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The phytogeographical and ecological aspects of street afforestation of Cachoeira do Sul, Rio Grande do Sul State, Brazil.

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Abstract

This study evaluated the diversity and phytogeographical aspects of trees on the streets of Cachoeira do Sul, Rio Grande do Sul State, Brazil. It also investigated the qualitative aspects related to health, maintenance and conflicts of street trees with the urban elements. We selected 15 streets from aerial imaging where all trees with a minimum of 15 cm at breast height were identified. The species diversity was estimated from the frequency of individuals per species and in the Shannon-Wiener Index H'. The phytogeographical origin of each species was examined in literature reviews and consultations with specialists. We sampled 2,400 individuals of 101 species belonging to 36 families. The four most frequent species showed density 53.8% of total individuals. The Shannon-Wiener Index H' was 3.14 nats/ind, and equability J' 0.68. There was a predominance of exotic species, with 57.4% of the tree individuals. In terms of frequency of individuals, 61.7% belonged to species from other parts of the world. Regarding the health of the trees, 22.8% showed problems. The results showed the trends in many Brazilian cities, which indicate a state of floristic homogeneity, with predominant use of exotic species, resulting in low species diversity.

Key-words: Urban forest; Street trees; Conflicts with afforestation

Arborização viária de Cachoeira do Sul/RS: diversidade, fitogeografia e conflitos com a infraestrutura urbana

Resumo

O presente estudo faz uma avaliação da diversidade arbórea e fitogeográfica das árvores presentes nas vias de Cachoeira do Sul, RS-Brasil, bem como uma sondagem de aspectos qualitativos referentes à integridade, manutenção e conflitos entre a vegetação viária e os equipamentos urbanos. Quinze ruas foram selecionadas para amostragem onde todos os indivíduos arbóreos com perímetro mínimo de 15 cm a altura do peito foram identificados. A diversidade foi estimada a partir da frequência de indivíduos por espécie e através do Índice de Shannon H'. A origem fitogeográfica de cada espécie foi examinada a partir de pesquisas bibliográficas e consultas a especialistas. As vias amostradas apresentaram 2.400 indivíduos distribuídos em 101 espécies, pertencentes a 36 famílias botânicas. As quatro espécies mais frequentes apresentaram densidade de 53,8% dos indivíduos totais. O Índice de Shannon H' foi de 3,14 nats/ind., e a Equabilidade de Pielou J' 0,68. Houve predominância de espécies exóticas, com 57,4%, e em relação ao número de indivíduos, 61,7% pertenceram a espécies oriundas de outras partes do mundo. Quanto à fitossanidade da vegetação, 22,8% apresentaram problemas. Os resultados obtidos apoiam pesquisas realizadas em diversas cidades brasileiras, que apontam um estado de homogeneidade florística, com utilização preponderante de espécimes exógenos, resultando em baixa diversidade.

Palavras-chave: Arborização urbana; Arborização de ruas; Conflitos em arborização

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INTRODUCTION

The quality of the urban environment has been a recurring subject in discussions regarding the future of cities in Brazil and in the world. After 2011, more than half of the world's population has lived in urban areas, according to a UNFPA report (2011). In developing countries, the migration flow to cities is still significant, and in Brazil, this figure reaches 84% of the population (IBGE, 2011).

Cities are landscapes where different elements interact in a systemic way, influencing the urban mosaic design. In this context, human actions, defined here as an anthropic element, have dominant influence on other components of the urban system, transforming cities in highly complex spaces, completely distinct from natural environments (CHRISTOFOLETTI, 1999).

Vegetation cover, mainly trees, is one of the elements involved in designing the urban landscape and greatly influences environmental quality. Different scientific disciplines have addressed this issue and they use operational categories, often distinct from each other, generating conceptual conflicts (LOBODA and ANGELIS, 2005). Based on the adaptations to classifications proposed by Lima et al. (1994), Cavalheiro et al. (1999), Santos and Teixeira, 2001, Daltoé et al. (2004), Gonçalves and Paiva (2004), Magalhães (2006) and Buccheri Filho (2006) and according to the space that afforestation occupies in the city on a larger scale, we classify it as: a) green areas, which correspond to public or private spaces of free access, such as parks, squares, campsites, among others; b) urban forests, which are forest remnants within cities; c) afforestation of backyards and gardens, in general, found in houses or private areas, such as residential sub-divisions and enterprises; and d) road afforestation, which consists of the vegetation cover along the streets, medians and roundabouts.

