per year, and on the slopes of the mountains these values reach 3500 mm of rain per year (Caviglione et al., 2000; Maack, 2002).

As a result of the high environmental variety the Dense Rainforest is the most heterogeneous, complex and rich forest ecosystem of Southern Brazil (Leite & Klein, 1990).

A compiled list of the tree flora of the Dense Rainforest of Southern Brazil, using data of the botanical collection of the Barbosa Rodrigues Herbaria, revealed 708 species. More than 50% of those species occur exclusively in this type of Atlantic Forest (Leite & Klein, 1990).

Dense Rainforest communities in the advanced stages of succession cover an area of 3937.5 km² or 51,5% of the original distribution area as interpreted from satellite images from 1999 (Pires et al., 2005).

Forward we present the five cattegories of the Atlantic Rainforest.

3.1.1 Lowland formation

In South Brazil, the Lowland formation (Coastal Plain Forest) is restricted to Quaternary coastal plains growing on tsites near to sea level to about 20 m a.s.l.. Poorly developed soils and the high susceptibility to flooding during the rainiest periods are remarkable factors that led to its typical floristic and structural composition (Leite & Klein, 1990; Veloso et al., 1991; IBGE, 1992; Roderjan et al., 2002; Pires et al., 2005).

This formation presents a continuous canopy (about 20-25 m height) and two physiognomies can be distinguished. *Calophyllum brasiliense* trees dominate the canopy of areas with soils subject to waterlogging (Histosols, Spodosols and Entisols). This species is generally associated with *Tabebuia cassinoides*, *Tapirira guianensis, Ficus luschnatiana*, *Ilex pseudobuxus*, *Clusia criuva* and *Pouteria beaurepairei*. In better-drained lands, non-hydromorphic Entisols (Quartzipsamments/Arenosols) and Spodosols support higher diversity. There are common in the canopy *Tapirira guianensis*, *Ocotea pulchella*, *Ficus organensis*, *Manilkara subcericea*, *Pera glabrata, Alchornea triplinervia*, *Andira anthelmia*, *Ilex theezans*, *Ternstroemia brasiliensis*, besides many Myrtaceae such as *Psidium cattleianum* and *Myrcia multiflora* (Leite & Klein, 1990; Silva, 1990; Jaster, 1995; Jaster, 2002; Roderjan et al., 2002; Pires et al., 2005).

3.1.2 Alluvial formation

The Alluvial Dense Rainforest grows in Fluvisols and Gleysols in alluvial plains influenced by mountain range sediments carried by rivers (Roderjan et al., 2002).

The canopy is usually 20-25 m tall and some expressive species of this formation are *Pseudobombax grandiflorum*, *Alchornea triplinervia*, *Ficus organensis*, *Andira anthelmia* and *Syagrus romanzoffiana*. *Inga sessilis, Coussapoa microcarpa, Psidium cattleianum*, *Ocotea pulchella*, *Myrcia insularis* and *Marlierea tomentosa* are also important in these communities (Roderjan et al., 2002; Pires et al., 2005; Zacarias, 2008).

3.1.3 Submontane formation

This ecosystem comprises the lower portions of slopes of the mountain ranges and the Ribeira River Valley. According to IBGE (1992), this formation occurs between 30 and 400 m a.s.l.. However, Roderjan et al. (2002) adapted the upper limit of the Submontane formation to 600 m a.s.l., considering the regional scale. Results of a survey performed by Blum & Roderjan (2007) agree well with this limit. The Submontane Atlantic Rainforest generally occurs on Argisols, Oxisols and Cambisols, mainly in colluvial fans (Roderjan et al., 2002).

The dense canopy varies between 25 and 30 m in height and is characterized by high tree diversity and richness. *Virola bicuhyba*, *Sloanea guianensis*, *Aspidosperma pyricollum*, *Cedrela fissilis*, *Cariniana estrellensis*, *Pseudopiptadenia warmingii* and *Schyzolobium parahyba* are frequent in the canopy. *Bathysa australis*, *Pausandra morisiana*, *Euterpe edulis*, *Geonoma gamiova* and *Psychotria nuda* are common in the dominated strata (Leite & Klein, 1990; Maack, 2002; Roderjan et al., 2002; Pires et al., 2005; Blum, 2006).

This formation presents the highest floristic diversity of Southern Brazil due to the combination of factors like soils with good physical support and nutritional capacity, higher temperatures and well distributed rainfalls (Leite & Klein, 1990; Roderjan et al., 2002). These features also promote the development of dense and large-sized arboreal communities, associated with terrestrial and epiphytic strata, extremely rich and abundant (Blum, 2010).

3.1.4 Montane formation

The forest communities distributed over the intermediate slopes of the mountain ranges at elevations above the Submontane limits are classified as Montane formations. According to Roderjan et al. (2002) and Blum (2006), in the state of Paraná these communities are situated between 600 and 1200 m a.s.l..

It is noteworthy that the upper limit is also variable depending on specific soil and climate and, in many cases, the Upper Montane formation can already occur below 1200 m a.s.l. (Pires et al., 2005). Floristic differences are observable in relation to the lower level, but

structurally and physiognomic, the Montane and Submontane formations are similar (Roderjan et al., 2002; Pires et al., 2005). Cambisols (with no textural gradient) and Entisols are very common in the Montane belt (Schorn, 1992; Roderjan, 1994, Blum, 2006).
The main environmental factors that affect the differentiation between the Montane and Submontane formations (Lower Montane Forests) are the climate, the topography and the soils. In the Montane Atlantic Forest it can occur occasional frosts, which are extremely limiting for many typical species of Submontane formation, that are subject to milder climate. It should be noted that the geomorphological differences result in distinct pedologies. The Montane terrains are steep and dissected while the Submontane sites are usually understated (Roderjan et al., 2002; Pires et al., 2005; Blum, 2006; 2010).
The canopy of the Montane Dense Rainforest is regular, varying about 20-25 m height. Several species of Lauraceae dominate in the upper strata, especially *Ocotea catharinensis*, *Ocotea odorifera, Ocotea bicolor* and *Cryptocarya aschersoniana. Aspidosperma pyricollum, Pouteria torta*, *Cabralea canjerana, Sloanea lasiocoma, Guapira opositta, Ilex paraguariensis* and *Guatteria australis* are also relevant. The lower strata are characterized by Myrtaceae, Rubiaceae and Monimiaceae families. Ferns (tree ferns) such as *Cyathea phalerata* and another species of Cyatheaceae are common in the understory (IBGE, 1992; Roderjan, 1994; Blum et al., 2001; Roderjan et al., 2002; Pires et al., 2005; Blum, 2006).

