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Article

Community structure and tree diversity in a subtropical forest in southern Brazil

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Abstract: Local and regional environmental variations lead to different species composition, creating transitional areas. An example is the Araucaria and Seasonal forest in southern Brazil. Our objectives were (1) to describe the tree community structure and composition of a subtropical forest in southern Brazil and (2) to compare the floristic relationships between two forest typologies (Araucaria and Seasonal forest) in order to characterize the study area and the distribution patterns of tree species. We conducted a survey at Chapecó National Forest (in southern Brazil) in an area of 1.2 ha, where all individuals ≥ 30 cm of circumference at breast height were sampled. Community structure was described using the traditional phytosociological parameters. The floristic relationships were obtained by comparing our results with compiled data from other scientific papers through cluster analyses using an unweighted average linkage method, based on Jaccard similarity coefficient. We sampled 809 individuals belonging to 61 species and 28 families. The richest family was Fabaceae and *Coussarea contracta* (Walp.) Müll.Arg. was the most abundant species. Taxonomic diversity was 3.06 and the evenness was 0.74. The floristic similarity revealed that species composition of our study area is more similar to Seasonal forest. Species composition is related to environmental factors such as great thermal amplitude and seasonality. This subtropical forest is well structured, highly diverse and extremely important for the local and regional biodiversity conservation.
Keywords: *Araucaria forest, Biodiversity conservation, Floristic similarity, Phytosociology, Seasonal forest, Transitional forest.*

Estrutura da comunidade e diversidade de espécies arbóreas em uma floresta subtropical no sul do Brasil

Resumo: Variações ambientais locais e regionais levam à composição de espécies diferentes e áreas de transições. Um exemplo é a floresta com araucária e a floresta estacional no sul do Brasil. Nossos objetivos foram (1) descrever a composição e estrutura da comunidade arbórea de uma floresta subtropical no sul do Brasil e (2) comparar as relações florísticas entre duas tipologias florestais (Floresta com Araucária e Floresta Estacional) a fim de caracterizar a área de estudo e o padrão de distribuição de espécies arbóreas. Nós realizamos uma pesquisa na Floresta Nacional de Chapecó (no sul do Brasil) em uma área de 1.2 hectares, onde todos os indivíduos com circunferência à altura do peito ≥ 30 cm foram amostrados. A estrutura da comunidade foi descrita utilizando os parâmetros fitossociológicos tradicionais. Obtivemos as relações florísticas através da comparação dos nossos resultados com dados compilados de outros trabalhos científicos, através de análises de agrupamento (método de ligação de distância média não ponderada, UPGMA, baseado no coeficiente de similaridade de Jaccard). Foram amostrados 809 indivíduos pertencentes a 61 espécies e 28 famílias. A família mais rica foi Fabaceae e *Coussarea contracta* (Walp.) Müll.Arg. a espécie mais abundante. A diversidade taxonômica foi de 3.06 e a equabilidade foi de 0.74. A similaridade florística revelou que a composição de espécies da nossa área de estudo é mais similar a da floresta estacional. A composição de espécies está relacionada a fatores ambientais como a amplitude térmica e sazonalidade. Esta floresta subtropical é bem estruturada, altamente diversa e muito importante para a conservação da biodiversidade local e regional.
Palavras-chave: *Floresta com araucária, Conservação da biodiversidade, Similaridade florística, Fitossociologia, Floresta estacional, Floresta de transição.*

Introduction

The community species composition results from processes that rule the assemblages. In general, the processes are related to neutral models (Hubbell 2001), niche-based models (Cornwell & Ackerly 2009) or both, in different scales (Xu et al. 2017). In general, the first are related to stochastic variations in the community (*eg*. dispersal limitations), and the second, to the influence of the environmental filters on species. These environmental filters are related to abiotic factors that prevent the establishment or persistence of a species in a location (*eg*. temperature, precipitation, and soil conditions) (Kraft et al. 2015, Oliveira-Filho et al. 2001).

The environmental characteristics can vary along the extent of an area, creating some special conditions to the development and occurrence of a set of species. Factors such as soil composition, rainfall patterns, latitudinal and altitudinal ranges lead to floristic differentiations (Liebsch et al. 2008). These variations create gradients (or ecotones), known as transitional areas with great biodiversity, especially because of the overlap of different physiognomies (Risser 1995). In general, studies in these areas are mainly in the transition of forested and non-forested areas (Junyan et al. 2014), and the forest-forest dynamics is poorly documented, especially because of the gaps in knowledge about the capacity of rearrangement of species distribution (Oliveira-Filho et al. 2014).

The Brazilian Atlantic Forest is one of the biodiversity hotspots of the world, because of the great endemism of species in this area (Myers et al. 2000). Originally, it covered more than 1,400.000 km² of Brazilian territory (Joly et al. 2014) and the geographical location ranges from the northeastern to southern Brazil (Morellato & Haddad 2000, Joly et al. 2014). The Atlantic Forest is defined by Oliveira-Filho and Fontes (2000) as *sensu stricto* (*s.s.*) and *sensu lato* (*s.l.*). The first is related to the forests along the Atlantic Ocean and the second, as a biome, to a set of physiognomies present at the extent of its distribution. In this study, we considered the concept of Atlantic Forest *s.l.*, including the forest physiognomies (Oliveira-Filho & Fontes 2000).

The floristic differences can be generated by local environmental factors, such as river valleys (important corridors of arboreal species dispersal) (Spichiger et al. 2004), edaphic factors, local topography and disturbances (Higuchi et al. 2012, Gonçalves & Souza 2014, Estevan et al. 2016). In the southern Brazil region, heterogeneous climatic conditions allow the occurrence of many different groups of species (Higuchi et al. 2012). In general, they are a mixture of tropical elements from Amazon region and temperate Austral-Antartic and Andean floras (Rambo 1951).

