



Vascular species composition of a contact zone between Seasonal and Araucaria forests in Guaraciaba, Far West of Santa Catarina state, southern Brazil

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Abstract: A floristic survey was carried out in a contact area between Araucaria Forest and Seasonal Forest areas, in the municipality of Guaraciaba, Far West of Santa Catarina state, southern Brazil. We provide a checklist containing 108 species and 42 plant families for the area. Families with the most encountered number of species were Myrtaceae (eight species), Solanaceae (eight), Euphorbiaceae (seven) and Poaceae (six). Two species are classified as endangered of extinction, following IUCN criteria. An analysis using UPGMA algorithm and species composition comparisons using additional 6 areas of Araucaria Forest and 6 areas of Seasonal Forest showed its greater relationship to other Araucaria Forest areas, but also the influence of the adjacent Seasonal Forest areas in the floristic composition of the surveyed area.

Key words: Araucaria Forest, Ecotone, Floristic, Seasonal Forest

INTRODUCTION

The Araucaria Forest is a southern subset of the Atlantic Forest of Brazil, which is considered a biodiversity hotspot (Myers *et al.* 2000), and it is a tropical rainforest where the most conspicuous element is, actually, a pine — *Araucaria angustifolia* (Bertol.) Kuntze, considered typical for that kind of vegetation (Veloso *et al.* 1991). Besides the massive presence of *A. angustifolia*, the forest could be characterized by the presence of several members of Lauraceae, as *Ocotea porosa* (Nees & Mart.) Barroso (*canela-imbúia*), *O. odorifera* Rohwer (*canela-sassafrás*) and *Nectandra megapotamica* (Spreng.) Mez, as well by other species as *Campomanesia xanthocarpa* Mart. ex O.Berg, *Ilex paraguariensis* A.St.-Hil. (*mate*), *Dicksonia sellowiana* Hook. (*xaxim*), *Podocarpus lambertii* Klotzsch ex Endl. and *Cedrela fissilis* Vell. (*cedro-rosa*; Maack 1968). Originally, the Araucaria Forest covered about 200,000 km² in southern and southeastern Brazil, besides smaller portions in Argentina and Paraguay (Carvalho 1994), and this occurrence coincides with an area of typically wet weather, with no dry season, where the annual average temperature is about 18°C, but can be lower than 15°C in three to six months (IBGE 2004). It has been

estimated that the decline of this forest in the last century reached more than 97% of its original area (IUCN 2013), and species such as *A. angustifolia*, *O. porosa*, *O. odorifera* and *Cedrela fissilis* are considered threatened with extinction (CNCFlora 2013; IUCN 2013).

Klein (1978) classified the Araucaria Forest in the state of Santa Catarina in four subdivisions, based on the composition of the understory layer of the forest: the forest of the Iguaçu–Negro basin; the forest of the Pelotas–Canoas basin; the forest of the Atlantic Zone; and the forest of the Far West. The forests of the Far West have a remarkable influence and, therefore, a similar appearance to the southern Seasonal Forest that covers the Uruguay River basin, mainly after the heavy exploitation of the pines. The Seasonal Forest has a discontinuous distribution in Brazil and typically it is characterized by a clear vertical structure and two well-demarcated climatic seasons, one rainy and the other dry, when more than half of the plants lose their leaves (Klein 1978). The southern region of Brazil, despite the absence of a typical dry season, possesses some patches of this kind of forest, an occurrence that could be explained by the incidence of a very cold season that would act as a similar physiological constrain (IBGE 2012). The presence of species of *Peltophorum*, *Anadenanthera* and *Apuleia* are remarkable in these forests, while *Luehea divaricata* Mart., *Vitex megapotamica* (Spreng.) Moldenke, *Inga uruguensis* Hook. & Arn. and *Sebastiania commersoniana* (Baill.) L.B.Sm. & Downs distinguish the alluvial formation (IBGE 2012).

Ecotones are contact areas of floristic mixtures between different kinds of vegetations. Because some ecotone areas occur between vegetations of similar structure, their recognition by small scales means, as aerial or satellite images, are not useful, and floristic surveys are needed to identify them (Veloso *et al.* 1991). Recent studies on biotic and abiotic factors acting in northern contact areas between rainforests and seasonal forests have found remarkable results (*e.g.*, Ivanauskas *et al.* 2008; Kunz *et al.* 2009), leading to the recognition of a new category in the Brazilian classification of vegetation (the Evergreen Seasonal Forest - IBGE 2012). In light of these new insights, other ecotone areas have been investigated (Haidar *et al.* 2013).