3.1.5 Upper Montane formation

In the state of Paraná, faults belonging to the Brasiliano (or Pan African) Cycle and the Ponta Grossa Arch currently confine the Upper Montane Rainforests (or Cloud Forests), allowing such vegetation to reach areas close to the main tops of the Sea Mountain Range (Scheer et al., in press b). This formation generally occurs from 1200 m a.s.l (Roderjan et al., 2002), even though it can be found at 900 m a.s.l., in small isolated mountains due to geomorphological conditions and the "*Massenerhebung* effect" (Grubb, 1971). In larger mountains, such as the Paraná Peak, the typical Upper Montane Rainforest ranges from 1400 to 1850 m a.s.l.., interspersed with high altitude grasslands. The changes in vegetation from forests to grasslands are abrupt and include ecotonal areas with "dwarf forests" or shrubby physiognomy with species of both formations across a gradient of a few meters (2-5 m).
Although typical Upper Montane Forests are composed by simplified tree associations, 346 vascular plant species have been detected in four mountain ranges (Scheer & Mocochinski, 2009). Small-sized trees ranging from 3 to 7 m tall, are subject to more restrict environmental conditions, such as low temperatures, strong winds and constant and heavy cloudiness, intense light radiation and shallow soils with low fertility and substantial histic horizons (Histosols and Leptosols). *Ilex microdonta*, *Siphoneugena reitzii*, *Myrceugenia seriatoramosa*, *Citronella paniculata, Weinmannia humilis*, *Ocotea porosa, Podocarpus sellowii* and *Drimys brasiliensis* are typical species in such areas (Leite & Klein, 1990; Roderjan, 1994, Koehler et al., 2002; Roderjan et al., 2002; Pires et al., 2005; Scheer, 2010; Scheer et al., in press a).

3.2 Araucaria Rainforest

Also called "Mixed Ombrophilous Forest" (IBGE, 1992), this forest physiognomy is characterized by merging elements from two distinct flora origins: the Tropical Afro-Brazilian and the Temperate Austro-Brazilian (Veloso et al., 1991). Classified as a Subtropical Forest, this ecosystem occurs mainly in the First and Second Plateaus of Paraná (mainly in the Center and the South of the state) at altitudes generally varying between 800 and 1000 m a.s.l. (Figure 1). In this region, temperatures are relatively low and frosts are common. In many locations, these formations share the landscape with natural grasslands.

According to Köppen System, the climate of the Araucaria Rainforest region is Cfb, with annual average temperatures between 16 and 18 ºC and average annual rainfall generally between 1400 and 1600 mm (Caviglione et al., 2000).
This forest formation shows structural variations related to environmental diversification, varying from dense formations with trees of ca. 25 to 35 m tall, to stunted formations consisting of variable density of trees and shrubs, associated with terrestrial ferns and bamboos (Leite & Klein, 1990). According to Maack (2002), *Araucaria angustifolia*, commonly known as the "Brazilian pine" or "Paraná pine" is the dominant tree of this region, distinguishing this landscape.
A compiled list of the Araucaria Rainforest tree flora of Southern Brazil, using data of the botanical collection of the Barbosa Rodrigues Herbaria, revealed 352 species. Almost 50% of those species occur exclusively in this type of Atlantic Forest (Leite & Klein, 1990).
Castella & Britez (2004) analyzed satellite images from 1998 and concluded that Araucaria Rainforest communities at intermediate or advanced succession stages still covered 13420.6 km² of the state of Paraná, representing about 16.2% of the original cover (Castella & Britez, 2004). However, primary remnants are much less representative.
Two formations are presented in this section: Alluvial and Montane Araucaria Rainforests.

3.2.1 Alluvial formation

The Alluvial Araucaria Rainforest is associated mainly with the Montane formation and is easily distinguished by its typical physiognomy. This is a riparian forest that always occupies alluvial lands adjacent to watercourses (IBGE, 1992; Roderjan et al., 2002).
The physiognomy is structurally characterized by a high density of medium and small individuals, with the canopy ranging between 10 and 20 m in height. Communities can present different degrees of development. In the fairly homogeneous associations, subject to soils with considerable hydromorphy, such as some Fluvisols and Gleysols, *Sebastiania commersoniana* is the most relevant species. In more developed associations *Vitex megapotamica, Schinus terebinthifolius, Allophylus edulis, Luehea divaricata, Symplocos uniflora, Blepharocalyx salicifolius, Myrrhinium atropurpureum, Myrciaria tenella* and *Daphnopsis racemosa* are present. Even *Araucaria angustifolia* can be observed where lower hydromorphy allows its growth (Leite & Klein, 1990; Roderjan et al., 2002; Barddal, 2002; Pires et al., 2005).

3.2.2 Montane formation

According to IBGE (1992), the altitudinal range of the Montane Araucaria Rainforest occurrence is between 400 and 1000 m a.s.l.. However, some authors, such as Leite & Klein (1990) and Roderjan et al. (2002), rightly argue that typical communities occur at altitudes higher than 800 m a.s.l. Below this altitudinal belt there is the beginning of the transition between the Montane Araucaria Rainforest and the Dense Atlantic Rainforest (on the east) or the Semideciduous Seasonal Forest (on the west).
The typical physiognomy is marked by the dominance of *Araucaria angustifolia*, standing out over a continuous canopy that reaches on average 25-30 m height. The continuous strata is characterized by *Ocotea porosa*, *Nectandra lanceolata, Matayba elaeagnoides, Casearia decandra*, *Podocarpus lambertii, Cinnamodendron dinisii, Sloanea lasiocoma, Campomanesia xanthocarpa, Cedrela fissilis, Nectandra grandiflora, Jacaranda puberula, Drimys brasiliensis, Ilex paraguariensis* and *Lithraea brasiliensis*. Species of Myrtaceae and Monimiaceae prevail in the dominated strata. Ferns, especially *Dicksonia sellowiana,* are also common (Leite & Klein, 1990; Durigan, 1999; Roderjan et al., 2002; Rondon Neto et al., 2002; Cordeiro & Rodrigues, 2007).

3.3 Semideciduous Seasonal Forest

The Semideciduous Seasonal Forest region in the the state of Paraná occurs mainly in the Third Plateau (almost the entire North and West of the state) in altitudes generally between 200 and 600 m a.s.l. (Roderjan et al., 2002).

According to the Köppen system, the climate can be classified as Cfa, or meso-thermic, wet. Daily mean temperatures in the coldest month are under 18 ºC and the mean temperature of the warmest month is over 22 ºC (Maack, 2002). However, in this ecosystem the year can be divided into two distinct seasons: one tropical with intense summer rainfalls and short dry periods, and another subtropical with low winter temperatures and scarce precipitation. During this unfavorable cold and dry period, between 20 and 50% of the canopy trees are deciduous (Veloso et al., 1991; IBGE, 1992). In very specific locations this forest has as ingrown ecosystem the Savanna (Cerrado), which reaches its austral limit in this specified region, covering otherwise a major part of Brazil's Mid-West (Figure 1).

The Semideciduous Seasonal Forest shows succinct variations ranging from the evergreen to deciduous trees, which reach heights close to 30-40 m without forming a continuous superior canopy. This feature allows a great deal of sunlight to reach the forest ground, turning possible the development of a vigorous lower stratum (Silva & Soares Silva, 2000). There are also shrubs, lianas and epiphytes, although in lower abundance and richness compared to rainforests (Leite et al., 1986; Lamprecht, 1990; Leite & Klein, 1990; Roderjan et al., 2002).

A compiled list of the tree flora of the Semideciduous Seasonal Forest of Southern Brazil, using data of the botanical collection of the Barbosa Rodrigues Herbaria, presents at least 213 tree species (Leite & Klein, 1990). Silva & Soares Silva (2000), found 206 arboreal species in Godoy State Park.

Satellite images taken in 1998, indicate that 4174.7 km² of Semideciduous Seasonal Forest communities at intermediate or advanced stages of succession covered only 5.4% of the original area of distribution in that year (SEMA, 2002). Some forests of the northern region were reduced to less than 1% in Maringá and 0.8% in Assaí municipalities (IPARDES, 1986).

Forward are presented the characterizations for the Alluvial and Submontane formations of this forest type.