As a consequence of this heterogeneity, many transitional areas are found in this region. For example, the Araucaria forest is surrounded by the Atlantic forest *s.s.* (*i.e.* Dense ombrophilous forest), Seasonal forest, grasslands and other vegetation types (Klein 1978; Overbeck et al. 2007; IBGE 2012). However, little is known about the floristic patterns of the arboreal components of these forests (Higuchi et al. 2012), especially in transitional areas. In order to answer these questions, we had two objectives in this study. In the first, we aimed at describing the tree community structure and composition of a subtropical forest in southern Brazil. In the second, we aimed at comparing the floristic relationships between two forest typologies (Araucaria and Seasonal forests) in order to characterize the study area and to contribute to the knowledge on the distribution patterns of tree species.

Material and Methods

1. *The southern Brazilian Atlantic Forest: the Araucaria and Seasonal forests*

The forest typologies in Santa Catarina state were initially described in an extensive fieldwork by the botanists Raulino Reitz and Roberto Miguel Klein (Klein 1978, 1960, Reitz et al. 1978, Klein 1963). Their results were summarized in two publications – the "Flora Ilustrada Catarinense" (in many papers since 1965) and the "Projeto Madeira de Santa Catarina" (Reitz et al. 1978), who became important for the knowledge about Santa Catarina's flora. Recently, another project was conducted in the state ("The Floristic and Forest Inventory of Santa Catarina State" (Vibrans et al. 2010)) and resulted in many papers and books about the species occurrence, plant genetic information and economic aspects of the population surrounding the forest (Vibrans et al. 2013a, b, 2010).

The results obtained from the inventory for Araucaria forest (AF) and Seasonal forest (SF) were summarized by Gasper, Uhlmann, et al. (2013) and Gasper, Sevegnani, et al. (2013) where they recorded 366 and 204 tree species, respectively. In the southern Atlantic forest *s.l.*, the presence of the conifer *Araucaria angustifolia* (Bertol.) Kuntze characterizes the AF. This species occurs at the Santa Catarina's plateau in elevations between 500 m to 1,500 m above sea level (a.s.l.) (Backes 2009). The climatic conditions for its occurrence are low temperature (12 °C in average) and high humidity (1.830 mm in average) (Rambo 1953, Backes 2009). Other species frequently associated with this forest are *Nectandra lanceolata* Nees, *Eugenia involucrata* DC., *Ocotea diospyrifolia* (Meisn.) Mez, *Ilex paraguariensis* A.St.-Hil. and *Cupania vernalis* Cambess. (Klein 1978; Jarenkow and Budke 2009). Otherwise, the Seasonal forest, also known as "Upper Uruguay River Basin" forest, is characterized by deciduous species (who lose their leaves in the cold season). It occurs in elevations between 150 m to 800 m a.s.l (Klein 1978, Gasper, Uhlmann, et al. 2013) and the temperature in the region is lower than 15 °C in average. Other species associated with this forest are *Apuleia leiocarpa* (Vogel) J.F.Macbr., *Diatenopteryx sorbifolia* Radlk., *Peltophorum dubium* (Spreng.) Taub. and *Myrocarpus frondosus* Allemão (Gasper, Uhlmann, et al. 2013, Klein 1978).

The west of the Santa Catarina state was traditionally characterized as a transitional area, composed by Araucaria and Seasonal forests. According to IBGE (2012), this region is substantially covered by Seasonal forest; However, Klein (1960) described it as Araucaria forest, mainly. Furthermore, many authors agree that the dynamics of these forests follow a west-east pattern and the species that compose the SF advances over the AF (Backes 2009; Waechter 2009; Jarenkow and Budke 2009; Gasper et al. 2013b, 2015).

2. *Study area*

The sampling was conducted at Chapecó National Forest (glebe one), a Conservation Unit for sustainable use located in the west of Santa Catarina, southern Brazil (27º05'19.9''S and 52º46'47.3''W) (Figure 1) (see details in Lucas & Fortes 2008). The climate is subtropical (Nimer 1989); the annual rainfall is well distributed during the year (the average rainfall is 2000 mm) and the average temperature ranges from 22 °C to 14 °C for the hotter and coldest month, respectively (http://www.inmet.gov.br). The regional landforms are characterized by the hilly topography of the Araucarias' Plateau, between 520 m

