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# VALUE OF AN URBAN FRAGMENT FOR THE CONSERVATION OF CERRADO IN THE FEDERAL DISTRICT OF BRAZIL

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**ABSTRACT**
The Brazilian Federal District (FD) has 25% of the total woody flora of the Cerrado biodiversity hotspot, but has lost most of its vegetation cover and 30% of its plant species are considered extinct. Here we evaluate the conservation potential of an urban Cerrado fragment in FD that is strategically located between key protected areas. The study was conducted in two sites within the Gama e Cabeça de Veado Environmental Protection Area: the "urban fragment" and a "control site". We found a high floristic and structural similarity between the sites, suggesting that in the past they formed a continuous landscape. The fragment was floristically diverse, with indices that are considered high and typical for Cerrado. The studied fragment, therefore, can help reduce the ongoing deterioration of FD's biodiversity, due to its vegetation representativeness and strategic location, potentially acting as a stepping stone between key protected areas. The study gives support to ongoing efforts to transform the studied area into a protected area.
**Keywords:** diversity; fragmentation; phytosociology; plants; stepping stones.

## INTRODUCTION

The Brazilian Cerrado is one of the world's biodiversity hotspots for its high endemism and great loss of original vegetation cover (Myers *et al*. 2000). The Cerrado is a biome with approximately 2 million Km$^2$, but currently holds only 23.7% of its original savanna vegetation cover (Oberbeck *et al.* 2015). The situation has likely worsened since then. Soil erosion, invasion by exotic grasses, and the use of fire for clearing land are widespread and major threats in this otherwise fire-adapted ecosystem (Klink & Machado 2005). Currently, only 2.7% of the Cerrado is within strict protected areas (corresponding to World Conservation Union's categories I–IV) (Jenkins *et al.* 2015).

The large-scale degradation of the Cerrado started in the 1960s with the transfer of the Brazil's capital to the newly constructed city of Brasília. In the Federal District (FD), urbanization, rather than conversion to agriculture and pasture, is the major threat to the native vegetation. An analysis of the floristic composition within the FD shows a woody flora of 236 species (Bridgewater *et al*. 2004). This means that 25% of the total woody flora of the Cerrado biome is represented in 0.3% of its area, illustrating the great conservation importance of the FD region (Bridgewater *et al*. 2004). Today, however, there is only about 20% of the original vegetation cover left in the FD, and at least 30% of the original plant species have been extinct (UNESCO 2003). Therefore, the FD is a priority area for conservation within the Cerrado biodiversity hotspot.

According to Bridgewater *et al.* (2004), informed conservation action within the Cerrado need to take into account the regional floristic patterns to ensure maximum protection of biodiversity, as the majority of species are not geographically widespread within the Biome. Protected areas have become one of conservation's cornerstones (Margules & Pressey 2000). However, they have rarely been planned on the basis of specific conservation goals (*e.g.* maximizing the number or type of species protected); instead protected areas are often placed where it is politically and economically easier (Margules & Pressey 2000). When systematic conservation planning is undertaken, it becomes clear that an unrealistically large fraction of Earth's surface would be necessary to achieve broad conservation goals (Ceballos *et al*. 2005). Because it is impossible to set aside enough protected areas, they tend to be relatively small and isolated from one another, and often support small populations that receive little or no immigration, and have an increased extinction probability (Pimm *et al.* 1988). Clearly, conservation throughout protected areas, although necessary, cannot be the only strategy. A network of protected areas, especially in the Tropics, must be complemented by smaller unprotected patches of vegetation that could act as stepping stones to larger patches, therefore enhancing connectivity between the protected areas (Fisher *et al*. 2006, Crouzeilles *et al*. 2012).

The case of the Brazilian FD is illustrative. The protected areas already established may not be effective because they were created without a thorough analysis of their relevance for protecting target species or ecosystems; many are partially or completely surrounded by human modified areas; and some already suffer from edge effect and invasion of exotic species (Lacerda 2002, UNESCO 2003, Silva *et al.* 2006).

Here we evaluate the conservation potential of an urban Cerrado fragment within the FD that is strategically located between key protected areas – and therefore may function as a stepping stone – by establishing its floristic representativeness.