Urban afforestation provides important services to the improvement of environmental quality. It helps maintain temperature balance through shading, acting on reflectance and absorbance of incident electromagnetic radiation. It also controls humidity in lower atmosphere through evapotranspiration. Vegetation cover, regardless of space that it occupies in the cities, eases the formation of heat islands, a typical phenomenon of urban environments (SHINZATO, 2009).

Tree cover is an element of ecological, aesthetic, recreational, psychological, and landscape functions, and planning urban afforestation is important to make the urban landscape less artificial. Vegetation cover also contributes to the reduction of air pollution and sound pollution acting as barriers to sound waves and noise. It also helps reduce soil impermeability and runoffs that can cause soil erosion (GÊISER et al., 1976; LIMA et al., 1994; DEMATTÊ, 1997).

For urban afforestation to provide its services, it is necessary to implement it and plan its maintenance taking into account aspects related to diversity and origin of the tree species to be used. Santamour Junior (1990) states that tree diversity should not exceed more than 10% of individuals per species, 20% of a genre, and 30% of a plant family, in order to avoid the incidence of epidemic and ecological problems.

Several authors, such as Blum et al. (2008), have underscored the significant use of exotic species, some of which are toxic, to the detriment of native species. The use of tree species native the region in urban afforestation contributes to equate this artificialized ecosystem, providing better environmental quality to urban citizens, important factor in life quality (ISERNHAGEN et al., 2009).

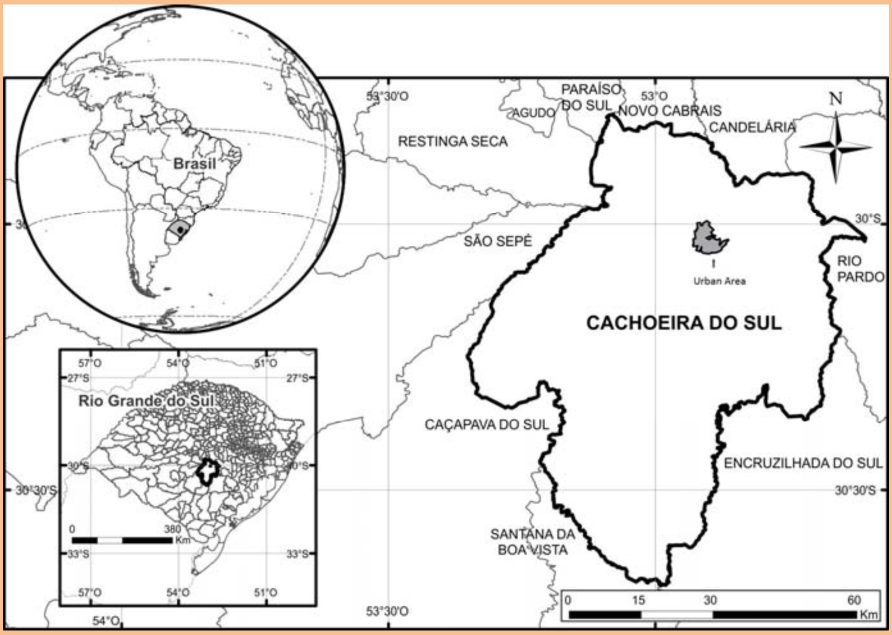
The afforestation of public roads may act interconnecting urban spaces like green areas, forest remnants, backyards, and gardens, forming corridors that can facilitate the flow of the fauna and flora in these environments (RACHID, 1999; SANTOS & TEIXEIRA, 2001; PAIVA & GONÇALVES, 2002; MENEGUETTI, 2003).

We conducted a survey and description of the vegetation cover on the public roads of Cachoeira do Sul, Rio Grande do Sul State, Brazil, and the objective of this this study was to: 1) know the floristic composition; 2) assess the phytogeographical origin of species and individuals; 3) estimate tree diversity; 4) examine plant health conditions such as the occurrence of pruning and disease, and 5) investigate conflicts between trees and sidewalks.

MATERIAL AND METHODS

Study site – The city of Cachoeira do Sul is on the left bank of the Jacuí River, a region called the “Central Depression” of Rio Grande do Sul State, Brazil (Fig. 1). It was the fifth town founded in the state and its settlement started around 1769.