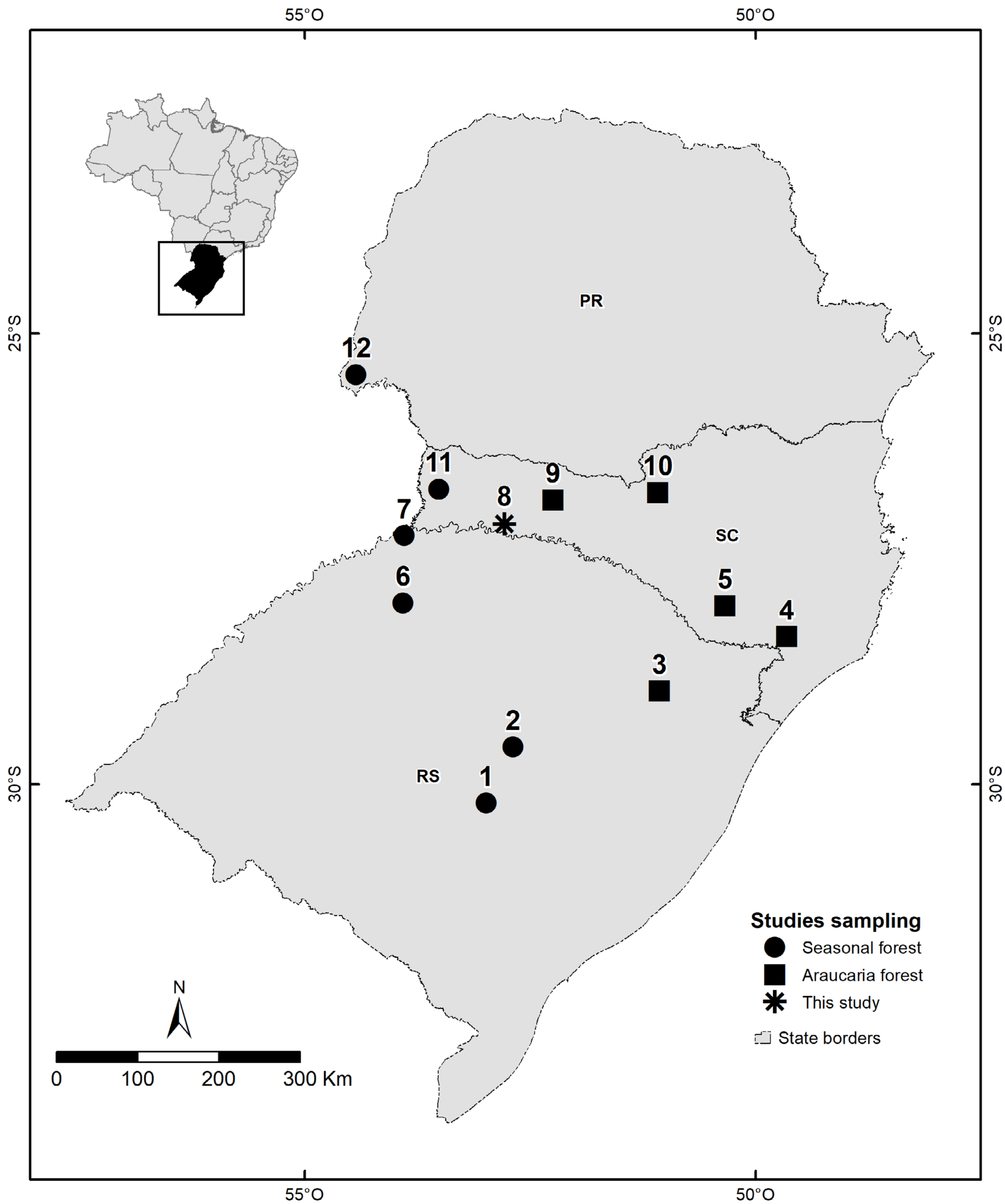

Figure 1. Location of the study area, at Chapecó National Forest, west Santa Catarina, southern Brazil (code number 8 - *). Information about Araucaria forest is presented as quadrats (numbers 9-12) and Seasonal forest as circles (numbers 1-7). Complete information about data sources data can be accessed in Table 1.

and 617 m a.s.l. and the predominant soils are Inceptisols and Oxisols (ICMBio 2013).

3. *Sampling units and data analysis*

The survey was conducted in a secondary forest, with more than 60 years without disturbance (in 2017). There, 24 permanent plots were systematically selected with 500 m² each one (50 m x 10 m), corresponding to a total area of 1.2 ha. To describe the community structure we measured trees ≥ 30 cm of circumference at breast height (c.b.h.) (which means ≥ 9.54 cm of diameter at breast height, d.b.h.). The maximum height was estimated for all individuals. Whenever possible, the individuals had species determination in field. For those which determination was not possible, we collected material for determination in laboratory. Voucher specimens were deposited in the

UNO Herbarium (UNO, at Universidade Comunitária da Região de Chapecó). The circumscription adopted for angiosperm families are in accordance with Angiosperm Phylogeny Group (The Angiosperm Phylogeny Group 2016).

The community structure was described using the phytosociological parameters (Mueller-Dombois & Ellenberg 1974). We evaluated the sample adequacy using a rarefaction curve (Magurran 2004) with the software Estimates 8.2, considering $\alpha \leq 0.05$. Taxonomic diversity was estimated using the Shannon-Weiner Index (H') and Pielou's evenness Index (J) (R version 3.3.1, *vegan* package) (R Core Team 2016).

To evaluate the floristic similarity we compiled information from scientific papers. Our selection criterion followed the conditions: a) survey at Araucaria or Seasonal forests and b) range of study restricted to southern Brazil, with the maximum distance of 350 km from the Chapecó National Forest (our study area) and more than 50 km between the surveys (data sources) to remove a possible effect of proximity, also considering, as possible, studies with similar sampling method and data collection effort (Fig. 1). We selected 12 papers, and most part of surveys employed plots for vegetation sampling; once a study used point-centered quarters (Benvenuti-Ferreira & Coelho 2009). The studies differ in regard to sampling effort and size criteria for individual inclusion (minimum c.b.h.). The information about each study is described in Table 1. We integrated our results to the matrix of compiled data and used an abundance matrix. The final matrix was composed by 145 arboreal species (genus and families identifications were excluded). We performed cluster analyses using an unweighted average linkage method (UPGMA) based on a Jaccard similarity coefficient (Legendre & Legendre 2012) (R version 3.3.1, *vegan* package).

Results

We sampled 809 individuals belonging to 61 species and 28 families. Families with the largest number of species were: Fabaceae (11), Lauraceae (5), Rutaceae (5), Salicaceae (4) and Sapindaceae (4) (Table 2). The mean density was 674 individuals/ha. *Coussarea contracta* (Walp.) Müll.Arg., *Ocotea diospyrifolia* (Meisn.) Mez, *Cupania vernalis* Cambess., *Araucaria angustifolia*, *Casearia sylvestris* Sw., *Diatenopteryx sorbifolia* Radlk. and *Myrocarpus frondosus* Allemão were the species with biggest relative density, representing 62.7% of the individuals sampled. These species even had the biggest relative dominance in basal area (more than 54%), relative frequency (37.9%), coverage value (58.2%) and importance value (51.5%) (Table 2). According to the Shannon index, the taxonomic diversity was 3.06 and the evenness (J) was 0.74 (Table 1). However, the rarefaction curve did not reach an asymptotic richness level (Figure 2).