3.3.1 Alluvial formation

This formation is distributed over riverine floodplains and some islands in the Paraná river, and also around some of its tributaries. The Alluvial formation occurs predominantly in soils with considerable hydromorphy, such as some Fluvisols, Entisols (Quartzipsamments) and Gleysols (Roderjan et al., 2002).

The Alluvial Semideciduous Seasonal Forest is characterized by a canopy about 15 to 20 m height and lower floristic diversity. Among the main species are *Cecropia pachystachya*, *Triplaris americana*, *Calophyllum brasiliense, Gallesia integrifolia* and *Chrysophyllum gonocarpum. Sebastiania commersoniana*, *Anadenanthera colubrina, Acrocomia aculeata* and *Inga uruguensis* are also common (Leite et al. 1986; IBGE, 1992, Roderjan et al., 2002; SEMA, 2002; Costa Filho et al., 2006).

3.3.2 Submontane formation

In the state of Paraná, this formation can be found under 600 m a.s.l.. The Submontane Semideciduous Seasonal Forest occurs in soils of different lithologies (sandstone and igneous extrusive rocks) that result in Oxisols, Ultisols, Regosols (Psamments), Inceptisols, Leptosols and Arenosols (Roderjan et al., 2002). Depending on the lithology, different textures and fertility levels can be found in these soils.

The emergent irregular canopy can reach around 35-40 m height. In the upper stratum are common *Aspidosperma polyneuron*, *Handroanthus heptaphyllus*, *Gallesia integrifolia*, *Balfourodendron riedelianum*, *Peltophorum dubium*, *Astronium graveolens*, *Diatenopteryx sorbifolia, Parapitadenia rigida, Cariniana estrellensis, Cedrela fissilis, Albizia hasslerii, Lonchocarpus guilleminianus*, *Machaerium stipitatum*, *Holocalyx balansae*, *Rauvolfia sellowii*, and *Nectandra megapotamica*, among others. The dominated strata are characterized by *Guarea macrophylla*, *Actinostemon concolor*, *Metrodorea nigra*, *Sorocea bomplandii* and *Pilocarpus pennatifolius* (Hueck, 1972; Leite et al., 1986; Leite & Klein, 1990; Maack, 2002; Roderjan et al., 2002; SEMA, 2002).

4. The studied Atlantic Forest formations

4.1 Analysis of the sampled sites in the Atlantic Forests

Among the 58 sites, comprising 29 ha of plots and 36627 sampled individuals, selected from 39 studies, the Dense Rainforest has the highest number of sampled sites (29 out of a total of 58) and the highest number of tree individuals found (Table 2). This great amount of data available is due to the high number of Upper Montane Dense Rainforest sampled sites, which present relatively many areas with primary and well preserved vegetation. In spite of the relatively smaller sampled area, small-sized trees present in high abundance make up for a high number of individuals found.

On the other hand, the Alluvial formation of the Dense Rainforest is the least sampled one (Table 2). The lack of phytosociological studies conducted in this formation may be related to its actual small cover area (representing only 0.89% of the remnants of Dense Rain Forest) (Pires et al., 2005), and also to its level of degradation, which make the search for typical and representative remnants difficult. According to this data, the studied area is almost six times smaller than the area of the neighbor Lowland formation. Therefore, this understudied vegetation needs more studies.

The low number of studied sites in the Semideciduous Seasonal Forest in the state of Paraná is also remarkable, especially when the great covering area (Figure 1) and the considerable latitudinal extension (22º 30′ - 26º 30′ S) of this ecosystem are considered. The lack of studies is related to the advanced stage of degradation of this forest type. In a few decades this ecosystem was reduced to scarce and fragmented remnants, generally in bad conservation conditions. We did not find phytosociological surveys in the Southwestern region of the state of Paraná, where the Semideciduous Forest is also found (Figure 1). Moreover, forest structure studies are not available even in the most representative remnant of the Submontane Semideciduous Forest of Southern Brazil, located in the Iguaçu National Park, a protected area of approximately 1852.6 km^2. This fact points out to the urgency of knowing better this important ecosystem and its resources.

Besides the similar sampled areas shown by the three Atlantic Forest types (Table 2), and highest number of studied sites for the Dense Rainforest, the sum of the 10 sites of the Semideciduous Forest comprises the largest sampled area (11.8 ha). The two most extensively sampled formations are the Montane Araucaria Rainforest and the Submontane Semideciduous Forest. However, these sampling areas are very small compared to the sampling area of other surveys in different ecosystems. As an example, a single study in the Amazonian Dense Forest, could easily cover an area of 20 ha (Pitman et al., 2002; Laurance et al., 2010).

4.2 Alfa diversity

In the 58 selected phytosociological surveys, 700 species, 256 genera and 83 families were sampled (Table 2). Of the total number of species, 10 *taxa* represent groups with

undetermined species at the family level and 58 *taxa* represent groups with undetermined species at the genus level. It is important to mention that the Atlantic Forest is habitat for many other tree species that were not found due to the criterion of inclusion, or due do the area needed to sample, that neither checklists can cover completely.

Biome	Atlantic Forest types	Atlantic Forest formations	Number of sites	Sampled area (ha)	Number of measured individuals	Number of species	Number of genera	Number of families	Shannon-Wiener Diversity Index	Simpson Diversity Index 1-D	Evenness
ATLANTIC FOREST			29	9.01	14165	469	174	72	5.11	0.99	-
	Dense Rainforest	*Alluvial*	2	0.32	766	78	59	32	3.38	0.94	0.77
		Lowland	4	1.86	2808	148	87	49	3.93	0.96	0.79
		Submontane	6	2.38	3251	265	132	57	4.61	0.98	0.83
		Montane	6	3.48	3140	210	101	52	4.64	0.98	0.87
		Upper Montane	11	0.97	4200	88	45	30	3.20	0.93	0.71
	Araucaria Rainforest		19	8.30	9196	220	101	51	4.29	0.97	-
		Aluvial	5	0.81	1792	79	54	33	2.48	0.74	0.57
		Montane	14	7.49	7404	211	99	50	4.38	0.98	0.82
	Semideciduous Forest		10	11.80	13265	282	154	60	4.64	0.99	-
		Alluvial	4	4.34	5354	157	107	43	4.26	0.98	0.84
		Submontane	6	7.46	7911	252	140	56	4.46	0.98	0.81
	ATLANTIC FOREST		**58**	**29.11**	**36627**	**700**	**256**	**83**	**5.53**	**0.99**	**-**

Table 2. Richness and other diversity parameters of the analyzed Atlantic Forest formations in the state of Paraná, Southern Brazil.

Among the Atlantic Forest types analyzed in this study, the Dense Rainforest is the richest in tree species (469). These species are distributed in 174 genera and 72 families. This tropical forest presents the highest tree diversity according to the Shannon-Wiener index, being its Montane and Submontane formations the most diverse (Table 2; Figure 3). Even though the analysis shows the highest diversity value in the Montane formation, according to many studies, the Submontane formation shows a tendency of being the most diverse (Guapyassú, 1994; Roderjan, 1994; Jaster, 1995; Athayde, 1997; Blum, 2006).

Tabarelli & Mantovani (1999) compiled phytosociological studies on the Dense Rainforest in Southeastern Brazil, which comprised 432 species measured in 2.3 ha and considered 2640 trees measured through the quarter-plot method. According to these authors the richness of these forests are low when compared to other Neotropical Forests of South America. However, more studies considering similar conditions (*e.g.* larger plots – 1 ha – with homogeneous sites) are needed to corroborate these results.