Figure 1. Location of the urban area of Cachoeira do Sul, Rio Grande do Sul, Brazil



The municipality has 83,827 inhabitants (IBGE 2010), from which 71,700 reside in the urban area distributed in 34,639 households. However, the city population amounted to more than 90,000 inhabitants in the early 1960s. This reduction is explained by the emancipations of districts, successive crises in the productive sector, as well as socio-cultural factors that stimulated the emigration after the 1970s (IBGE, 2011).

The city is inserted between three distinct vegetation formations: fields (pampa); areas of ecological tension; and remnants of “Seasonal

Deciduous Forest" (alluvial) along the banks of the tributary of the Jacuí River (TEIXEIRA et al., 1986; MALUF et al., 1994)

In the urban area, the soils are generally deep and well drained and show elements of sedimentary dynamics of the Jacuí River (JUSTUS et al., 1986). The altitude of the city is between 26-120 m, with gently undulating relief.

The climate in the region is considered humid subtropical Cfa, without defined a dry period (Köppen classification). The estimated average rainfall is 1,594 mm/year. The average annual temperature is 19.2°C, with an average in the hottest month above 24°C and a in the coldest month around 13°C (IPAGRO, 1992).

Data collection – In this study, road afforestation was considered "all vegetation and shrub-sized inserted into the corresponding sidewalks, flowerbeds, and roundabouts along the city public roads". We used aerial photographs to select the streets to be inventoried within the urban area. As a criterion of the choice for the sampling points, we decided to cover urban the space homogenously, listing streets in different parts of the city. The streets selected were Ernesto Pertile, Gregório da Fonseca, Marechal Hermes, Dom Pedro II, Olindo Scarparo, Dona Hermínia, Dom Pedrito, Aníbal Loureiro, Aparício Borges, Juvêncio Soares, João Neves da Fontoura, Conde de Porto Alegre, Horácio Borges, João Carlos Gaspary and Ricardo Schaurich (Fig. 2).

The fieldwork to collect data was carried out between November 2011 and February 2012. We inventoried all tree individuals with a minimum of 15 cm at DBH, within the space corresponding to the road. Shrubby individuals with at least 3 m tall were included in the sample. We also included in the inventory species of the Arecaceae family.

Figure 2. Aerial image of the sampling sites in the urban landscape of Cachoeira do Sul, Rio Grande do Sul State, Brazil. The yellow lines indicate the sampled streets.
Source: Adapted from *Google Earth™ Mapping Service*, 2012

We collected data indicative of quality and plant health such as occurrence of drastic pruning, the presence of parasites, conflicts between the root system and sidewalks, and diseases occurrence from each tree individual sampled.

The known tree species were identified *in loco* or through consultation of the W3Tropicos database of the Missouri Botanical Garden. Native species were identified by comparison with material of the ICN-UFRGS herbarium and consulting the database Digital Flora of Rio Grande do Sul. The botanical families were grouped according to the recommendations of APG III (Angyosperm Phylogeny Group, 2009).

The tree diversity on public roads was estimated based on the relative abundance and frequency of individuals per species, and through the diversity indexes Shannon Wiener Index H' and Pielou J', obtained with the aid of the PAST applicative version 1.37, 2005

The phytogeographical origin of each species was examined from bibliographic reviews and consultations to databases of Digital Flora of Rio Grande do Sul and Missouri Botanical Garden W3Tropicos. We considered native (N), species originating from plant formations occurring in Brazil, which have natural occurrence in the region of study. We considered native/regional (NR), species whose ecosystems are represented in the southern region of Brazil and occurring in the region of study. Species originally from ecosystems outside the Brazilian territory were considered exotic (E) (ISERNHAGEN et al., 2009).

RESULTS AND DISCUSSION

The 15 streets surveyed amounted to 22,574 m, where 2,400 tree individuals were identified belonging to 101 species, distributed in 86 genera and 35 botanical families. Three individuals were not identified and 46 were dead (Table 1).