The diameter structure followed the traditional inverted-J curve, with most of the individuals at the first diameter class (almost 50%) (Figure 2). Individuals with largest diameter are represented by *Luehea divaricata* Mart. & Zucc. (107 cm d.b.h) and *A. angustifolia* (81.5 cm d.b.h.). Most of the individuals were from six to 15 meters height and, in general, the abundance decreased as the height grew up (Figure 2). The emergent species (over 20 m height) were *A. angustifolia*, *D. sorbifolia*, *M. frondosus*, *O. diospyrifolia*, *Helietta apiculata* Benth., *Lamanonia ternata* Vell., *Matayba elaeagnoides* Radlk., *Parapiptadenia rigida* (Benth.) Brenan, *Peltophorum dubium* (Spreng.) Taub. and *Prunus myrtifolia* (L.) Urb.

Table 1. Data compiled from studies at Araucaria and Seasonal forests in order to evaluate the species similarity. Source: papers where the data were obtained; SL: sampling location; CO: site code; A: total sampled area (in hectares); c.b.h: minimum tree circumference criteria (cm); N: number of species sampled; RF: Richest families at community; Abundant species: Most abundant species at community; Total abundance: number of individuals sampled at community; RD: *Araucaria angustifolia* relative dominance at community; H': Shannon-Wiener diversity index; J: Pielou's evenness index.

Source	SL	CO	A	c.b.h.	N	RF	Abundant species (N)	Total abundance	RD (%)	H'	J
This study	SC	8	1,2	30	61	Fabaceae (11); Lauraceae (5); Rutaceae (5); Salicaceae (4); Sapindaceae (4)	*Coussarea contracta* (177); *Ocotea diospyrifolia* (110); *Cupania vernalis* (84); *Araucaria angustifolia* (45); *Casearia sylvestris* (32).	809	5,5	3,06	0,74
							Seasonal forest				
Lindenmaier & Budke (2006)	RS	1	1	15	49	Myrtaceae (7); Meliaceae (4); Salicaceae (5); Fabaceae (5).	*Eugenia ramboi* (397); *Cordia americana* (111); *Sorocea bomplandii* (94); *Casearia sylvestris* (68); *Cabralea canjerana* (56).	1097	-	2,68	0,66
Jarenkow & Waechter (2001)	RS	2	1	15,7	55	Fabaceae (7); Myrtaceae (6); Euphorbiaceae (5); Lauraceae (5); Meliaceae (5)	*Gymnanthes concolor* (632); *Euterpe edulis* (434); *Sorocea bomplandii* (255).	1855	-	2,24	0,56
Benvenuti-Ferreira & Coelho (2009)	RS	6	0,25	15,7	63	Fabaceae (11); Myrtaceae (4); Rutaceae (4); Sapindaceae (4); Lauraceae (4); Euphorbiaceae (4)	*Cordia americana* (45); *Diatenopteryx sorbifolia* (39); *Prunus myrtifolia* (27); *Matayba elaeagnoides* (26); *Machaerium stipitatum* (22).	508	-	3,68	0,89

Continuation Table 1.

Source	SL	CO	A	c.b.h.	N	RF	Abundant species (N)	Total abundance	RD (%)	H'	J
Balbinot et al. (2016)	RS	7	1	31,4	83	Fabaceae (14); Myrtaceae (4); Euphorbiaceae (4); Rutaceae (4); Meliaceae (4)	*Syagrus romanzoffiana* (130); *Sebastiania commersoniana* (53); *Nectandra megapotamica* (49); *Lonchocarpus muehlbergianus* (44); *Eugenia subterminalis* (30).	842	-	3,72	-
Schneider & Rocha (2014)	SC	11	0,4	25	54	Fabaceae (9); Myrtaceae (5); Meliaceae (5); Sapincaceae (4); Lauraceae (4);	*Sorocea bomplandii* (52); *Nectandra megapotamica* (50); *Syagrus romanzoffiana* (27); *Trichilia claussenii* (27).	512	-	3,47	0,87
Gris et al. (2014)	PR	12	0,4	15	70	Fabaceae (10); Meliaceae (7); Myrtaceae (5); Lauraceae (4); Rutaceae (4)	*Euterpe edulis* (159); *Sorocea bomplandii* (99); *Guarea kunthiana* (57).	518	-	3,37	0,79
Araucaria forest											
Rondon-Neto et al. (2002)	RS	3	0,8	15,7	37	Myrtaceae (9); Lauraceae (3); Sapindaceae (3); Asteraceae (2); Rutaceae (2)	*Araucaria angustifolia* (217); *Sebastiania commersoniana* (43); *Lithraea brasiliensis* (41); *Zanthoxylum rhoifolium* (39); *Myrcia* sp. (38)	673	32,2	2,77	-
Ferreira et al. (2016)	SC	4	1	15,7	55	Myrtaceae (10); Asteraceae (5); Anacardiaceae (4); Lauraceae (4)	*Lithraea brasiliensis* (176); *Podocarpus lambertii* (125); *Araucaria angustifolia* (97); *Blepharocalix salicifolius* (97); *Acca sellowiana* (96).	1457	6,6	3,21	0,79
Silva et al. (2012)	SC	5	1	15,7	87	Myrtaceae (18); Asteraceae (6); Lauraceae (5); Salicaceae (5)	*Araucaria angustifolia* (198); *Myrcia splendens* (159); *Podocarpus lambertii* (139); *Jacaranda puberula* (103); *Myrcia bombycina* (78).	1783	11,1	3,60	0,82
Santos et al. (2012)	SC	9	0,66	30	36	Lauraceae (7); Myrtaceae (4); Bignoniaceae (3); Fabaceae (3); Sapindaceae (3)	*Prunus myrtifolia* (80); *Cupania vernalis* (37); *Nectandra megapotamica* (30); *Matayba elaeagnoides* (25); *Ocotea spixiana* (21).	439	3,5	2,79	-
Lingner et al. (2007)	SC	10	2,5	60	41	Myrtaceae (5); Asteraceae (3); Sapindaceae (3); Euphorbiaceae (2); Cunoniaceae (2)	*Araucaria angustifolia* (162); *Ocotea porosa* (75); *Cupania vernalis* (62); *Capsicodendron dinisii* (33); *Matayba elaeagnoides* (23).	502	32,2	2,54	-