## MATERIAL AND METHODS

### *Study area and sampling design*

The study was conducted at two sites within the Gama e Cabeça de Veado Environmental Protection Area, in the vicinities of the city of Brasília, FD, Brazil: (1) a fragment of Cerrado within the urban network of the capital city of Brasília (called "urban fragment" hereafter), and (2) a relatively well preserved Cerrado area within the University of Brasília (UnB) Experimental Reserve, which worked as a control site (called "control site", hereafter). The two *sensu stricto* Cerrado vegetation sites are approximately 4 km apart. Ten 1,000 $m^2$ plots were surveyed in each site for floristic structure and diversity.

The urban fragment is a 34 ha patch of *sensu stricto* Cerrado vegetation located between the highway DF-055 and SMPW Q. 26, and bisected by the EFCA Railway (15°53'10"S, 47°57'28"W) (Figure 1). It is composed of Cerrado patches at different levels of preservation, from nearly intact to only partially deforested. The urban fragment was formed during the disorderly (and often illegal) urban sprawl that took place in the region, once the Brazilian capital moved to the newly constructed city of Brasília in 1960. The fragment is located in Gama e Cabeça de Veado Enviromental Protection's buffer zone (UNESCO, 2003), but it is under constant threat by the extending urban network, as are the entire FD's protected areas (Guimarães *et al*. 2013). There are some spots that have been invaded by exotic grasses, such as *Brachiaria* sp., *Paspalum* sp. and *Melinis minutiflora*. To establish the plots, a grid was drawn over a paper map of the fragment; ten 1,000 $m^2$ plots were raffled and then located *in situ*, being numbered from 1 to 10.

The control site is located inside Fazenda Água Limpa, within the UnB Experimental Reserve (15°57'54"S, 47°55'05"W), approximately 20 km from the city of Brasília. Its total area is ca. 4,000 ha, being part of UNESCO's Cerrado Biosphere Reserve, along with The Brazilian Institute of Geography and Statistics (Portuguese acronym IBGE) Ecological Reserve and the Brasília Botanical Garden (Figure 1). Ten plots were raffled out of 21 plots that have already been established in UnB Experimental Reserve since 1985, as part of a long-term inventory project (Felfili *et al.* 2000).

### *Data collection and analysis*

Fieldwork was conducted from October 2003 to April 2004. We identified all woody individuals at the species level. Only trees with a radius $\geq$ 5.0 cm at 30 cm from the ground level were included in the analysis. The phytosociological parameters were calculated for both areas using the procedures described in Felfili & Rezende (2003).

In order to evaluate the sufficiency in sampling, we calculated the standard error and confidence interval (CI) for density and basal areas, and plotted the species-area curve (Felfili & Imaña-Ecintas 2001). The calculation of sampling adequacy is important to evaluate the efficiency of sampling and whether the results are representative of the total population.