Table 1. Families, species, absolute abundance (A), relative abundance (RA), absolute frequency (AF), relative frequency (RF) and phytogeographical origin of tree species (PO) sampled on public streets Cachoeira do Sul, Rio Grande do Sul State, Brazil.
(Source: E = exotic, N = native, NR = native/regional)

Family	Species	A	RA%	F	RF%	PO
Anacardiaceae	*Mangifera indica* L.	2	0.08	2	13.3	E
	Schinus terebinthifolius Raddi	40	1.66	11	73.3	NR
Annonaceae	*Annona neosalicifolia* H. Hainer.	5	0.20	5	33.3	NR
Apocynaceae	*Nerium oleander* L.	4	0.16	4	26.6	E
	Plumeria rubra L.	3	0.12	3	20.0	E
	Tabernaemontana catharinensis A. DC.	1	0.04	1	6.6	NR
	Thevetia peruviana (Pers.) K. Schum.	12	0.50	9	60.0	E
Araliaceae	*Schefflera actinophylla* (Endl.) Harms.	1	0.04	1	6.6	E
Araucariaceae	*Araucaria angustifolia* (Bertol.) Kuntze	1	0.04	1	6.6	NR
Arecaceae	*Archontophoenix cunninghamii* H. Wendl. & Drude	1	0.04	1	6.6	E
	Butia capitata (Mart.) Becc.	3	0.08	3	20.0	NR
	Syagrus romanzoffiana (Cham.) Glassman	15	0.62	5	33.3	NR

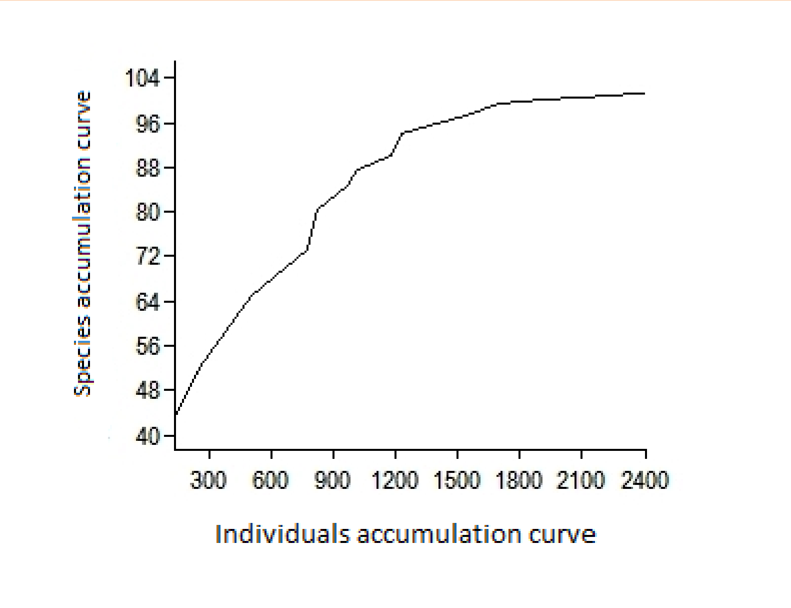
	Washingtonia robusta H. Wendl.	6	0.25	1	6.6	E
Asparagaceae	*Cordyline terminalis* (L.) Kunth	2	0.08	3	20.0	E
	Dracaena marginata Hort.	2	0.08	2	13.3	E
	Yucca elephantipes Regel	6	0.25	4	26.6	E
Bignoniaceae	*Jacaranda mimosifolia* D. Don	68	2.83	15	100	E
	Handroanthus albus (Cham.) Mattos	37	1.54	14	93.3	N
	Handroanthus chrysotrichus (Mart. ex A. DC.) Mattos	305	12.7	15	100	N
	Handroanthus heptaphyllus (Vell.) Mattos	34	1.41	13	86.6	NR
	Handroanthus roseo-albus (Ridl.) Mattos	1	0.04	1	6.6	N
	Spathodea campanulata P. Beauv.	21	0.87	8	53.3	E
Boraginaceae	*Cordia trichotoma* (Vell.) Arráb. ex Steud.	1	0.04	1	6.6	NR
	Cordia americana (L.) Gottshling & J.E.Mill.	2	0.08	2	13.3	NR
Cannabaceae	*Trema micrantha* (L.) Blume	1	0.04	1	6.6	NR
Caricaceae	*Carica papaya* L.	2	0.08	2	20.0	NR
Cupressaceae	*Cupressus cf.sempervirens* L.	9	0.37	7	13.3	E
	Thuya occidentalis L.	7	0.29	3	20.0	E
Ebenaceae	*Diospyros kaki* Thumb.	1	0.04	1	6.6	E
Euphorbiaceae	*Euphorbia cotinifolia* L.	1	0.04	1	6.6	E
	Manihot esculenta Krantz	3	0.12	3	20.0	N
Fabaceae	*Acacia podalyriaefolia* A. Cunn.	3	0.12	2	13.3	E
	Bauhinia forficata Link	8	0.33	2	13.3	NR
	Bauhinia variegata L.	21	0.87	7	46.6	E
	Caesalpinia leiostachya (Benth.) Duke	1	0.04	1	6.6	NR
	Caesalpinia pluviosa DC.	76	3.16	14	93.3	NR
	Calliandra brevipes Benth.	4	0.16	2	13.3	NR
	Cassia fistula L.	7	0.29	5	33.3	E
	Delonix regia (Bojer ex Hook.) Raf.	10	0.41	6	40.0	E
	Enterolobium contortisiliquum (Vell.) Morong	4	0.16	2	13.3	NR
	Erythrina crista-galli L.	1	0.04	1	6.6	NR
	Inga marginata Kunth	146	6.08	15	100	NR
	Inga vera Kunth	4	0.16	4	26.6	NR
	Leucaena leucocephala (Lam.) de Wit	3	0.12	3	20.0	E
	Paraptadenia rigida (Benth.) Brenan.	4	0.16	3	20.0	NR
	Peltophorum dubium (Spreg.) Taub.	53	2.20	12	80.0	NR
	Schizolobium parahyba (Vell.) S. F. Blake	5	0.20	1	6.6	N
	Senna macranthera (DC. ex Collad.) H.S. Irwin & Barneby	18	0.75	9	60.0	N
	Senna multijuga (Rich.) H.S. Irwin & Barneby	11	0.45	8	53.3	N
	Tipuana tipu Benth. Kuntze	22	0.91	6	40.0	E
Junglandaceae	*Carya illinoensis* (Wang.)Kock	6	0.25	6	40.0	E
Lauraceae	*Cinnamomum zeylanicum* Blume	47	1.95	15	100	E
	Nectandra megapotamica (Spreng.) Mez	3	0.12	3	20.0	NR
	Persea americana Mill.	4	0.16	4	26.6	E
Lythraceae	*Lagerstroemia indica* L.	512	21.3	15	100	E
Magnoliaceae	*Magnolia champaca* L.	3	0.12	2	13.3	E
	Magnolia liliflora Desr	1	0.04	1	6.6	E
	Magnolia ovata (A. St.-Hil.) Spreng.	1	0.04	1	6.6	N
Malvaceae	*Brachychiton populneus* (Schott & Endl.) R. Br.	4	0.16	3	20.0	E
	Ceiba speciosa (A. St.-Hil.) Ravenna	2	0.08	1	6.6	N