Floristic similarity revealed that our study area (code number 8 - *) was more similar to the species composition of Seasonal forest (cophenetic correlation coefficient: 0.9092) (Figure 3). The cluster indicated two groups, and the first division was between species composition from both two forest typologies. Seasonal forest group was divided according to the hydrography: forests from the upper Uruguay and Paraná and Jacuí river basins. On the other hand, the higher altitude was important for the Araucaria forest in the southern Brazilian mountains. Furthermore, surveys geographically closer were more similar in species composition; Fabaceae has a greater richness in Seasonal forests from Uruguay and Paraná river basins, Myrtaceae is highly represented in Araucaria forests from northeastern Rio Grande do Sul, and Lauraceae is well distributed in both forest typologies (Table 1, Fig.1). In terms of species composition*, M. elaeagnoides*, *P. myrtifolia*, *Allophylus edulis* (A.St.-Hil., Cambess. & A. Juss.) Radlk, *Campomanesia xanthocarpa* O.Berg, *Cedrela fissilis* Vell. and *Nectandra megapotamica* (Spreng.) were registered in most part of the studies and also in our sampling. Otherwise, *A. angustifolia* was sampled only in Araucaria forests, broadly associated to higher altitudes in Santa Catarina and Rio Grande do Sul states.

Discussion

1. *Tree community structure and composition in a subtropical forest in southern Brazil*

The tree taxonomic diversity and evenness indexes found in this study had intermediate values when compared to other surveys in southern Brazil (Table 1). These indexes indicated the balance of few dominant species and many species with lower abundance. This result reflects the ecological stability and maturity of the community (Wright 2007, Warring et al. 2016).

Table 2. Structural parameters of the tree community surveyed at Chapecó National Forest, west Santa Catarina, southern Brazil. Species: identification of the species sampled in this study; N: number of individuals; RD: relative density (%); RF: relative frequency (%); RDo: relative dominance (%); IV: importance value (%); CV: coverage value (%).

Family	Species	N	RD	RF	RDo	IV	CV
Rubiaceae	*Coussarea contracta* (Walp.) Müll.Arg.	177	21,88	6,6	5,56	11,3	13,72
Lauraceae	*Ocotea diospyrifolia* (Meisn.) Mez	110	13,6	7,2	20,52	13,8	17,06
Sapindaceae	*Cupania vernalis* Cambess.	84	10,38	6,3	6,46	7,7	8,42
Araucariaceae	*Araucaria angustifolia* (Bertol.) Kuntze	45	5,56	6,0	14,79	8,8	10,18
Salicaceae	*Casearia sylvestris* Sw.	32	3,96	4,2	1,38	3,2	2,67
Sapindaceae	*Diatenopteryx sorbifolia* Radlk.	30	3,71	4,2	2,80	3,6	3,25
Fabaceae	*Myrocarpus frondosus* Allemão	27	3,34	3,6	2,54	3,2	2,94
Myrtaceae	*Campomanesia xanthocarpa* (Mart.) O.Berg	20	2,47	3,9	1,31	2,6	1,89
Rutaceae	*Helietta apiculata* Benth.	19	2,35	3,0	1,70	2,3	2,02
Sapindaceae	*Matayba elaeagnoides* Radlk.	19	2,35	3,9	4,21	3,5	3,28
Primulaceae	*Myrsine umbellata* Mart.	18	2,22	3,6	0,83	2,2	1,53
Boraginaceae	*Cordia americana* (L.) Gottschling & J.S.Mill.	17	2,1	1,5	3,50	2,4	2,80
Salicaceae	*Banara tomentosa* Clos	16	1,98	2,7	0,52	1,7	1,25
Meliaceae	*Cedrela fissilis* Vell.	16	1,98	4,2	3,92	3,4	2,95
Sapotaceae	*Chrysophyllum marginatum* (Hook. & Arn.) Radlk.	16	1,98	3,0	1,24	2,1	1,61
Malvaceae	*Luehea divaricata* Mart. & Zucc.	12	1,48	1,8	6,71	3,3	4,10
Salicaceae	*Casearia decandra* Jacq.	11	1,36	2,4	0,32	1,4	0,84
Fabaceae	*Ateleia glazioveana* Baill.	10	1,24	1,8	2,47	1,8	1,85
Lauraceae	*Nectandra megapotamica* (Spreng.) Mez	9	1,11	1,5	0,79	1,1	0,95
Rutaceae	*Pilocarpus pennatifolius* Lem.	9	1,11	0,6	0,24	0,7	0,68
Fabaceae	*Peltophorum dubium* (Spreng.) Taub.	7	0,87	1,8	2,73	1,8	1,80
Loganiaceae	*Strychnos brasiliensis* Mart.	7	0,87	1,2	0,34	0,8	0,60
Meliaceae	*Cabralea canjerana* (Vell.) Mart.	6	0,74	1,8	0,29	0,9	0,51
Sapotaceae	*Chrysophyllum gonocarpum* (Mart. & Eichler ex Miq.) Engl.	6	0,74	0,9	0,25	0,6	0,50
Annonaceae	*Annona rugulosa* (Schltdl.) H.Rainer	5	0,62	1,5	0,17	0,8	0,40
Salicaceae	*Casearia obliqua* Spreng.	5	0,62	1,5	0,25	0,8	0,43
Aquifoliaceae	*Ilex paraguariensis* A.St.-Hil.	5	0,62	1,2	0,57	0,8	0,59
Fabaceae	*Parapiptadenia rigida* (Benth.) Brenan	5	0,62	1,5	3,34	1,8	1,98
Moraceae	*Sorocea bonplandii* (Baill.) W.C.Burger et al.	5	0,62	0,9	0,12	0,6	0,37
Lauraceae	*Nectandra lanceolata* Nees	4	0,49	0,9	0,91	0,8	0,70
Euphorbiaceae	*Gymnanthes klotzschiana* Müll.Arg.	4	0,49	0,9	0,34	0,6	0,42
Sapindaceae	*Allophylus edulis* (A.St.-Hil. et al.) Hieron. ex Niederl.	3	0,37	0,6	0,26	0,4	0,31
Rutaceae	*Balfourodendron riedelianum* (Engl.) Engl.	3	0,37	0,3	0,11	0,3	0,24
Boraginaceae	*Cordia trichotoma* (Vell.) Arráb. ex Steud.	3	0,37	0,9	0,49	0,6	0,43
Myrtaceae	*Eugenia involucrata* DC.	3	0,37	0,9	0,08	0,5	0,23
Fabaceae	*Muellera campestris* (Mart. ex Benth.) M.J. Silva & A.M.G. Azevedo	3	0,37	0,9	0,74	0,7	0,55
Polygonaceae	*Ruprechtia laxiflora* Meisn.	3	0,37	0,9	0,26	0,5	0,32
Rutaceae	*Zanthoxylum petiolare* A.St.-Hil. & Tul.	3	0,37	0,9	0,22	0,5	0,29
Apocynaceae	*Aspidosperma australe* Müll.Arg.	2	0,25	0,6	0,42	0,4	0,34
Fabaceae	*Calliandra foliolosa* Benth.	2	0,25	0,6	0,04	0,3	0,14
Fabaceae	*Erythrina falcata* Benth.	2	0,25	0,6	0,51	0,5	0,38
Fabaceae	*Holocalyx balansae* Micheli	2	0,25	0,6	0,73	0,5	0,49
Aquifoliaceae	*Ilex brevicuspis* Reissek	2	0,25	0,6	0,40	0,4	0,32
Bignoniaceae	*Jacaranda micrantha* Cham.	2	0,25	0,6	0,39	0,4	0,32
Cunoniaceae	*Lamanonia ternata* Vell.	2	0,25	0,3	1,77	0,8	1,01