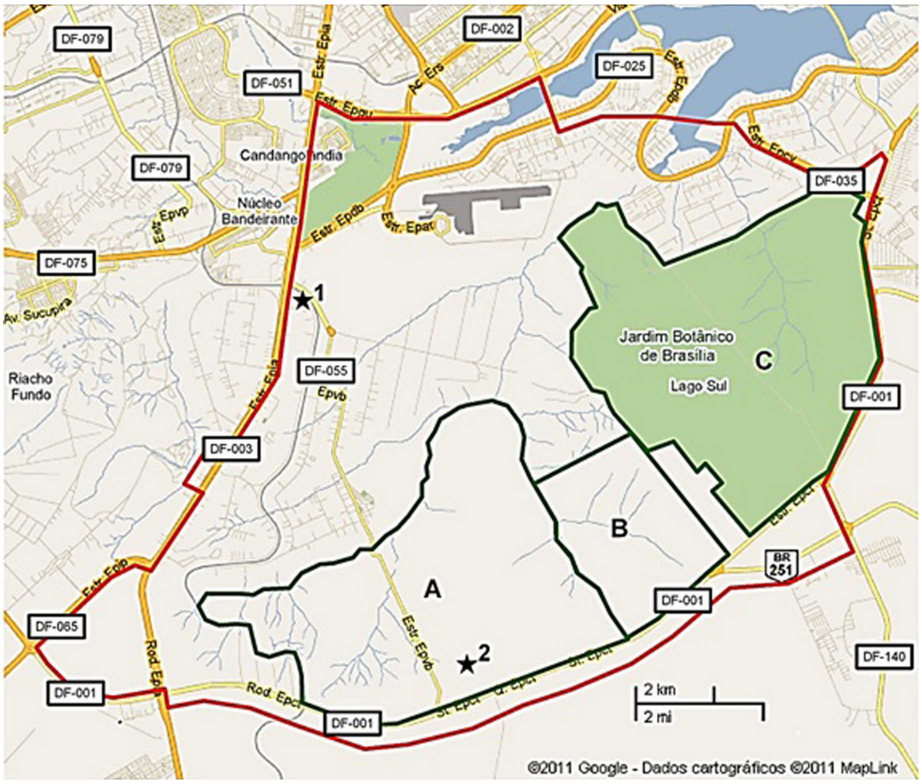


**Figure 1.** Study Area. Red Line: Gama Cabeça de Veado Environmental Protection Area; Green Line: Cerrado Biosphere Reserve, comprised UnB Experimental Reserve (A), IBGE Ecological Reserve (B), and Brasilia Botanical Garden (C); Black stars: study sites, with fragment (1) and the control (2). Modified from Google Maps (maps.google.com.br).

We calculated Shannon's and Simpson's diversity indices, Sorensen's floristic similarity index, and Czekanoswki's structural similarity index in order to determine the plant diversity of each site and the similarity indices between sites, following the methodology used in other studies conducted within this physiognomy (Felfili & Rezende 2003). A matrix for the variable density of 72 species and two samples (the two sites) was built to perform a Two-Way Species Indicator Analysis (TWINSPAN) and a Detrended Correspondence Analysis (DECORANA) as in Kent & Coker (1994) and Felfili & Rezende (2003).

Diametric distributions of the areas were compared using Kolmogorov-Smirnov test (McCoy & Mushinsky 1999). The diameter distribution within classes was also evaluated by calculating Liocourt's "q" coefficient. This coefficient is calculated dividing the density of individuals from one diametric class by the previous class, the result representing the number of recruitment of new individuals in the area. A constant *q* value indicates equilibrium between mortality and recruitment of trees. The calculated "q" quotient may determine if the recruitment of trees is below the expected for a community with good regenerating capacity (Borges-Filho & Felfili 2003).

## RESULTS

The standard error percentage calculated for the absolute density and basal area variables was less than 10% for both study sites (Table 1), suggesting a satisfactory and representative sampling of the plant population of these two areas (Felfili *et al*. 2001, Felfili & Felfili 2001, Felfili & Imaña-Ecintas 2001, Andrade *et al*. 2002).

A total of 1,031 woody individuals were found in the urban fragment, out of which 920 were living trees divided into 64 species, 52 genera and 35 families (Table 2). The total living tree basal area was 8.2 $m^2$ $ha^{-1}$. The number of dead

**Table 1.** Basal area and density means, standard errors and confidence intervals (CI) of woody individuals with diameters ≥ 5.0 cm at 30 cm from ground level.

| Statistical Parameters | Urban Fragment | Control site |
|---|---|---|
| **Basal area** | | |
| Mean (μ) | 13.6 m/ha | 9.4 m/ha |
| Standard error (%) | 7.22 | 9.83 |
| Confidence interval | P [11.4 ≤ μ ≤ 15.8] = 0.95 | P [7.3 ≤ μ ≤ 11.5] = 0.95 |
| **Density** | | |
| Mean (μ) | 1,033 ind/ha | 1,160 ind/ha |
| Standard error (%) | 7.13 | 7.98 |

trees within the sampling effort was 111 (12.1% of the total number of woody individuals). In the control site, we found 1,160 woody trees: 1,048 living individuals divided into 56 species, 45 genera and 29 families (Table 2), and 112 dead trees (10.7%). The total living tree basal area was equal to 6.6 $m^2$ $ha^{-1}$.

The species-area curve is cumulative and considers the numerical ordering of the ten 1 ha plots in each study site. The curves plotted for both areas show a tendency to stabilization after 5,000 $m^2$, or 50% of the sampled area. At that point, 77% (49 species) of all species found in the fragment, and 82% (46 species) of those found in the control site had already been recorded (Figure 2). Eight of ten sampled plots in both fragment and control sites contained more than 90% of the species found in the1 ha sample area: a total of 58 out of the 64 species in the fragment, and 51 out of the 56 species in the control site. Our findings, therefore, reflect a satisfactory sampling intensity of both study sites and can be floristically representative of the fragment and control sites' woody vegetation structure. The fragment's species-area curve is more ascending than that of the control, which suggests that the number of new species could slightly increase if more plots were surveyed, but the stabilization of the curve would still be reached.