However, some diversity indexes such as Eveness presented for the Atlantic Forest types can be influenced by the disproportionate sampling among their formations.

According to Table 2, the Araucaria Rainforest presents less than half of the Dense Rainforest tree species richness (220), in part due to its lower environmental heterogeneity

and altitudinal range. In addition, the colder climate in the Araucaria Rainforest region probably restricts the occurrence of a substantial number of species.
The Semideciduous Seasonal Forest shows intermediate values of species richness (282) and diversity when compared with the two types of Rainforests. (Table 2; Figure 3).

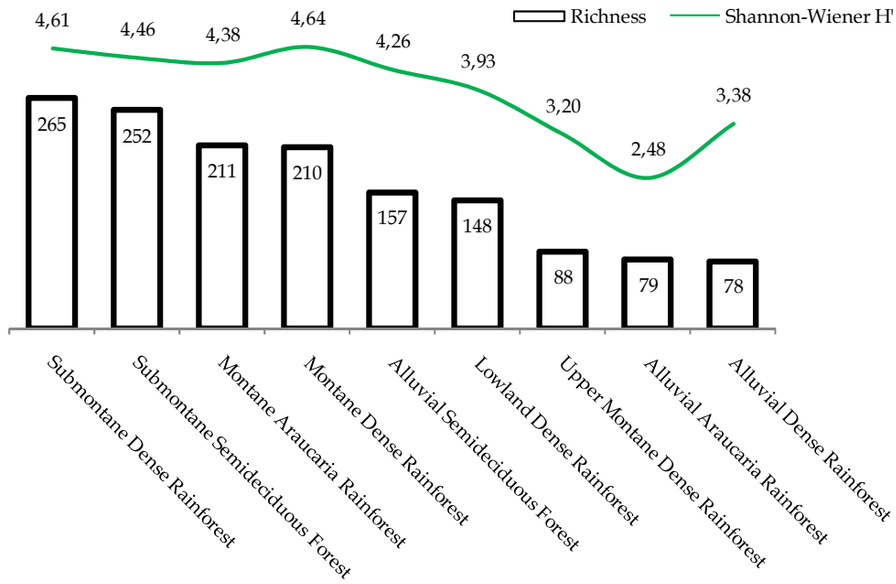


Fig. 3. Tree richness and Shannon-Wiener diversity indexes of the Atlantic Forest formations in the state of Paraná, Southern Brazil.

The higher richness when compared with the Araucaria Rainforest is due to some distinct environmental conditions, such as lower altitude, which result in higher temperatures. On the other hand, the restriction imposed by the seasonal climate, especially by the unfavorable dry season, prevents the Seasonal Forest to reach values of species richness similar to those observed in the Dense Rainforest (i.e. 66% higher). A lower difference (31%) in this parameter between these two types of forest was observed by Oliveira Filho & Fontes (2000) in floristic surveys in Southeastern Brazil.
The Submontane formations present the highest richness of tree species, followed by the Montane formations (Figure 3). The Lowland, Upper Montane and Alluvial formations present lower richness. From the data available, the Alluvial Dense Rainforest has the lowest number of species. However, this is certainly related to the lack of inventories in this type of forest. Due its proximity and environmental similarity with the coastal Lowland formation, it is probable that the real values of tree species richness of both forests are similar.
Therefore, among the Atlantic Forest formations, the Alluvial Araucaria Rainforest can be considered the least rich in tree species. This is due to two important environmental factors: the milder climate, with frequent frosts; and the hydromorphic feature of its soils, with high susceptibility to flooding during the rainiest periods.
According to Table 3, Myrtaceae, Fabaceae and Lauraceae are the families with the highest tree species richness of the Atlantic Forest, making up to 40% of the measured Rainforest species and 35% of the Semideciduous Seasonal Forest species.
Myrtaceae presents the highest number of tree species in the two Rainforests, reaching 112 species in the Dense Rainforest, while Fabaceae is the richest family of the Semideciduous

Forest. Some tree families, such as Fabaceae, Moraceae, Sapotaceae and Meliaceae, show a tendency of preferring warmer environments. On the other hand, Aquifoliaceae, Asteraceae and Myrsinaceae present comparatively high floristic expression in the Rainforest environments. In addition, Melastomataceae presents high species richness only in the Dense Rainforest. According to Gentry (1995) and Oliveira-Filho et al. (2000), with increasing altitude there is a decrease in Fabaceae richness and an increase in Aquifoliaceae and Asteraceae richness.

At the genus level, *Eugenia* is the richest in the tropical forests (mainly in the Dense Rainforest), even though the Araucaria Rainforest (subtropical) presents many species of this taxon. Oliveira-Filho et al. (2000) observed the same tendency in an extensive survey on floristic differentiation patterns among Atlantic Forests in Southeastern Brazil. The richness of *Eugenia* is relatively higher in slope rain forests, and its relative position is reversed with *Myrcia* in lowland (including alluvial) and plateau (Araucaria Rainforest) formations. *Marlierea* has a considerable number of species in Lowland and Submontane formations of the Dense Rainforest, whilst *Myrceugenia* has many species in Upper Montane and Montane formations of both rainforests (Table 4).

Ocotea is among the three genera with the highest number of tree species in the three Atlantic Forest types in the state of Paraná. *Ilex* and *Myrceugenia* have a considerable number of species in the two rainforests, whilst *Trichilia* and *Cordia* have many species in the Semideciduous Forest (Tables 3 and 4).

Dense Rainforest (S=469; N=29)				**Araucaria Rainforest (S=220; N=19)**				**Semideciduous Forest (S=282; N=10)**			
Family	**S**	**Genus**	**S**	**Family**	**S**	**Genus**	**S**	**Family**	**S**	**Genus**	**S**
Myrtaceae	112	*Eugenia*	39	Myrtaceae	49	*Myrcia*	14	Fabaceae	47	*Eugenia*	13
Lauraceae	39	*Myrcia*	25	Lauraceae	23	*Ocotea*	11	Myrtaceae	32	*Nectandra*	8
Fabaceae	35	*Ocotea*	18	Fabaceae	18	*Eugenia*	10	Lauraceae	19	*Ocotea*	8
Rubiaceae	24	*Miconia*	12	Asteraceae	10	*Myrceugenia*	8	Meliaceae	13	*Trichilia*	8
Melastomataceae	21	*Ilex*	11	Rubiaceae	10	*Ilex*	6	Rubiaceae	11	*Cordia*	7
Moraceae	12	*Myrceugenia*	11	Salicaceae	8	*Myrsine*	6	Solanaceae	11	*Solanum*	7
Sapotaceae	12	*Calyptranthes*	10	Solanaceae	8	*Solanum*	6	Salicaceae	10	*Inga*	6
Aquifoliaceae	11	*Inga*	9	Aquifoliaceae	6	*Symplocos*	6	Euphorbiaceae	9	*Myrcia*	6
Euphorbiaceae	11	*Nectandra*	9	Myrsinaceae	6	*Casearia*	5	Rutaceae	9	*Casearia*	5
Asteraceae	9	*Marlierea*	8	Sapindaceae	6	*Maytenus*	5	Boraginaceae	7	*Ficus*	5
Myrsinaceae	9	*Myrsine*	8	Symplocaceae	6	*Allophylus*	4	Moraceae	7	*Lonchocarpus*	5
Annonaceae	8	*Symplocos*	8	Annonaceae	5	*Lonchocarpus*	4	Sapotaceae	7	*Machaerium*	5
Meliaceae	8	*Coccoloba*	7	Celastraceae	5	*Machaerium*	4	Annonaceae	6	*Pouteria*	5
Salicaceae	8	*Psychotria*	7	Euphorbiaceae	4	*Nectandra*	4	Malvaceae	6	*Sloanea*	4
Sapindaceae	8	*Ficus*	6	Rutaceae	4	*Piptocarpha*	4	Sapindaceae	6	*Zanthoxylum*	4

Table 3. The 15 best represented families and genera measured in the three Atlantic Forest types of the state of Paraná, Southern Brazil. S = number of species, N = number of sites.