	Dombeya wallichii (Lindl.) K. Schum.	4	0.16	1	6.6	E
	Hibiscus rosa-sinensis L.	30	1.25	11	73.3	E
	Luehea divaricata Mart.	3	0.12	3	20.0	NR
	Pachira glabra Pasq.	1	0.04	1	6.6	E
Melastomataceae	*Tibouchina granulosa* (Ders.) Cogn.	9	0.37	6	40.0	N
Meliaceae	*Melia azedarach* L.	69	2.87	13	86.6	E
Moraceae	*Ficus benjamina* L.	30	1.25	10	66.6	E
	Ficus benjamina L. var. variegata	10	0.41	6	40.0	E
	Morus nigra L.	24	1.00	11	73.3	E
Myrtaceae	*Callistemon speciosus* (Sims) DC.	20	0.83	6	40.0	E
	Eugenia involucrata DC.	6	0.25	5	33.3	NR
	Eugenia uniflora L.	28	1.16	12	80.0	NR
	Myrcianthes pungens (O. Berg.) D. Legrand	8	0.33	6	40.0	NR
	Myrciaria cauliflora (Mart.) O. Berg.	1	0.04	1	6.6	N
	Psidium cattleyanum var. *coriaceum* (Mart. ex O. Berg) Kiaersk.	12	0.50	7	46.6	N
	Psidium guajava L.	12	0.50	8	53.3	E
	Syzygium cumini (L.) Skeels	20	0.83	11	73.3	E
	Myrtaceae 1	2	0.08	2	13.3	E
Oleaceae	*Ligustrum lucidum* W. T. Aiton	330	13.7	15	100	E
Oxalidaceae	*Averrhoa carambola* L.	1	0.04	1	6.6	E
Platanaceae	*Platanus occidentalis* L.	1	0.04	1	6.6	E
Pinaceae	*Pinus taeda* L.	1	0.04	1	6.6	E
Proteaceae	*Grevillea robusta* A. Cunn. ex R. Br.	5	0.20	3	20.0	E
Rhamnaceae	*Hovenia dulcis* Thunb.	11	0.45	9	60.0	E
Rosaceae	*Eriobotrya japonica* (Thunb.) Lindl.	6	0.25	5	33.3	E
	Prunus domestica L.	3	0.12	2	13.3	E
	Prunus persica (L.) Batsch.	1	0.04	1	6.6	E
	Pyrus communis L.	2	0.08	1	6.6	E
Rutaceae	*Citrus* spp.	56	2.33	13	86.6	E
	Murraya paniculata (L.) Jack	11	0.45	7	46.6	E
	Zanthoxylum hyemale A. St.-Hil.	3	0.12	1	6.6	NR
Salicaceae	*Casearia sylvestris* Sw.	3	0.12	3	20.0	NR
	Populus alba L.	4	0.16	3	20.0	E
	Salix babylonica L.	3	0.12	3	20.0	E
	Salix humboldtiana Andersson	2	0.08	1	6.6	NR
Sapindaceae	*Acer palmatum* Raf.	5	0.20	5	33.3	E
	Allophylus edulis (A. St.-Hil., Cambess. & A. Juss.) Radlk.	4	0.16	3	20.0	NR
Solanaceae	*Brunfelsia uniflora* (Pohl) D. Don.	3	0.12	3	20.0	N
	Solanum mauricianum Scop.	1	0.04	1	6.6	NR
Verbenaceae	*Duranta rapens* L.	25	1.04	4	26.6	E
	Non-identified 1	1	0.04	1	6.6	
	Non-identified 2	1	0.04	1	6.6	
	Dead individuals	46	1.91	14	93.3	