Figure 1. Images of the studied site, located in the municipality of Guaraciaba, Santa Catarina state, in the colder season (left) and in the warmer season (right).

The soils in the west portion of the state of Santa Catarina are remarkable for their fertility (“Terra Roxa”, Rhodic Nitisol), and the native pines were strongly exploited because of its wood. Therefore, the region saw intensive forest devastation during its colonization, as in the “Constestado War” in the early twenty-century, and the establishment of several small agricultural properties allocated on chemically and physically degenerated soils (Andreola *et al.* 2000).

Here we present a floristic survey in a forest with *Araucaria angustifolia* in the Far West of Santa Catarina and, in addition, a comparison of these data with the ones found in several surveys in different Araucaria Forest and Seasonal Forest areas, in order to provide a better understanding of the relationships between the two forests in the region, and contribute to the knowledge of the flora of the region.

MATERIALS AND METHODS

Study Site

The present study was carried out in a private property with an area of about 120,000 m² of native forest, in the municipality of Guaraciaba, Far West of the state of Santa Catarina, bordering Argentina (26°38'53"S, 53°34'52"W, 510 m above sea level; Figure 1). The Liso River borders the area for about 950 m, with average width of 10 m. The weather is Cfa, according to the Koppen classification, the average temperature in the warmer month is about 23°C and in the colder one is about 14°C (Serra 1977). The precipitation is uniform during the whole year, with about 150 mm of precipitation in the driest month (winter), and about 250 mm in the wettest

one (EMBRAPA 1998). The soil in the area is a Typic Hapludoll (EMBRAPA 1998) and the vegetation of the municipality is in a Seasonal Forest area, but very close to the Araucaria Forest region, according to IBGE 2004.

Data collection

The floristic survey was carried out between the spring of 2009 (September) and the winter of 2010 (August). The vascular plants were collected, including herbs, shrubs, trees, climbers and epiphytes. Small trails were opened inside the forest to cover the whole area. The materials were treated following traditional methods, and the identifications were carried out using specific literature, mainly the Flora Ilustrada Catarinense (Reitz 1965-onwards), herbarium comparisons and consultation with specialists. The plants were deposited in the herbaria UPCB and MBM (acronyms following Thiers, continuously updated). We checked orthography and authors names using the Tropicos (Missouri Botanical Garden, <http://www.tropicos.org>) and Lista de Espécies da Flora do Brasil 2013 databases (<http://floradobrasil.jbrj.gov.br>), and the latter for the vegetation occurrence data as well.

Data analysis

A floristic database of presence/absence was elaborated using the tree species found in the present survey and in 12 additional surveys, six of them conducted in areas of Araucaria Forests, and the other six in areas of Seasonal Forests (Table 1; Figure 2). The names of species were standardized using the accepted name by Tropicos 2013 (Missouri Botanical

Table 1. References, locations and type of vegetation of 12 floristic surveys used for UPGMA comparison. Veg = Vegetation type; AF = Araucaria Forest; SF = Seasonal Forest; R-SF = Riparian-Seasonal Forest. SP, PR, SC and RS respectively São Paulo, Paraná, Santa Catarina and Rio Grande do Sul states.

n	Study	Locality	Coordinates	Veg
01	Negrelle and Silva 1992	Caçador/SC	26°47' S, 52°01' W	AF
02	Formento <i>et al.</i> 2004	Campo Belo do Sul/SC	28°00' S, 50°49' W	AF
03	Giongo and Waechter 2007	Encruzilhada do Sul/RS	30°30' S, 52°42' W	AF
04	Kozera <i>et al.</i> 2006	Curitiba/PR	25°25' S, 49°15' W *	AF
05	Rondon Neto <i>et al.</i> 2002	Criúva/RS	29°00' S, 50°55' W	AF
06	Negrelle and Leuchtenberger 2001	Ponta Grossa/PR	25°15' S, 50°03' W **	AF
07	Jarenkow and Waechter 2001	Vale do Sol/RS	29°34' S, 52°40' W	SF
08	Ivanauskas and Rodrigues 2000	Piracicaba/SP	22°39' S, 47°39' W	SF
09	Longhi <i>et al.</i> 1999	Santa Maria/RS	29°41' S, 53°48' W *	SF
10	Vaccaro <i>et al.</i> 1999	Santa Tereza/RS	29°09' S, 51°42' W	SF
11	Jurinitz and Jarenkow 2003	Camaquã/RS	30°41' S, 51°53' W	SF
12	Budke <i>et al.</i> 2005	Santa Maria/RS	29°41' S, 53°48' W *	R-SF

Garden, <http://www.tropicos.org>). The similarity between pairs of areas was calculated using Jaccard coefficient and a dendrogram with the relationships among the areas was produced based in the UPGMA algorithm, using the software PAST (Hammer *et al.* 2001).