Continuation Table 2.

Family	Species	N	RD	RF	RDo	IV	CV
Lauraceae	*Ocotea puberula* (Rich.) Nees	2	0,25	0,6	0,56	0,5	0,40
Euphorbiaceae	*Sebastiania brasiliensis* Spreng.	2	0,25	0,3	0,11	0,2	0,18
Euphorbiaceae	*Actinostemon concolor* (Spreng.) Müll.Arg.	1	0,12	0,3	0,02	0,2	0,07
Annonaceae	*Annona neosalicifolia* H.Rainer	1	0,12	0,3	0,02	0,2	0,07
Fabaceae	*Apuleia leiocarpa* (Vogel) J.F.Macbr.	1	0,12	0,3	0,22	0,2	0,17
Erythroxylaceae	*Erythroxylum deciduum* A.St.-Hil.	1	0,12	0,3	0,24	0,2	0,18
Myrtaceae	*Eugenia pyriformis* Cambess.	1	0,12	0,3	0,12	0,2	0,12
Fabaceae	*Inga virescens* Benth.	1	0,12	0,3	0,03	0,2	0,07
Fabaceae	*Machaerium stipitatum* Vogel	1	0,12	0,3	0,05	0,2	0,08
Lauraceae	*Ocotea pulchella* (Nees & Mart.) Mez	1	0,12	0,3	0,03	0,2	0,08
Simaroubaceae	*Picrasma crenata* (Vell.) Engl.	1	0,12	0,3	0,03	0,2	0,07
Rosaceae	*Prunus myrtifolia* (L.) Urb.	1	0,12	0,3	0,84	0,4	0,48
Rubiaceae	*Randia ferox* (Cham. & Schltdl.) DC.	1	0,12	0,3	0,04	0,2	0,08
Styraceae	*Styrax leprosus* Hook. & Arn.	1	0,12	0,3	0,07	0,2	0,09
Apocynaceae	*Tabernaemontana catharinensis* A.DC.	1	0,12	0,3	0,08	0,2	0,10
Rutaceae	*Zanthoxylum kleinii* (R.S.Cowan) P.G.Waterman	1	0,12	0,3	0,02	0,2	0,07