The most abundant species found in phytosociological studies in the Atlantic Forest formations in the state of Paraná are given in Table 5. Except for the Alluvial, the sampling for all the other formations can be considered very representative of what can be found in these forests. This compilation obtained data for at least 2800 individuals and four sites for each formation, whereas phytosociological studies for the Semideciduous Seasonal forest in the Southwest of the state of Paraná cannot be found.

Dense Rainforest (S=469; N=29)										Araucaria Rainforest (S=220; N=19)				Semideciduous Forest (S=282; N=10)			
Alluvial* (N=2)	**S 78**	**Lowland (N=4)**	**S 148**	**Submontane (N=6)**	**S 265**	**Montane (N=6)**	**S 210**	**Upper Montane (N=11)**	**S 88**	**Aluvial (N=5)**	**S 79**	**Montane (N=14)**	**S 211**	**Alluvial (N=4)**	**S 157**	**Submontane (N=6)**	**S 252**
Myrtaceae	18	Myrtaceae	35	Myrtaceae	53	Myrtaceae	47	Myrtaceae	26	Myrtaceae	22	Myrtaceae	45	Fabaceae	28	Fabaceae	45
Fabaceae	7	Fabaceae	13	Fabaceae	23	Lauraceae	28	Lauraceae	8	Fabaceae	8	Lauraceae	23	Myrtaceae	16	Myrtaceae	31
Melastomataceae	6	Lauraceae	9	Lauraceae	19	Fabaceae	14	Aquifoliaceae	7	Aquifoliaceae	4	Fabaceae	14	Meliaceae	11	Lauraceae	19
Rubiaceae	6	Myrsinaceae	6	Rubiaceae	15	Rubiaceae	13	Asteraceae	5	Salicaceae	4	Asteraceae	10	Lauraceae	8	Meliaceae	13
Aquifoliaceae	3	Rubiaceae	6	Melastomataceae	13	Aquifoliaceae	7	Symplocaceae	4	Euphorbiaceae	3	Rubiaceae	10	Euphorbiaceae	6	Salicaceae	10
Bignoniaceae	3	Euphorbiaceae	5	Sapotaceae	11	Melastomataceae	7	Cunoniaceae	3	Lauraceae	3	Salicaceae	8	Sapindaceae	6	Rubiaceae	9
Clusiaceae	3	Melastomataceae	5	Moraceae	10	Proteaceae	5	Melastomataceae	3	Myrsinaceae	3	Solanaceae	8	Sapotaceae	6	Rutaceae	9
Annonaceae	2	Moraceae	5	Euphorbiaceae	8	Sapindaceae	5	Rubiaceae	3	Rubiaceae	3	Aquifoliaceae	6	Rubiaceae	5	Euphorbiaceae	8
Arecaceae	2	Aquifoliaceae	4	Meliaceae	8	Asteraceae	4	Celastraceae	2	Sapindaceae	3	Myrsinaceae	6	Rutaceae	5	Solanaceae	8
Lauraceae	2	Arecaceae	4	Annonaceae	6	Cunoniaceae	4	Clethraceae	2	Anacardiaceae	2	Sapindaceae	6	Annonaceae	4	Boraginaceae	7
Meliaceae	2	Bignoniaceae	4	Cyatheaceae	5	Euphorbiaceae	4	Ericaceae	2	Symplocaceae	2	Symplocaceae	6	Apocynaceae	4	Moraceae	7
Sapindaceae	2	Sapotaceae	4	Monimiaceae	5	Monimiaceae	4	Myrsinaceae	2	Annonaceae	1	Annonaceae	5	Boraginaceae	4	Annonaceae	5
Sapotaceae	2	Annonaceae	3	Salicaceae	5	Myrsinaceae	4	Polygonaceae	2	Araucariaceae	1	Celastraceae	5	Salicaceae	4	Malvaceae	5
Urticaceae	2	Clusiaceae	3	Apocynaceae	4	Salicaceae	4	Proteaceae	2	Arecaceae	1	Euphorbiaceae	4	Anacardiaceae	3	Sapindaceae	5
Anacardiaceae	1	Cyatheaceae	3	Arecaceae	4	Solanaceae	4	Winteraceae	2	Bignoniaceae	1	Rutaceae	4	Malvaceae	3	Apocynaceae	4
Myrcia	9	*Myrcia*	11	*Eugenia*	20	*Eugenia*	16	*Eugenia*	7	*Myrcia*	8	*Myrcia*	14	*Eugenia*	8	*Eugenia*	12
Miconia	4	*Eugenia*	8	*Myrcia*	10	*Ocotea*	15	*Myrcia*	7	*Ilex*	4	*Ocotea*	11	*Trichilia*	6	*Nectandra*	8
Eugenia	3	*Calyptranthes*	5	*Miconia*	9	*Myrcia*	9	*Ilex*	6	*Eugenia*	3	*Eugenia*	10	*Cordia*	4	*Ocotea*	8
Ilex	3	*Marlierea*	5	*Ocotea*	9	*Ilex*	7	*Myrceugenia*	6	*Myrceugenia*	3	*Myrceugenia*	7	*Nectandra*	4	*Trichilia*	8
Andira	2	*Myrsine*	5	*Marlierea*	6	*Myrceugenia*	6	*Ocotea*	5	*Myrsine*	3	*Ilex*	6	*Pouteria*	4	*Cordia*	7
Inga	2	*Ficus*	4	*Calyptranthes*	5	*Nectandra*	5	*Symplocos*	4	*Casearia*	2	*Myrsine*	6	*Campomanesia*	3	*Inga*	6
Psychotria	2	*Ilex*	4	*Cyathea*	5	*Calyptranthes*	4	*Persea*	3	*Erythrina*	2	*Solanum*	6	*Casearia*	3	*Myrcia*	6
Tibouchina	2	*Inga*	4	*Inga*	5	*Casearia*	4	*Agarista*	2	*Inga*	2	*Symplocos*	6	*Guarea*	3	*Casearia*	5
Abarema	1	*Nectandra*	4	*Mollinedia*	5	*Inga*	4	*Clethra*	2	*Machaerium*	2	*Casearia*	5	*Inga*	3	*Ficus*	5
Alchornea	1	*Alchornea*	3	*Psychotria*	5	*Mollinedia*	4	*Coccoloba*	2	*Ocotea*	2	*Maytenus*	5	*Lonchocarpus*	3	*Lonchocarpus*	5
Amaioua	1	*Miconia*	3	*Trichilia*	5	*Myrsine*	4	*Daphnopsis*	2	*Sebastiania*	2	*Allophylus*	4	*Machaerium*	3	*Machaerium*	5
Aniba	1	*Ocotea*	3	*Brosimum*	4	*Roupala*	4	*Drimys*	2	*Symplocos*	2	*Lonchocarpus*	4	*Ocotea*	3	*Solanum*	5
Blepharocalyx	1	*Pouteria*	3	*Campomanesia*	4	*Rudgea*	4	*Maytenus*	2	*Allophylus*	1	*Machaerium*	4	*Sloanea*	3	*Zanthoxylum*	4
Brosimum	1	*Andira*	2	*Nectandra*	4	*Alchornea*	3	*Miconia*	2	*Araucaria*	1	*Nectandra*	4	*Allophylus*	2	*Albizia*	3
Cabralea	1	*Byrsonima*	2	*Chrysophyllum*	4	*Cinnamomum*	3	*Myrsine*	2	*Banara*	1	*Zanthoxylum*	4	*Aspidosperma*	2	*Campomanesia*	3

Table 4. The 15 best represented families and genera measured in the nine Atlantic Forest formations of the state of Paraná, Southern Brazil. S = number of species, N = number of sites. *Data from Zacarias (2008).