The curves of diametric distribution of the areas have an inverted J-shape (Figure 3), showing that most individuals have diameters < 9 cm (51.2% for urban fragment and 70.2% for

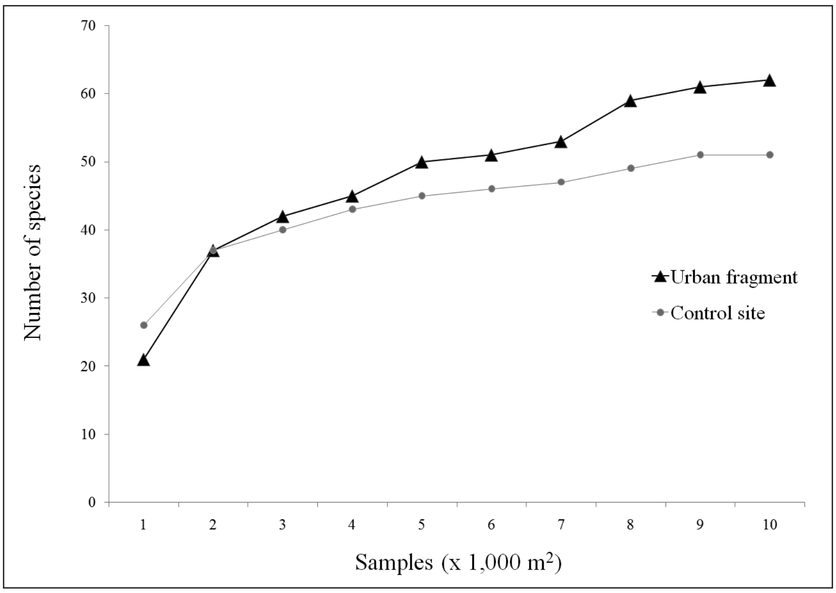


**Figure 2.** Urban fragment and control sites' species-area curve according to the 1 ha sample effort.

**Table 2.** Tree species recorded in two sites in Brasília – Federal District: (1) the urban fragment and (2) a control area in Brasília (UnB) Experimental Reserve.

| Species | Study Site | Family |
|---|---|---|
| 1. *Acosmium dasycarpum* (Vog.) Yakovl. | 1, 2 | Leg. Papilionoideae |
| 2. *Aegiphila sellowiana* Cham | 2 | Verbenaceae |
| 3. *Agonandra brasiliensis* Benth.& Hook. f. | 2 | Opiliaceae |
| 4. *Andira paniculata* Benth. | 1 | Leg.Papilionoideae |
| 5. *Annona crassiflora* Mart. | 2 | Annonaceae |
| 6. *Aspidosperma macrocarpon* Mart. | 1, 2 | Apocynaceae |
| 7. *Aspidosperma tomentosum* Mart. | 1, 2 | Apocynaceae |
| 8. *Austroplenckia populnea* (Reiss.) Lund. | 1, 2 | Celastraceae |
| 9. *Blepharocalyx salicifolius* (H.B. & K.) Berg | 1, 2 | Myrtaceae |
| 10. *Bowdichia virgiloides* H.B. & K. | 1, 2 | Leg.Papilionoideae |
| 11. *Byrsonima coccolobifolia* H.B. & K. | 1, 2 | Malpighiaceae |
| 12. *Byrsonima crassa* Nied. | 1, 2 | Malpighiaceae |
| 13. *Byrsonima verbascifolia* (L.) Rich ex A. L. Juss | 1, 2 | Malpighiaceae |
| 14. *Caryocar brasiliense* Camb. | 1, 2 | Caryocaraceae |
| 15. *Chamaecrista orbiculata* (Benth.) I. & B. | 2 | Leg. Caesalpinoideae |
| 16. *Connarus suberosus* Planch | 1, 2 | Connaraceae |
| 17. *Copaifera langsdorffii* Desf. | 2 | Leg. Caesalpinoideae |
| 18. *Couepia grandiflora* (Mart. &Zucc.) Benth. | 2 | Chrysobalanaceae |
| 19. *Cybianthus detergens* Mart. | 2 | Myrsinaceae |
| 20. *Dalbergia miscolobium* (Vog.) Malme. = *dolichopetala* | 1, 2 | Leg. Papilionoideae |
| 21. *Davilla elliptica* St. Hil | 1 | Dilleniaceae |
| 22. *Dimorphandra mollis* Benth. | 1, 2 | Leg. Mimosoideae |
| 23. *Diospyros burchellii* DC. | 1, 2 | Ebenaceae |
| 24. *Emmotum nitens* (Benth.) Miers. | 2 | Icacinaceae |
| 25. *Enterolobium gummiferum* (Mart.) Macb. | 1, 2 | Leg. Mimosoideae |
| 26. *Eremanthus glomerulatus* Less | 1, 2 | Compositae |
| 27. *Eriotheca pubescens* (Mart.& Zucc.) Schott. & Endl. | 1, 2 | Bombacaceae |
| 28. *Erythroxylum deciduum* St. Hil. | 1, 2 | Erythroxylaceae |
| 29. *Erythroxylum suberosum* St. Hil. | 1, 2 | Erythroxylaceae |
| 30. *Erythroxylum tortuosum* Mart. | 1, 2 | Erythroxylaceae |
| 31. *Guapira noxia* (Netto) Lund | 1, 2 | Nyctaginaceae |
| 32. *Hancornia speciosa* Gomez | 1 | Apocynaceae |
| 33. *Heteropterys byrsonimifolia* A. Juss. | 1 | Malpighiaceae |
| 34. *Hymenae astigonocarpa* Mart. ex Hayne | 1, 2 | Leg. Caesalpinoideae |
| 35. *Kielmeyera coriacea* (Spreng.) Mart. | 1, 2 | Guttiferae (Clusiaceae) |
| 36. *Kielmeyera speciosa* St. Hil. | 1 | Guttiferae (Clusiaceae) |
| 37. *Lafoensia pacari* St.Hil. | 1, 2 | Lythraceae |
| 38. *Machaerium acutifolium* Vog. | 2 | Leg. Papilionoideae |