The indicator of sample adequacy for the inventory of road afforestation was obtained through the rarefaction technique, which indicated the stabilization in the species accumulation curve (Fig. 3). In relatively homogeneous environments in cities, the technique of accumulation of species indicates if the sampling effort is satisfactory, or if additional sampling is required where new species could appear.

Unlike natural forests, which have varying patterns of spatial distribution of tree populations, in urban areas the indicator of sufficiency is efficient to know if the sampling is representative and reflects more accurately the vegetal richness in the street afforestation.

Figure 3. Species accumulation curve of the tree inventory on the streets of Cachoeira do Sul, Rio Grande do Sul State, Brazil, 2012



To generate the abundance index, which corresponds to the density of arboreal elements per linear space, we used only the data on one side of the road. The estimated index was 53.15 trees/Km, considered high when compared to cities in Brazil. In Campos do Jordão, São Paulo State, for example, Andrade (2002) recorded 17.22 trees/km, in an inventory of 48,544 m streets where only 836 individuals were found. In Colorado, Rio Grande do Sul State, the abundance index was 43 trees/km (RABER and REBELATO, 2010). Rachid and Couto (1999) found 2,958 elements (live trees, dead plants and open pits), in 98.21 km of sidewalks and with an estimate of 30.12 trees/km of sidewalks.

This index is used to represent the density of trees along sidewalks, and to date, there is no number considered ideal or recommended. Its use in research level is based on comparisons with other studies, and its use gains relevance in management projects. Analyzed in isolation, without the intersection of qualitative data, the index adds little to the understanding of the reality street afforestation in cities.

The tree families with higher species richness were Fabaceae with 19 species, Myrtaceae with 10, Bignoniaceae and Malvaceae with six species each. In the ratio of individuals per family, 80% of the total number of individuals belonged to only six families (Table 1).

Several studies on road afforestation and green areas carried out in Brazilian cities point to the family Fabaceae as the primary taxon in species richness and in number of individuals (RUSCHEL and LEITE, 2002; SOUZA et al., 2004; KURIHARA et al., 2005; CORREIA, 2006; RABER, 2010; ANDREATTA et al., 2011). The families Myrtaceae, Bignoniaceae and Rutaceae also had significant occurrence. All of these families mentioned here, as well as the others mentioned in Table 1, are widely used, and they seem to be cultivated for their aesthetic structures (flowers, leaves, fruits, etc.) and desirable landscaped patterns (SOUZA and LORENZI, 2005).