RESULTS

A total of 108 angiosperm species in 42 families were found in the area (Table 2). Myrtaceae (eight spp.), Solanaceae (eight), Euphorbiaceae (seven) and Poaceae (six) were the families with the most encountered number of species, while Myrtaceae (six spp.), Lauraceae (four) and Sapindaceae (four) were the families with the most encountered number of tree species. Three species, *Elephantopus mollis* Kunth, *Eriobotrya japonica* (Thunb.) Lindl. and *Citrus reticulata* Blanco are exotic species, not native to the region, while 32 species (30%) are endemic to the Atlantic Forest *s.l.* and 19 (18%) are widely distributed (Lista da Flora do Brasil 2013, <http://floradobrasil.jbrj.gov.br>).

The dataset built with the species of trees reported from 12 additionally surveyed areas is composed by 148 species in total, 34 of them were only reported by the surveys performed in Seasonal Forest areas while 28 of the total were only reported by surveys performed in Araucaria Forest areas.

DISCUSSION

In a wide survey on the southernmost forests of Brazil, Gonçalves and Souza (2013) were able to determine indicator species for the Araucaria Forest and for the Seasonal Forest. According to them, the present studied area possesses six species indicator of Seasonal Forest (*Casearia sylvestris* Sw., *Luehea divaricata*, *Cordia americana* (L.) Gottschling & J.S.Mill., *Parapiptadenia rigida* Benth., *V. megapotamica* and *Helietta apiculata* Benth.), and five of Araucaria Forest (*A. angustifolia*, *C. xanthocarpa*, *Cryptocarya aschersoniana* Mez, *Matayba elaeagnoides* Radlk. and *O. pulchella*). Additionally, those authors found that the westernmost Araucaria Forests in Rio Grande do Sul, the southern neighbor state of Santa Catarina, could be seen as Seasonal Forest areas with the presence of the diagnostic *A. angustifolia*, what would suggests

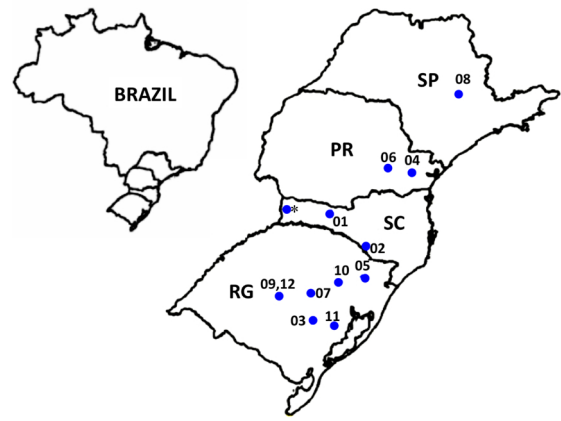


Figure 2. Location of the studied areas. * = present survey; see Table 1 for numbers information; SP, PR, SC and RS respectively São Paulo, Paraná, Santa Catarina and Rio Grande do Sul states.

an enlargement of the current distribution of the Araucaria Forest (Gonçalves and Souza 2013). *Araucaria angustifolia* and *Cedrela lilloi* C.DC., found in the present studied area, are in the Red List of Threatened Species of IUCN (IUCN 2013) and in the Brazilian Red List as endangered species. The plant richness and the presence of endangered species in the area showed the importance of the conservation of the remnant forested areas in the region.

Based on that dataset, four exclusive species from Seasonal Forests areas occurred in the surveyed area: *Aiouea saligna* Meisn., *Cordia americana*, *Eugenia hyemalis* Cambess. and *Trichilia elegans* A. Juss., while six species exclusive from Araucaria Forest areas occurred: *Araucaria angustifolia*, *Campomanesia guazumifolia* (Cambess.) O.Berg, *Cryptocarya aschersoniana*, *Jacaranda puberula* Cham., *Miconia cinerascens* Miq. and *Prunus myrtifolia* (L.) Urb., evidencing the mixed nature of the area.