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| Species | Study Site | Family |
|---|---|---|
| 39. *Miconia albicans* (Sw.) Triana | 1 | Melastomataceae |
| 40. *Miconia chamissois* Naud. | 2 | Melastomataceae |
| 41. *Miconia ferruginata* (D.C.) | 1, 2 | Melastomataceae |
| 42. *Miconia pohliana* Cogn. | 1, 2 | Melastomataceae |
| 43. *Mimosa claussenii* Benth. | 1, 2 | Leg. Mimosoideae |
| 44. *Myrcia sellowiana* Berg. | 2 | Myrtaceae |
| 45. *Myrsine guianensis* (Aubl.) Kuntz. | 1, 2 | Myrsinaceae |
| 46. *Ouratea hexasperma* (St.Hil.) Baill. | 1, 2 | Ochnaceae |
| 47. *Palicourea rigida* Kunth | 1, 2 | Rubiaceae |
| 48. *Piptocarpha rotundifolia* (Less.) Baker. | 1, 2 | Compositae |
| 49. *Plathymenia reticulata* Benth. | 2 | Leg. Mimosoideae |
| 50. *Pouteria ramiflora* (Mart.) Radlk. | 1, 2 | Sapotaceae |
| 51. *Pouteria torta* (Mart.) Radlk. | 2 | Sapotaceae |
| 52. *Psidium myrsinites* Mart. ex. DC. | 2 | Myrtaceae |
| 53. *Psidium laruotteana* Cambess. | 1, 2 | Myrtaceae |
| 54. *Pterodon pubescens* (Benth.) Benth. | 1, 2 | Leg. Papilionoideae |
| 55. *Qualea grandiflora* Mart. | 1, 2 | Vochysyaceae |
| 56. *Qualea multiflora* Mart. | 1, 2 | Vochysyaceae |
| 57. *Qualea parviflora* Mart. | 1, 2 | Vochysyaceae |
| 58. *Roupala montana* R.Br. | 1, 2 | Proteaceae |
| 59. *Rourea induta* Planch. | 1 | Connaraceae |
| 60. *Salacia crassifolia* (Mart.) G. Don. | 1, 2 | Hippocrateaceae |
| 61. *Schefflera macrocarpa* (Seem.) D.C. Frodin | 1, 2 | Araliaceae |
| 62. *Sclerolobium paniculatum* Vog. | 1, 2 | Leg. Caesalpinoideae |
| 63. *Strychnos pseudoquina* St.Hil. | 1, 2 | Loganiaceae |
| 64. *Stryphnodendron adstringens* (Mart.) Cov. | 1, 2 | Leg. Mimosoideae |
| 65. *Styrax ferrugineus* Nees & Mart. | 1, 2 | Styracaceae |
| 66. *Symplocus rhamnifolia* A. DC. | 1, 2 | Symplocaceae |
| 67. *Tabebuia ochracea* (Cham.) Standl. | 1, 2 | Bignoniaceae |
| 68. *Tocoyena formosa* (Cham & Schlecht.) K. Schum. | 2 | Rubiaceae |
| 69. *Vatairea macrocarpa* (Benth.) Ducke | 1, 2 | Leg. Papilionoideae |
| 70. *Vochysia elliptica* Mart. | 1 | Vochysyaceae |
| 71. *Vochysia rufa* Mart. | 2 | Vochysyaceae |
| 72. *Vochysia thyrsoidea* Pohl. | 1, 2 | Vochysyaceae |