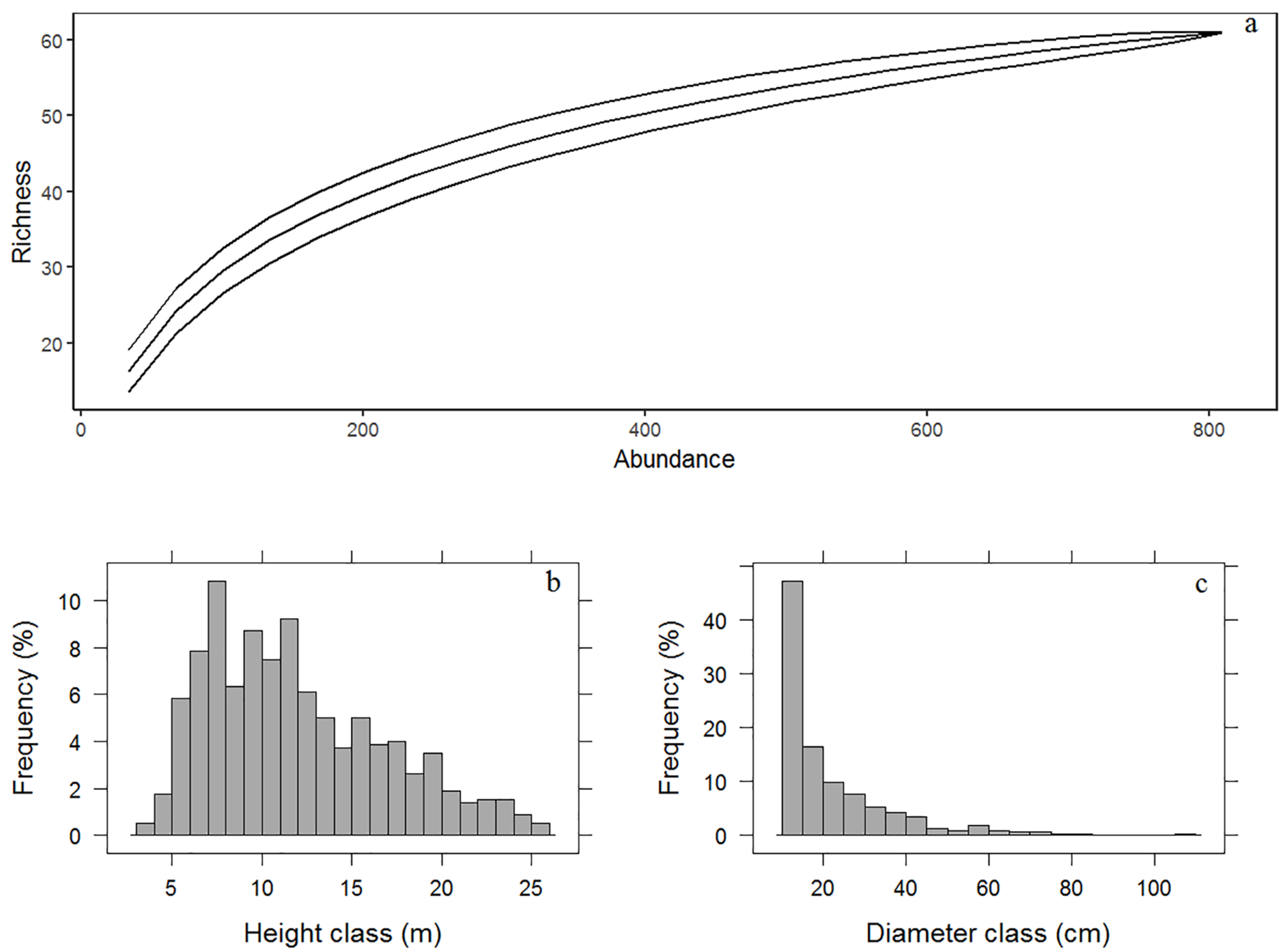

Figure 2. Tree community structure of Chapecó National Forest, west Santa Catarina, southern Brazil. a) Sample adequacy represented by a rarefaction curve standardizing a number of species and individuals. Upper and lower line estimates are also showed. b) Height distribution from three to 26 meters height. c) Diameter classes from 9.54 cm to 107 cm, with intervals of five centimeters each class. The first class presents all individuals with 9.54 cm to 15 cm d.b.h.

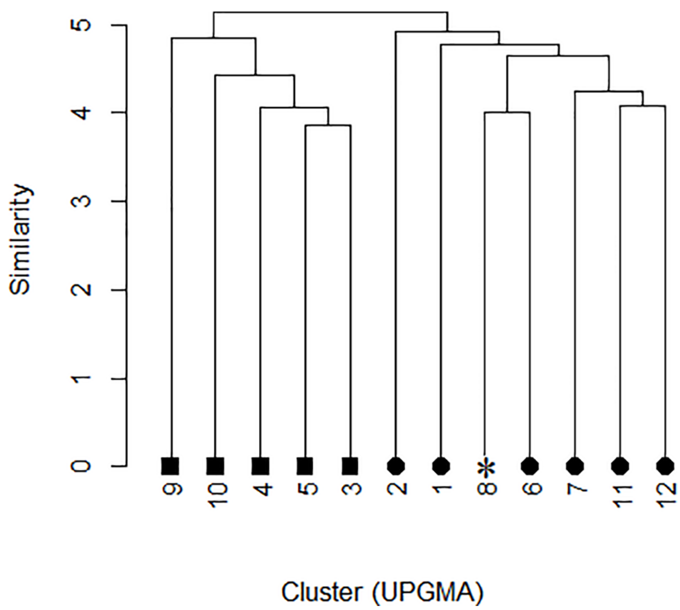

Figure 3. Cluster analysis, using the unweighted pair group method with arithmetic mean (UPGMA) and Jaccard similarity coefficient demonstrating the floristic similarities of 12 studies sampled at Araucaria and Seasonal forests, in southern Brazil. Cophenetic Correlation Coefficient = 0.9092. See table 1 and fig 1 for site codes.

The species with higher importance values are common and important in other surveys in the Araucaria and Seasonal forests of Santa Catarina (Gasper, Uhlmann, et al. 2013, Gasper, Sevegnani, et al. 2013, Gasper et al. 2015, Vibrans et al. 2011, Schneider & Rocha 2014, Vibrans et al. 2013a, 2012). *Ocotea diospyrifolia*, *Cupania vernalis*, *Casearia sylvestris*, *Diatenopteryx sorbifolia* and *Myrocarpus frondosus* are common at Seasonal forest (Fontana & Sevegnani 2012) and *A. angustifolia*, *Coussarea contracta* e *Cupania vernalis,* are typical from components of early and intermediate successional stages in the Araucaria forest of Santa Catarina (Klauberg et al. 2010, Vibrans et al. 2011). According to Gasper et al. (2015), *Cupania vernalis*, *Diatenopteryx sorbifolia* and *Myrocarpus frondosus* characterize the transitional forests from the west of Santa Catarina.