According to the cluster analyses among the 13 areas (Figure 3), the Seasonal Forest area from Piracicaba/SP (area 08) was found as sister to all the others areas, while the Araucaria forest of Ponta Grossa/PR (area 06) as sister to the remaining eleven areas. The highest similarity index (45%) was

Table 2. Vascular plants present in an Araucaria forest area in Guaraciaba, Far West of Santa Catarina state (continued on following page).

Families and species	Voucher specimens	Families and species	Voucher specimens
Acanthaceae		Boraginaceae	
<i>Hygrophila costata</i> Nees	Gnigler 107	<i>Cordia americana</i> (L.) Gottschling & J.S.Mill.	Gnigler 56;135
Araceae		<i>Heliotropium transalpinum</i> Vell.	Gnigler 41
Araceae 1	Gnigler 200	<i>Tournefortia paniculata</i> Cham.	Gnigler 53;86
Araliaceae		Bromeliaceae	
<i>Hydrocotyle leucocephala</i> Cham. & Schlttdl.	Gnigler 23	<i>Aechmea recurvata</i> (Klotzsch) L.B.Sm.	Gnigler 203
Araucariaceae		<i>Tillandsia</i> sp.	Gnigler 25
<i>Araucaria angustifolia</i> (Bertol.) Kuntze	Gnigler 201	Cactaceae	
Arecaceae		<i>Rhipsalis teres</i> (Vell.) Steud.	Gnigler 82
Arecaceae Indeterminada	Gnigler 202	Campanulaceae	
Asteraceae		<i>Lobelia hassleri</i> Zahlbr.	Gnigler 76
<i>Senecio brasiliensis</i> (Spreng.) Less.	Gnigler 36	Cannabaceae	
<i>Smallanthus connatus</i> (Spreng.) H.Rob.	Gnigler 32	<i>Celtis iguanaea</i> (Jacq.) Sarg.	Gnigler 52
<i>Elephantopus mollis</i> Kunth	Gnigler 92	Commelinaceae	
Begoniaceae		<i>Dichorisandra hexandra</i> (Aubl.) Kuntze ex Hand.-Mazz.	Gnigler 65
<i>Begonia cucullata</i> Willd.	Gnigler 51	<i>Tradescantia fluminensis</i> Vell.	Gnigler 13
Bignoniaceae		Cucurbitaceae	
<i>Jacaranda puberula</i> Cham.	Gnigler 19; 112	<i>Wilbrandia ebracteata</i> Cogn.	Gnigler 40

Table 2. Continued.