Of the 101 identified species on sidewalks of the streets sampled in Cachoeira do Sul, four species accounted for 53.8% of the total number of individuals sampled, which are *Lagerstroemia indica*, *Ligustrum lucidum*, *Handroanthus chrysotrichus* and *Inga marginata* (Table 1).

The floristic richness in this study was considered high when compared to other studies carried out in cities in southern Brazil. In Porto Alegre (RS), Salvi et al., (2011) recorded 61 species, in Santa Maria (RS), Andreatta et al., (2011) found 95 species, and Canoas (RS) presented 73 species on the sidewalks of neighborhoods and suburbs (CORREIA, 2006). In Lajeado (RS), 69 species were identified (RUSCHEL and LEITE, 2002), and in Colorado (RS), 45 species were identified on the streets (RABER, 2010). Lindenmaier and Santos (2008) inventoried the green areas of Cachoeira do Sul (study site of our inventory) and found 132 taxa. Souza et al., (2004) found 75 species in the urban afforestation in the city of Jaú (São Paulo State). In Bocaína (São Paulo State), Marques (2005) identified 60 species on public roads in the city. In Campos do Jordão (São Paulo State), Andrade (2002) recorded 32 species (apud ISERNHAGEN, 2009).

The number of species can vary significantly between cities, regardless of demographic condition or geographic location. This variation not always reveals lower or greater diversity, which depends on a larger scale, floristic aspects such as the abundance of individuals per species and phytogeographical relations of its components. Patterns of richness and diversity of urban road afforestation are heavily influenced by the anthropic factor, which refers to the actions of public authorities such as afforestation projects, and actions of individual citizens who often plant trees in front of their homes.

Of the total number of species surveyed, 57 were exotic (56.4% of the total), originally from other regions of the world. Fourteen species were native (13.8%) and native the regional (NR) recorded 30 species (29.7%). We sampled 2,400 tree individuals, where 61.7% were exotic, 17% native, and 19.3% NR. Some species originally from Rio Grande do Sul State, however, without occurrence in the forests of the central region of the state, as the case of *Ceiba speciosa* and *Magnolia ovata*, were considered native. The data shows the predominance of exotic elements for the number of species and abundance of individuals.

The intensive use of exotic species is a representation of old landscape patterns, where more eccentrics of the species attributes are valued with primacy for the afforestation on sidewalks with afforestation homogeneous. The current paradigm in urban afforestation, both on the road and in green areas, indicates the emergence of a model called “ecosystemic” (JOSAFA, 2008), where the aesthetic factor is less privileged, and the potential environmental features of the vegetation cover within the urban system are the central idea. However, the use of exotic species in afforestation should not underestimated, once sidewalk space is extremely restrictive where many native forest species are unable to develop.

Regarding the diversity estimates, the species with greater frequency, *L. indica* recorded 21.3% of the total number of individuals, which means 512 individuals form the total of 2,400 individuals. The four most abundant species totaled together 50.54% of total individuals. Conversely, there was a considerable index of species with only one individual, 19.8% of the total (Table 1).

Tree diversity in urban areas has been a central issue in several studies on afforestation in Brazil, and its character is associated with the quality of the urban environment. The most widely used measure in studies to describe tree diversity in urban spaces is the abundance of individuals per species. Grey and Deneke (1978) recommend 10% of individuals for an arboreal population in an urban area due to phytosanitary issues.

Santamour Junior (1990) recommends 10% frequency for a species, 20% for genre and 30% for family. In the vegetation cover of Cachoeira do Sul (RS), we found three species with high abundance and frequency, *Ligustrum lucidum*, *Lagerstroemia indica* and *Handroanthus chrysotrichus* with relative abundance of more than 10%. Consequently, the genus *Lagerstroemia* presented occurrence higher than 20%, however, none of the families exceeded 30% of frequency. Milano and Dalcin (2000) recommend an ideal index of frequency for species between 10-15%.

For a better analysis of the tree diversity, we also relate the abundance of individuals to the phytogeographical origin of the species. Although species richness found in the road afforestation of Cachoeira do Sul was considered high, more than half of the species (57.4%) are exotic, featuring, thus, lower ecological potential when compared to native species in the study. Furthermore, the abundance of individuals belonging to exotic species was also high (61.7%).