Alluvial* (N=2)	I (766)	Dense Rainforest (N=29; I=14288) Lowland (N=4)	I (2808)	Submontane (N=6)	I (3251)	Montane (N=6)	I (3140)	Upper Montane (N=11)	I (4200)
Canopy species									
Tabebuia cassinoides	112	*Tabebuia cassinoides*	287	*Sloanea guianensis*	121	*Nectandra reticulata*	126	*Ilex microdonta*	700
Psidium cattleianum	75	*Clusia criuva*	183	*Calyptranthes grandifolia*	117	*Alchornea triplinervia*	85	*Siphoneugena reitzii*	637
Pera glabrata	55	*Ocotea pulchella*	183	*Guapira opposita*	100	*Ilex paraguariensis*	79	*Drimys angustifolia*	280
Syagrus romanzoffiana	44	*Calophyllum brasiliense*	178	*Hieronyma alchorneoides*	100	*Ocotea odorifera*	76	*Myrcia pulchra*	278
Tibouchina trichopoda	34	*Ternstroemia brasiliensis*	100	*Eugenia cerasiflora*	52	*Cryptocarya aschersoniana*	67	*Ocotea porosa*	206
Andira anthelmia	16	*Ilex pseudobuxus*	88	*Marlierea tomentosa*	50	*Syagrus romanzoffiana*	63	*Myrceugenia seriatoramosa*	180
Handroanthus umbellatus	14	*Pera glabrata*	81	*Virola bicuhyba*	43	*Cabralea canjerana*	56	*Handroanthus catarinensis*	177
Ocotea pulchella	12	*Psidium cattleianum*	81	*Marlierea silvatica*	42	*Myrsine umbellata*	55	*Ilex chamaedryfolia*	151
Inga edulis	11	*Tapirira guianensis*	59	*Trichilia lepidota*	39	*Ocotea porosa*	53	*Citronella paniculata*	139
Maytenus robusta	11	*Syagrus romanzoffiana*	57	*Cupania oblongifolia*	33	*Weinmannia paulliniifolia*	51	*Blepharocalyx salicifolius*	129
Ilex pseudobuxus	10	*Byrsonima ligustrifolia*	49	*Protium kleinii*	28	*Ocotea catharinensis*	47	*Weinmannia humilis*	111
Amaioua guianensis	9	*Guapira opposita*	47	*Cecropia pachystachya*	27	*Guatteria australis*	46	*Ouratea vaccinioides*	96
Jacaranda puberula	9	*Myrcia pubipetala*	46	*Quiina glazovii*	26	*Ocotea bicolor*	45	*Eugenia neomyrtifolia*	87
Calophyllum brasiliense	8	*Myrcia racemosa*	45	*Calyptranthes lucida*	26	*Guapira opposita*	43	*Pimenta pseudocaryophyllus*	70
Myrcia glabra	8	*Pouteria beaurepairei*	38	*Alchornea triplinervia*	25	*Cupania vernalis*	37	*Myrcia dichrophylla*	63
Understory species								*Myrcia guianensis*	61
Psychotria nuda	97	*Cyathea atrovirens*	182	*Psychotria nuda*	176	*Cyathea phalerata*	187	*Ternstroemia brasiliensis*	61
Eugenia blastantha	24	*Erythroxylum amplifolium*	64	*Rudgea jasminoides*	161	*Cordiera concolor*	93	*Myrcia hartwegiana*	60
Euterpe edulis	23	*Myrcia multiflora*	60	*Garcinia gardneriana*	115	*Alsophila setosa*	87	*Podocarpus sellowii*	50
Guarea macrophylla	17	*Marlierea tomentosa*	53	*Euterpe edulis*	114	*Dicksonia sellowiana*	79	*Laplacea fructicosa*	46
Myrcia insularis	12	*Hedyosmum brasiliense*	33	*Bathysa australis*	113	*Ocotea teleiandra*	54	*Ocotea vaccinioides*	45

Table 5. Species with the highest number of individuals measured for each formation of Atlantic Forest in the state of Paraná, Southern Brazil. I = number of sampled individuals, N = number of sites. *Data from Zacarias (2008).

Table 5. (Continued)

Araucaria Rainforest (N=19; I=9196)				Semideciduous Seasonal Forest (N=10; I=13264)			
Alluvial* (N=5)	**I (1792)**	**Montane (N=14)**	**I (7404)**	**Alluvial (N=4)**	**I (5354)**	**Submontane (N=6)**	**I (7911)**
Canopy species							
Sebastiania commersoniana	903	*Araucaria angustifolia*	514	*Cecropia pachystachya*	393	*Astronium graveolens*	263
Allophylus edulis	62	*Campomanesia xanthocarpa*	364	*Triplaris americana*	245	*Parapiptadenia rigida*	232
Schinus terebinthifolius	56	*Podocarpus lambertii*	293	*Gallesia integrifolia*	174	*Campomanesia xanthocarpa*	226
Myrrhinium atropurpureum	52	*Matayba elaeagnoides*	291	*Peltophorum dubium*	152	*Machaerium stipitatum*	224
Blepharocalyx salicifolius	45	*Allophylus edulis*	200	*Sloanea guianensis*	152	*Luehea divaricata*	224
Vitex megapotamica	42	*Casearia decandra*	200	*Calophyllum brasiliense*	147	*Casearia gossypiosperma*	205
Myrsine umbellata	37	*Cupania vernalis*	171	*Alchornea triplinervia*	144	*Aspidosperma polyneuron*	187
Campomanesia xanthocarpa	27	*Nectandra grandiflora*	157	*Croton floribundus*	135	*Balfourodendron riedelianum*	169
Symplocos uniflora	24	*Cinnamodendron dinisii*	150	*Ocotea diospyrifolia*	127	*Nectandra megapotamica*	167
Casearia decandra	20	*Styrax leprosus*	138	*Astronium graveolens*	118	*Apuleia leiocarpa*	101
Erythrina crista-galli	18	*Ilex paraguariensis*	136	*Hymenaea courbaril*	114	*Senegalia polyphylla*	96
Matayba elaeagnoides	15	*Ocotea porosa*	127	*Guarea guidonia*	106	*Holocalyx balansae*	94
Myrcia splendens	15	*Nectandra megapotamica*	105	*Parapiptadenia rigida*	99	*Nectandra reticulata*	93
Prunus myrtifolia	13	*Lonchocarpus campestris*	86	*Nectandra reticulata*	95	*Lonchocarpus campestris*	93
Erythroxylum deciduum	12	*Luehea divaricata*	85	*Lonchocarpus cultratus*	94	*Peltophorum dubium*	92
Understory species							
Myrciaria tenella	141	*Eugenia uniflora*	345	*Chrysophyllum gonocarpum*	152	*Metrodorea nigra*	471
Myrceugenia glaucescens	36	*Sebastiania commersoniana*	271	*Zygia cauliflora*	148	*Chrysophyllum gonocarpum*	393
Myrcia laruotteana	30	*Casearia sylvestris*	191	*Actinostemon concolor*	118	*Plinia rivularis*	270
Sebastiania brasiliensis	28	*Dicksonia sellowiana*	69	*Guarea kunthiana*	91	*Zygia cauliflora*	244
Daphnopsis racemosa	20	*Brunfelsia pilosa*	60	*Metrodorea nigra*	70	*Eugenia uniflora*	154