Families and species	Voucher specimens	Families and species	Voucher specimens
Cyperaceae		<i>Guadua tagoara</i> (Nees) Kunth	Gnigler 144
<i>Cyperus hermaphroditus</i> (Jacq.) Standl.	Gnigler 110	<i>Ichnanthus cf. nemoralis</i> (Schrad. ex Schult.) Hitchc. & Chase	Gnigler 67
<i>Cyperus incomtus</i> Kunth	Gnigler 14	<i>Pseudechinolaena polystachya</i> (Kunth) Stapf	Gnigler 78
Dioscoreaceae		<i>Setaria vulpiseta</i> (Lam.) Roem. & Schult.	Gnigler 85
<i>Dioscorea polygonoides</i> Humb. & Bonpl. ex Willd.	Gnigler 91	<i>Steinchisma laxa</i> (Sw.) Zuloaga	Gnigler 64
<i>Dioscorea subhastata</i> Vell.	Gnigler 45	Polygonaceae	
Euphorbiaceae		<i>Polygonum punctatum</i> Elliott	Gnigler 105
<i>Astraea lobata</i> (L.) Klotzsch	Gnigler 59	Rosaceae	
<i>Bernardia pulchella</i> (Baill.) Müll.Arg.	Gnigler 68;98;96	<i>Eriobotrya japonica</i> (Thunb.) Lindl.	Gnigler 100
<i>Euphorbia heterophylla</i> L.	Gnigler 86	<i>Prunus myrtifolia</i> (L.) Urb.	Gnigler 88
<i>Manihot grahamii</i> Hook.	Gnigler 28	<i>Prunus sellowii</i> Koehne	Gnigler 138
<i>Sebastiania brasiliensis</i> Spreng.	Gnigler 103	<i>Prunus subcoriacea</i> (Chodat & Hassl.) Koehne	Gnigler 17
<i>Sebastiania commersoniana</i> (Baill.) L.B.Sm. & Downs	Gnigler 05;118;125	<i>Rubus brasiliensis</i> Mart.	Gnigler 61
<i>Tragia volubilis</i> L.	Gnigler 12; 81	Rubiaceae	
Fabaceae		<i>Galianthe brasiliensis</i> (Spreng.) E.L.Cabral & Bacigalupo	Gnigler 90
<i>Dalbergia frutescens</i> (Vell.) Britton	Gnigler 143	<i>Galianthe hispidula</i> (A.Rich. ex DC.) E.L.Cabral & Bacigalupo	Gnigler 21
<i>Desmodium affine</i> Schldtl.	Gnigler 73	<i>Spermacoce</i> sp.	Gnigler 60
<i>Mimosa regnellii</i> Benth.	Gnigler 99	<i>Manettia paraguayensis</i> Chodat	Gnigler 146
<i>Parapiptadenia rigida</i> Benth.	Gnigler 29	Ruscaceae	
<i>Senna araucarietorum</i> H.S Irwin & Barneby	Gnigler 50;87	<i>Cordyline spectabilis</i> Kunth & Bouché	Gnigler 47
Lamiaceae		Rutaceae	
<i>Justicia yhuensis</i> Lindau	Gnigler 26	<i>Citrus reticulata</i> Blanco	Gnigler 06
<i>Salvia guaranitica</i> A.St.-Hil. ex Benth.	Gnigler 27	<i>Heliopsis apiculata</i> Benth.	Gnigler 66; 132
<i>Vitex megapotamica</i> (Spreng.) Moldenke	Gnigler 140	<i>Zanthoxylum rhoifolium</i> Lam.	Gnigler 93; 126
Lauraceae		Salicaceae	
<i>Aiouea saligna</i> Meisn.	Gnigler 136	<i>Casearia sylvestris</i> Sw.	Gnigler 111
<i>Cryptocarya aschersoniana</i> Mez	Gnigler 79	<i>Casearia decandra</i> Jacq.	Gnigler 03; 129
<i>Nectandra megapotamica</i> (Spreng.) Mez	Gnigler 04; 122	Sapindaceae	
<i>Ocotea pulchella</i> (Nees & Mart.) Mez	Gnigler 127	<i>Allophylus edulis</i> (A. St.-Hil. et al.) Hieron ex Niederl.	Gnigler 43
Malvaceae		<i>Allophylus guaraniticus</i> (A.St.-Hil.) Radlk.	Gnigler 102
<i>Luehea divaricata</i> Mart. & Zucc.	Gnigler 83	<i>Matayba elaeagnoides</i> Radlk.	Gnigler 20
<i>Pavonia dusenii</i> Krapov.	Gnigler 75	<i>Trichilia elegans</i> A. Juss.	Gnigler 22; 119
<i>Pavonia prionophylla</i> R.E. Fr.	Gnigler 30	Solanaceae	
<i>Pavonia sepium</i> A.St.-Hil.	Gnigler 142	<i>Capsicum flexuosum</i> Sendtn.	Gnigler 38
<i>Sida rhombifolia</i> L.	Gnigler 31	<i>Cestrum intermedium</i> Sendtn.	Gnigler 34
Marantaceae		<i>Solanum americanum</i> Mill.	Gnigler 35
<i>Calathea eichleri</i> Petersen	Gnigler 77	<i>Solanum corymbiflorum</i> (Sendtn.) Bohs	Gnigler 10; 42
<i>Maranta sobolifera</i> L.Andersson	Gnigler 63	<i>Solanum guaraniticum</i> A.St.-Hil.	Gnigler 39
Melastomataceae		<i>Solanum iraniense</i> L.B.Sm. & Downs	Gnigler 72
<i>Leandra australis</i> (Cham.) Cogn.	Gnigler 15; 46	<i>Solanum laxum</i> Spreng.	Gnigler 37
<i>Leandra xanthocoma</i> (Naudin) Cogn.	Gnigler 62	<i>Solanum mauritianum</i> Scop.	Gnigler 58
<i>Miconia cinerascens</i> Miq.	Gnigler 108	Styracaceae	
<i>Tibouchina debilis</i> Cogn.	Gnigler 109	<i>Styrax leprosus</i> Hook. & Arn.	Gnigler 122
Meliaceae		Symplocaceae	
<i>Cedrela lilloi</i> C.DC.	Gnigler 89; 120	<i>Symplocos tetrandra</i> Mart.	Gnigler 94; 124; 131
Myrtaceae		Urticaceae	
<i>Campomanesia guaviroba</i> (DC.) Kiaersk.	Gnigler 54	<i>Boehmeria caudata</i> Sw.	Gnigler 49
<i>Campomanesia guazumifolia</i> (Cambess.) O.Berg	Gnigler 24	<i>Urera baccifera</i> (L.) Gaudich. ex Wedd.	Gnigler 204
<i>Campomanesia xanthocarpa</i> (Mart.) O.Berg	Gnigler 11	Verbenaceae	
<i>Eugenia hyemalis</i> Cambess.	Gnigler 16	<i>Glandularia guaranitica</i> Tronc.	Gnigler 08
<i>Eugenia uniflora</i> L.	Gnigler 101	<i>Lantana camara</i> L.	Gnigler 71
<i>Eugenia uruguayensis</i> Cambess.	Gnigler 74	Vitaceae	
<i>Myrcianthes gigantea</i> (D.Legrand) D.Legrand	Gnigler 141	<i>Cissus striata</i> Ruiz & Pav.	Gnigler 145
<i>Myrciaria floribunda</i> (H.West ex Willd.) O.Berg	Gnigler 70	<i>Cissus verticillata</i> (L.) Nicolson & C.E.Jarvis	Gnigler 69
Orchidaceae		Vivianiaceae	
<i>Capanemia micromera</i> Barb.Rodr.	Gnigler 104	<i>Caesarea albiflora</i> Cambess.	Gnigler 07
Poaceae			
<i>Bromus brachyanthera</i> Döll	Gnigler 44		