control site), which is a characteristic of tropical environments (Felfili *et al*. 2000). The difference between the diametric distribution of the sites was not significant (KS test, D calculated = 0.2528 < D tabled = 0.391; P = 95%). Because the control site has a higher percentage of individuals classified in the lower diametric classes, it also presents a higher regenerating process than the fragment. This is shown by Liocourt's "q" ratios (Table 3) calculated for the high frequency – in number of individuals - diametric classes (5 cm to 33 cm). The diametric distribution of species with absolute

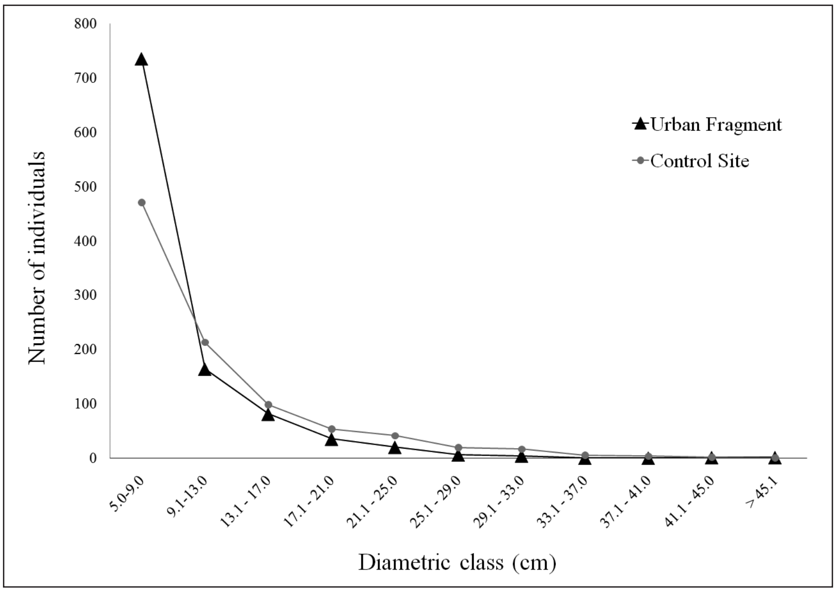


**Figure 3.** Urban fragment and control sites' distribution of trunks' diameters for all woody individuals with diameter > 5cm at 30cm from the soil. Associated Liocourt's "q" quotient is presented in Table 2.

**Table 3.** Diametric classes of woody trees in the urban fragment and in the control site associated with Liocourt's "q" quotient.

| Diametric Class (cm) | Urban Fragment | Control Site |
|---|---|---|
| 5.0 - 9.0 | 0.45 | 0.22 |
| 9.1 – 13.0 | 0.46 | 0.49 |
| 13.1 - 17.0 | 0.54 | 0.43 |
| 17.1 - 21.0 | 0.77 | 0.57 |
| 21.1 - 25.0 | 0.46 | 0.30 |
| 25.1 - 99.0 | 0.84 | 0.67 |
| 29.1 - 33.0 | 0.31 | 0.00 |
| 33.1 - 37.0 | 0.60 | 0.00 |
| 37.1 - 41.0 | 0.33 | 0 .00 |
| 41.1 - 45.0 | 0.00 | 1.00 |

density > 20 individuals $ha^{-1}$ shows that both study sites have species classified as pioneers, such as *Byrsomina crassa* and *Ouratea hexasperma*. These species were especially frequent in perturbed areas within the sites. The other species are classified as "non-preferential" and are broadly distributed in the biome (Felfili *et al*. 2000, Bridgewater *et al*. 2004).