We did not observe the asymptotic richness level in the rarefaction curve. It was found in other studies and was justified by the environmental heterogeneity or human influence in the landscape (Ruschel et al. 2007, Benvenuti-Ferreira & Coelho 2009). Also, it is important to remember that forest communities are dynamic entities, where species are associated with some spatial and temporal variations (Schilling & Batista 2008). In our study, this result is probably related to this dynamic and either the small number (24) and big size of each sampling unit (500 m²), whereas the usually recommended for these studies are sampling units that maximize the sampling area (*e.g.* more sampling units with a smaller size).

The inverted-J curve of diameter classes found in this study is common for different forest typologies and it indicates the forest regeneration and permanence of the species in forest structure (Balbinot et al. 2016). Most individuals sampled are small trees of the forest understory and it is also indicative of forest regeneration capacity (Cunha & Silva Jr. 2012). On the other hand, individuals in the biggest size classes usually represent species with greater longevity (Chao et al. 2008) and their mortality contributes to de gap dynamics in forests (Yamamoto 2000).

Fabaceae frequently exhibits great species richness at Seasonal forests in southern Brazil (Jurinitz & Jarenkow 2003, Benvenuti-Ferreira & Coelho 2009). It is related to the immigration corridor of the Uruguay and Paraná river basins, which connects the species of Fabaceae from the north to southern Brazil. However, further from the corridor towards the south, the number of species of this family decreases (Budke et al. 2005, Benvenuti-Ferreira & Coelho 2009, Jurinitz & Jarenkow 2003). On the other hand, Lauraceae species are usually described as highly abundant in the Araucaria forest, acting as indicator species associated to this forest typology (Gasper, Sevegnani, et al. 2013). Leyser et al. (2009) demonstrated high species richness of Fabaceae and Lauraceae in the transitional area between Araucaria and Seasonal forest, as found in this study, which may also indicate an association between these families in ecotonal areas. In general, Myrtaceae species are widely distributed in Atlantic forest *s.l.*, but with lower abundance in the SF of Santa Catarina, leading to a rare occurrence specially driven by the climatic filters in the region (Fontana et al. 2014). These associations reflect complex species interactions which may also contribute powerfully to forest structuring and patterns of species distributions, leading to more studies and efforts in ecotonal areas.

2. Floristic relationships between two forest typologies

Despite the presence of *A. angustifolia*, the transitional forest of this study has great floristic similarity to the Seasonal forest. According to the cluster analysis, the vegetation type was the main grouping factor, followed by geographical proximity, as observed by other authors (Oliveira-Filho et al. 2001, Gonçalves & Souza 2014, Estevan et al. 2016). The species composition of our study area must be also related to the altitude of the region, which is close to Uruguay river valley (around 600 m a.s.l.). In general, altitude is considered an important variable for the species distribution in the Atlantic forest *s.l.* (Eisenlohr et al. 2015), especially for Araucaria forest species, which occurrence is conditioned by higher altitudes, leading to higher local densities (Backes 2009, Higuchi et al. 2012, Viani et al. 2011). In our case, the lower altitude could be acting as an environmental filter (Higuchi et al. 2012), associated with the great amplitude and thermal seasonality and higher maximum temperature in the hottest month leading to the limitation of the species range of the Araucaria forest and with a pronounced presence of the Seasonal forest species (Gasper, Uhlmann, et al. 2013, Gasper et al. 2015).

Among the potential drivers associated to species occurrence and distribution, the biogeographic factor is another important driver related to actual species occurrence and communities diversity in southern Brazil (Rezende et al. 2016). It may be thus related to the species composition of Seasonal forests, which is also promoted by dispersal from Paraná river basin and the Misiones forests (Gasper et al. 2012) and leads to higher species diversity and great floristic similarity to rainforests (Eisenlohr & Oliveira-Filho 2015; Rezende et al. 2016). In the other hand, the Araucaria forest has a low number of unique species (Eisenlohr & Oliveira-Filho 2015) and presents physiognomic, floristic and structural differences throughout its distribution (Jarenkow and Budke 2009; Higuchi et al. 2012), leading to a particular forest structure and composition, different from other forest types (Eisenlohr & Oliveira-Filho 2015). This forest occurs mainly in regions with higher altitude and has a gradual overlap of the species towards southwestern Brazil, making contact with the Seasonal forest species on Uruguay and Paraná river basins (Jarenkow and Budke 2009).

Regard to the *A. angustifolia* dynamics along the time in this forest, there is a clear pattern of reduction of the population (Bordin 2018), which reinforces the Seasonal forest species turnover on the Araucaria forest species. Paleoecological analysis in the Araucaria forest areas at Rio Grande do Sul state revealed that population of *A. angustifolia* was much larger than today, where we can find typical semi-deciduous species occurring in these areas (Behling et al. 2016). It indicates that same pattern of turnover from Araucaria to Seasonal forest species composition is a trend found in other Atlantic Forest *s.l.* areas.

The subtropical forest presented here is well structured and highly diverse. Also, is an extremely important forest fragment for the local and regional biodiversity conservation, especially due to the presence of Seasonal forest species (Bergamin et al. 2017).

Concerning to forest characterization, despite the presence of *Araucaria angustifolia*, the species composition is closely related to the Seasonal forests, reinforcing the strong west-east pattern of species composition. Briefly, Seasonal forest is the floristic classification that should be considered in further analysis. This turnover of species along the regions strengthens the conservation necessity for protecting this pool of species and remaining forested areas, especially in this conservation unit.

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Author Contributions

Kauane Maiara Bordin: contributed in the concept and design of the study, data collection, data analysis, interpretation and to manuscript preparation, providing critical revision, and adding intellectual content.

Letícia Daiana Ferreira, Adriano Rosina, Marciana Malacarne, Patricia Zanotelli: contributed to data collection and intellectual content.

Samuel Fernando Adami: data analysis, interpretation and to manuscript preparation and intellectual content.

Giovana Secretti Vendruscolo: contributed in the concept and design of the study, data collection, data analysis, interpretation and to manuscript preparation, providing critical revision, and adding intellectual content.

Conflict of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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