found between two Seasonal Forest areas (areas 07 and 10) and, together to area 11, they form a sister clade to a larger clade composed mostly by Araucaria Forest areas. Area 12, a Riparian-Seasonal Forest, was found as highly correlated to area 09 (36%), a non-riparian Seasonal Forest located at the same municipality, Santa Maria in Rio Grande do Sul state. Both areas are embedded within the Araucaria Forest clade, while the studied area was found as a sister group to this whole clade.

Forested areas in the Far West of Santa Catarina state are very rare, and the study and conservation of the remaining areas are urgent. The higher correlation among the southern Seasonal Forest areas to the Araucaria Forest areas than to the northern Seasonal Forest area (area 08, São Paulo state) illustrates how the surrounding areas influence this kind of forest. Our results show the mixed composition of the studied area. The peculiar nature of northern contact zones between rainforests and seasonal forests is bringing up elucidative views of the Brazilian vegetation. A comprehensive study including abiotic factors acting in the vegetation in the studied area, as well as efforts to survey other remnant areas of forest in the Far West of Santa Catarina state would greatly improve the current knowledge of the historical and ecological dynamics of the forests of southern Brazil.

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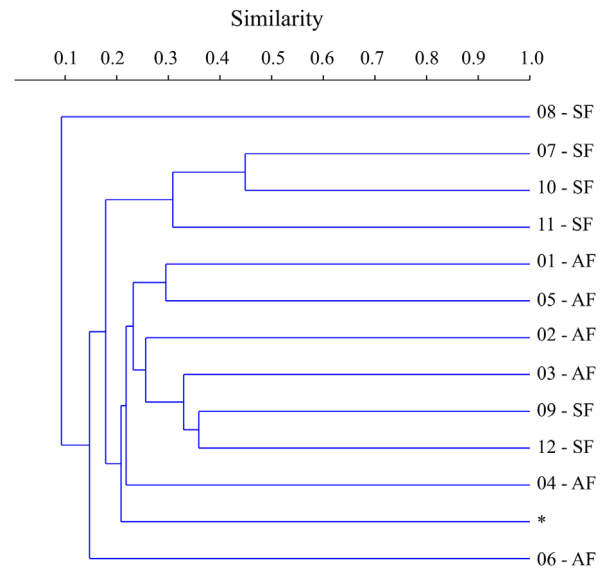


Figure 3. Dendrogram obtained from an UPGMA analysis and Jaccard coefficient of similarity of 13 areas. * = present survey; see table 1 for numbers legend; AF = Araucaria forest areas; SF = Seasonal forest areas.

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