Sorensen's floristic similarity index and the Czekanowski's structural similarity index between the two study sites were 0.790 and 55.719, respectively. Such numbers are considered high (Kent & Coker 1994, Felfili & Rezende 2003, Bridgewater *et al*. 2004). Both the TWINSPAN classification of vegetation and the DECORANA ordering show that structural and floristic differences between the two study sites are not significant (self-value = 0.2339), confirming the results presented thus far. The vegetation in the two sites is therefore apparently homogenous and similar.

## DISCUSSION

We show that the vegetation of the urban fragment studied is in a good state of conservation and is a legitimate representative of the Cerrado found in the Cerrado Biosphere reserve and other protected areas (Felfili *et al*. 2000, Bridgewater *et al*. 2004). The high floristic and structural similarity of the urban fragment and the control site suggests that in the past they might have formed a continuous landscape of *sensu stricto* Cerrado, which was fragmented by the spreading of Brasília's urban network. The urban fragment is floristically diverse, with indices that are considered high and typical for tropical environments (Felfili & Rezende 2003, Fidelis & Godoy 2003, Saporetti *et al*. 2003). The fragment's high floristic diversity, nonetheless, may be partially explained by the fact that communities that go through some kind of disturbing event present an increase in the number of species associated to the temporarily admission of pioneer or opportunistic species, such as *Byrsomina crassa* and *Ouratea hexasperma*, which showed high densities in the fragment (Rezende 2002, Fiedler *et al*. 2004). It is important to note, however, that because the study only systematically evaluated the woody component of the vegetation, it provides an incomplete account of its likely conservation state that must be interpreted as an initial step towards its characterization.

Although the FD has a myriad of protected areas, most of them are within the so-called "sustainable use" category of the Brazilian National System of Nature Conservation Units (SNUC 2003, Rylands & Brandon 2005), which have little restriction to human activities and, therefore, provide very little protection. "Environmental Protected Areas" – such as Gama e Cabeça de Veado – are within this category, and can routinely harbor urban areas inside it, as shown in Figure 1. Nonetheless, the FD has five "integral protection" reserves (Silva *et al.* 2006), which have strong restriction in human activities and, when restrictions are enforced, provide effective protection. The integral protection reserves are: one National Park, two Biological Reserves, and two Ecological Stations (PARNA, REBIO and EE, in Portuguese acronym, respectively). The urban fragment studied is strategically located between these five integral protection areas (clockwise: 15 km S of PARNA Brasilia, ~25 km SW of REBIO Contagem, ~50 km SW of EE Águas Emendadas, ~10 km NW from EE Botanical Garden, and ~30 km SE of REBIO Rio Descoberto).

Because of its vegetation representativeness and strategic location, the urban fragment studied may not only help reducing the ongoing deterioration of FD's biodiversity, but may also act as a stepping stone between protected areas, especially integral protection environmental reserves that may harbor greater populations of wildlife, although this hypothesis must be tested for this and other fragments in the FD. The integrity of the fragment's vegetation, however, might be hampered by edge effect (Laurance *et al.* 1998, 2003, Hoffmann *et al.* 2004) and invasion of exotic species (MacDougall &Turkington 2005). The high tree mortality recorded in it is characteristic of similar physiognomies with a higher frequency of disturbing events (Andrade *et al*. 2002). Indeed, bush fires every dry season and disposal of construction and domestic waste in the fragment remain a great challenge to the protection of its integrity. On the other hand, the fragment might be benefiting from its immersion in an urban matrix, because the presence of houses and roads may have lowered the intensity (although not the frequency, UNESCO 2003) of bush fires in the area. Consequently, the fragment's vegetation might be less impacted by fires than it would otherwise. The fragment is now part of a restoration project (http://www.projetoapa.unb.br), being gradually restored and protected. Furthermore, the preliminary results of the present study have encouraged the Forestry Department of the University of Brasilia to send a proposal to the FD's Government to transform the urban fragment into an urban park for environmental education purposes (Christopher Fagg, personal communication). As we have shown here, this represents an important step towards the conservation of the Cerrado remnants within the FD.

We suggest, as a first step towards a more conservation friendly landscape in the FD, that other studies be conducted using this methodology to identify more fragments that could compose an interesting network of stepping stones and improve connectivity among protected areas, and as a second step to test whether they in fact act as stepping stones.

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