5. Beta diversity of Atlantic Forest formations

According to the Venn diagrams (Figure 4), the two Rainforest types share at least 99 tree species, most of them very common in the Montane formations of both forest types, like *Cinnamodendrum dinisii, Ocotea porosa, Drimys brasiliensis* and *Ocotea odorifera*. The surveys carried out in the Dense Rainforest shared 94 species with the Semideciduous Forest, which in turn shared 88 species with the Araucaria Rainforest. At least 50 arboreal species (8% of the species measured) occur in the three Atlantic Forest types, such as *Campomanesia xanthocarpa, Casearia sylvestris, Alchornea triplinervia, Nectandra megapotamica, Sloanea guianensis, Cupania vernalis, Casearia decandra, Syagrus romanzoffiana, Blepharocalyx salicifolius, Myrsine umbellata, Ocotea pulchella* and *Ilex paraguariensis*, among the most abundant.

A total of 272 species were found exclusively in the Dense Rainforest, e.g. *Tibouchina trichopoda*, *Andira anthelmia*, *Handroanthus umbellatus*, *Tabebuia cassinoides*, *Clusia criuva*, *Pera glabrata*, *Ternstroemia brasiliensis*, *Virola bicuhyba*, *Marlierea tomentosa*, *Cupania oblongifolia*, *Protium kleinii*, *Quiina glazovii*, *Aspidosperma pyriccolum*, *Myrcia freyreissiana*, *Siphoneugena reitzii*, *Drimys angustifolia* and *Handroanthus catarinensis*.

At least 51 tree species were found only in Araucaria Rainforest surveys, such as *Podocarpus lambertii, Nectandra grandiflora, Lithraea brasiliensis, Guettarda uruguensis, Curitiba prismatica, Symplocos celastrinea, Myrrhinium atropurpureum, Myrcianthes pungens, Ocotea nutans, Erythroxylum deciduum, Cinnamomum amoenum and Zanthoxylum kleinii.*

Among the 127 species found only in the Semideciduous Seasonal Forest (Figure 4), the most abundant are *Chrysophyllum gonocarpum, Metrodorea nigra, Astronium graveolens, Parapiptadenia rigida, Plinia rivularis, Casearia gossypiosperma, Triplaris americana, Balfourodendron riedelianum, Peltophorum dubium, Holocalyx balansae, Aspidosperma polyneuron and Gallesia integrifolia.*

The dendrogram using Sorensen's similarity coefficients for tree species (Figure 5) shows two major distinct groups. The first one comprises the five Dense Rainforest formations, and the second comprises the Araucaria Rainforest and the Semideciduous Seasonal Forest, reinforcing the data given in Venn diagram (Figure 4). These two types of Atlantic Forest

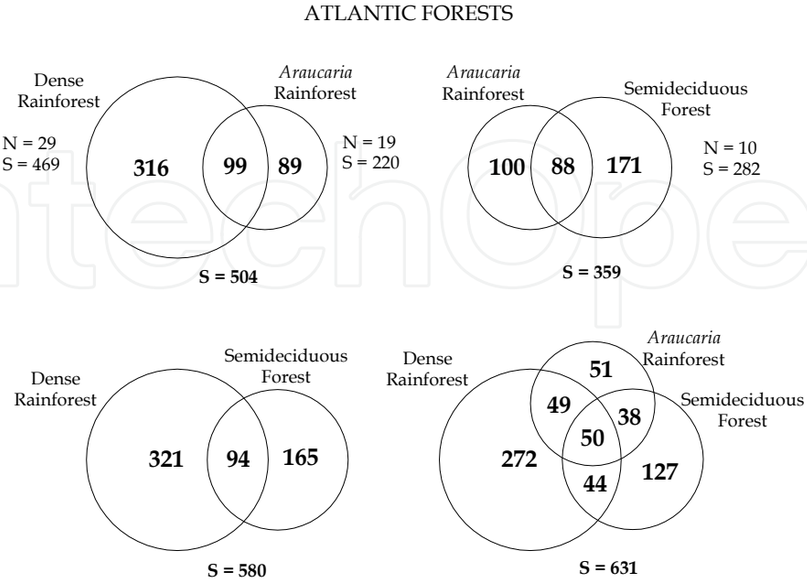


Fig. 4. Venn diagrams presenting the number of measured tree species shared in the 58 sites of the three types of Atlantic Forest in the state of Paraná, Southern Brazil.

share 24.5% of the total species. The two Rainforests share 19.6% of the species and the Semideciduous Seasonal Forest share 16.2% of the species with the Dense Rainforest. These values differ from those found by Oliveira-Filho & Fontes (2000), in which Dense Rainforest and Semideciduous Forest of Southeastern Brazil shared a high proportion of tree species in their checklists: 50% and 66% respectively.

The comparatively high floristic similarity within the Southeastern region than in the Southern region, can be related to the absence of Araucaria Rainforests between these two tropical forests further north.

In the group of the Dense Rainforest, "slope forests" were separated from the "coastal and alluvial plain" forests (Figure 5). The second main group divided the Araucaria Rainforest and the Semideciduous Seasonal Forest.

Pair wise comparisons of the Sorensen's similarity coefficients show values ranging from 0.09 between the Alluvial Semideciduous Forest and the Upper Montane Dense Rainforests to 0.61 between the two formations of the Semideciduous Forest.

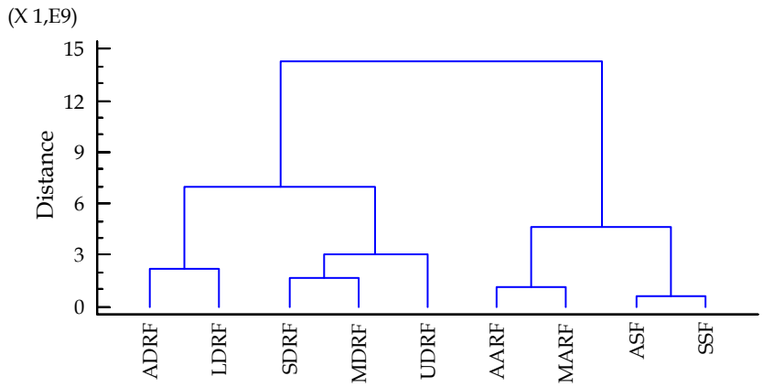


Fig. 5. Dendrogram showing the similarity between tree species measured in nine main formations of the Atlantic Forest of the state of Paraná, Southern Brazil. The cluster analysis was carried out using Sorensen's similarity coefficients, squared euclidean distances and the Ward's method of agglomeration (DRF – Dense Rainforest; ARF – Araucaria Rainforest; SF – Seasonal Forest; A – Alluvial; L – Lowland; S – Submontane; M – Montane; U – Upper Montane).