The estimated diversity according to the Shannon-Weiner Index H’ for this study was 3.14 nats/individuals, and the Pielou Evenness J’ was 0.68, considered an intermediate value when compared to other cities in southern Brazil. Raber and Rebelato (2010) found the Shannon-Weiner Index H’ 2.95 nats/individuals in Colorado (RS). Meneguetti (2003) registered 2.61 nats/individuals for Orla de Santos (SP). Lindenmaier and Santos (2008) found a Shannon-Weiner Index H’ 3.85 nats/individuals and evenness J’ of 0.79 for the green areas of Cachoeira do Sul.

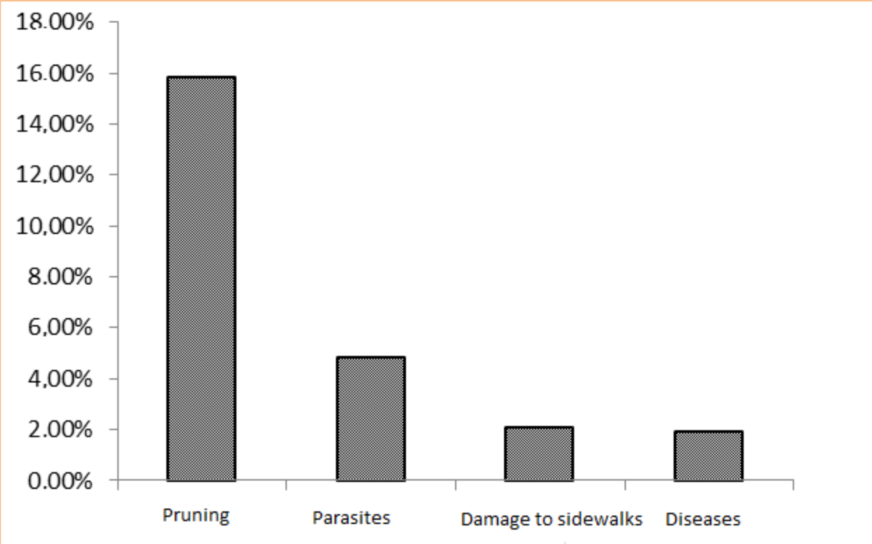
About 20% of the individuals sampled had some problems related to drastic pruning, presence of parasites, phytopathogens and conflict between the root system and sidewalks. Among the main problems that affect the tree health, pruning showed the highest frequency, affecting 15.83% of the sampled trees (Fig. 4).

This figure, in large part, is attributed to the planting of inappropriate species in the spaces, as well as the ignorance of the population in terms of maintenance procedures and the absence of public policies for urban forestation. Presumably, this scenario is also a reflection of socio-cultural aspects.

The conflict between the root system of trees and sidewalks is also problematic to road vegetation, caused in most cases by the inadequacy of the stature of the tree species planted in the reduced space of sidewalks.

Among the individuals sampled, 46 were dead, but still standing (1.9% of the samples). The systematic observations in the fieldwork showed that the death of trees result from drastic pruning or attempts of tree suppression on the part of the population, after confirming the inadequacy of the tree characteristics for the site where they were inserted. Many individuals that undergo pruning practices showed damages caused by phytopathogenic fungi.

Figure 4. Main problems related to quality of trees on the streets of Cachoeira do Sul, Rio Grande do Sul, Brazil.



The presence of parasites registered 5.2% of the total frequency. *Tripodanthus acutifolius* (Ruiz & Pav.) Tiegh. and *Phoradendron affine* (DC.) Engler & k. Krause were the two species of parasites identified on the trees. *P. affine* was observed living predominantly on individuals of *Handroanthus chrysotrichus*, a species native to the Brazilian Cerrado. The high frequency of this parasite in individuals of *H. chrysotrichus* indicates the high specificity between these two species, and the possibility of an infestation, which would restrict the use of this species in road afforestation of Cachoeira do Sul (RS).

CONCLUSIONS

The results obtained through the variables examined allow to conclude that road afforestation of Cachoeira do Sul features:

- intermediate/rich richness of species, especially when compared to other Brazilian cities;

- predominance of exotic species and individuals with low presence of individuals of local flora;

- tree diversity considered intermediate level;

- high number of individuals damaged by pruning and of dead individuals;

- problems with phytopathogenic infestation;

- high rate of conflicts between the tree root system of plants with sidewalks.

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