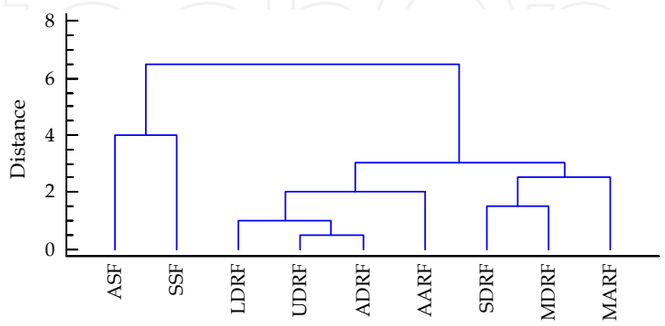
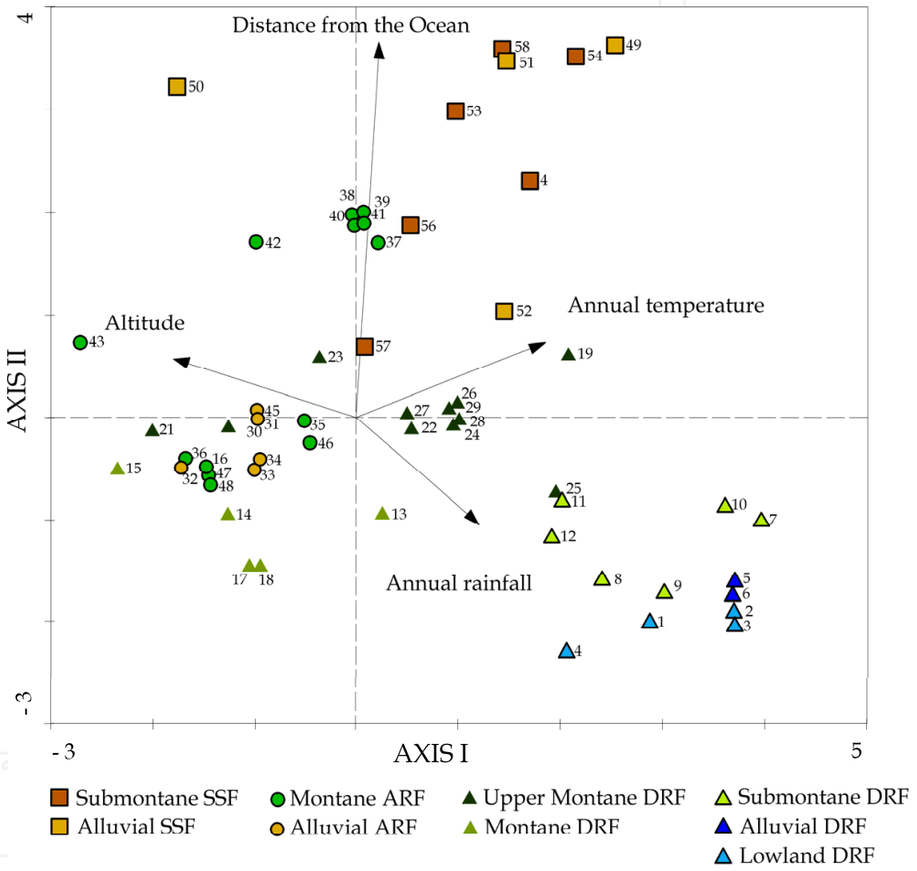


Fig. 6. Dendrogram clustering all Atlantic Forest sites through abundance similarities for tree species with squared euclidean distances and the Ward's method of agglomeration (DRF – Dense Rainforest; ARF – Araucaria Rainforest; SF – Seasonal Forest; A – Alluvial; L – Lowland; S – Submontane; M – Montane; U – Upper Montane).

The dendrogram based on abundance data (Figure 6) shows some different results as compared with the dendrogram based on the Sorensen's similarity. In the first group are the two Semideciduous Forests, while in the second are all studied Rainforests. This group is divided in two subgroups: one presenting the highest tree species richness and diversities (Shannon-Wiener index) among the rainforests analyzed and other with the lowest richness and diversities.

The first axis resulting from the CCA (eigenvalue = λ = 0.637) showed a gradient associated with altitude on one hand and annual temperature an rainfall on the other, separating Montane Rainforests (on the left) and Lowland and Alluvial Rainforests (on the right) (Figure 7). Oliveira-Filho & Fontes (2000) and Scudeller et al. (2001) found similar patterns for these variables in studies in Southeastern Brazil.



	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues (species)	0.637	0.425	0.311	0.212
Cumulative percentage variance:				
• of species data	4.4	7.3	9.4	10.8
• of species-environment relation	40.2	67.0	86.7	100.0
Species-environment correlations	0.899	0.860	0.826	0.212
Significance of species-environment correlation (Monte Carlo test)	0.001	0.001	0.001	0.001

Fig. 7. Biplot of a Canonical Correspondence (CCA) applied to species found in 58 sites in Atlantic Forests in the state of Paraná, Southern Brazil. Numbers are related to sites presented in Table 1.

The second axis (λ = 0.425) shows the Semideciduous Seasonal Forest tree species and their abundance change with increasing the distance from the ocean, and decreasing rainfall (and probably increasing rainfall seasonality). The opposite occurred with Submontane, Alluvial and Lowland Dense Rainforests.
The relatively high eigenvalues found (> 0.3), indicate considerable abundance and species turnover along gradients mainly in axis 1 and 2. As also found by Scudeller et al. (2001), the low variance explained by the first axis indicates that other variables not investigated or methodological restrictions in this study probably influenced the abundance distribution.

6. Final considerations

The literature review and the data compilation resulted in an important database to understand how the Atlantic Forest is being studied in terms of forest structure and tree diversity. The most abundant tree species of this compilation probably corroborate with those found in studies on the Atlantic Forest further South in Brazil (including the state of Santa Catarina), and in Southeastern Brazil (*e.g.* São Paulo state formations). However, studies analyzing these relationships are needed.
Although many formations are relatively well studied in this respect, some formations such as the alluvial forests, mainly in the Dense Rainforest domain, are understudied. The same situation can be observed for the entire Semideciduous Seasonal Forest. Even more interesting is the lack of phytosociological data about this forest type in the Southwestern region of the state of Paraná. Therefore, future research is needed to build up a database for other and more specific studies. Knowing the species that share (or should share) the environment with ourselves is crucial to those who want to observe the habitat, interpret it and to promote conservation, preservation and true sustainable development.

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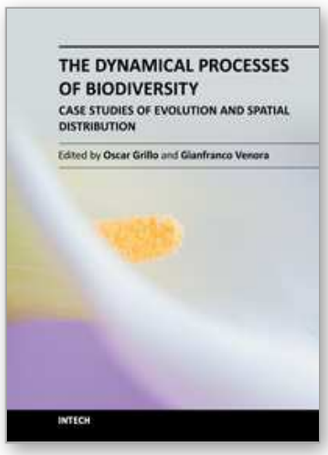

The Dynamical Processes of Biodiversity - Case Studies of Evolution and Spatial Distribution

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Driven by the increasing necessity to define the biological diversity frame of widespread, endemic and threatened species, as well as by the stimulating chance to describe new species, the study of the evolutive and spatial dynamics is in constant execution. Systematic overviews, biogeographic and phylogenic backgrounds, species composition and distribution in restricted areas are focal topics of the 15 interesting independent chapters collected in this book, chosen to offer to the reader an overall view of the present condition in which our planet is.

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