Richness of Cerrado Woody Species Engaged in Ecological Restoration in the Brazilian Federal District

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Abstract

This study has evaluated the richness of Cerrado woody species engaged in ecological restoration in the Brazilian Federal District (BFD). A survey gathered information on plant species traded by local nurseries, species recommended in restoration plans (PRADs), species effectively introduced in areas under restoration, and species present in preserved fragments of Cerrado. Results summed 566 Cerrado woody species from 80 botanical families of which 171 species were traded by local nurseries, 277 were recommended in PRADs, 190 were effectively used in restoration projects, and 434 species were sampled in fragments of native Cerrado. We found low similarity between species composition available in nurseries, recommended in PRADs, used in restoration projects and present in preserved fragments of native Cerrado. Such results indicate a poor connection between steps related to the selection of native woody species that make up initial plant communities on sites under ecological restoration.

Keywords: Cerrado, plant diversity, rehabilitation.

1. INTRODUCTION

The Cerrado biome houses more than 11,000 species of vascular plants and is the richest savanna in plant species in the world (Mendoça et al., 2008). This biome has undergone severe degradation from the 1960s (Rada, 2013) mainly to support agriculture, urbanization, and mining activities (Beuchle et al., 2015; Klink & Machado, 2005; Sano et al., 2010; Spera et al., 2016). As a result, only 54% of the original area remains under natural vegetation cover (Brasil, 2015).

Huge environmental liabilities in Brazilian biomes have triggered the demand for ecological restoration plans and projects, which aim at implementing strategies to rehabilitate natural ecosystems, environmental services, and ecological sustainability on degraded sites (Chazdon, 2008). As such, restoration projects intend to recover ecological and structural characteristics of ecosystems close to the previous original conditions (Palmer et al., 2016). Many techniques have been used to achieve restoration goals, such as natural regeneration, assisted regeneration, direct seeding, nucleation, and tree plantation, which is the most common and traditional practice of ecological restoration (Reis et al., 2010).

When projects rely on tree plantation, species richness and composition are vital characteristics of plant communities that will start up ecological succession on sites under restoration (Crouzeilles et al., 2017; Rodrigues et al., 2009; Siqueira et al., 2015). However, many projects that opted for tree plantation have selected a limited number of woody species to compose initial plant communities (Barbosa et al., 2003; Brancalion et al., 2013; Corrêa et al., 2015; Durigan et al., 2010; Rodrigues et al., 2009). Failures in restoration projects have often been attributed to low species richness and low diversity of initial plant communities (Barbosa et al., 2003).

Based on such a scenario, our objectives were to evaluate the richness of Cerrado woody species that has been recommended, available, and used for ecological restoration in the Brazilian Federal District and analyze its implications.

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2. MATERIALS AND METHODS

2.1. Study area

This work was developed in the Brazilian Federal District (BFD), which is located on the Brazilian Central Plateau (Oliveira & Pompermayer, 2012). BFD’s altitude ranges from 1,000 m to 1,200 m (Martins et al., 2004), local climate is Tropical Savanna (Aw, in Köppen-Geiger classification) with dry winters, rainy summers, and an annual rainfall mean of 1,500 mm (INMET, 2018). All the fourteen Cerrado phytophysiognomies occur in the BFD (Walter, 2001) and 38.0% of BFD’s territory was originally covered by savanna formations, 43.2% by grassland formations, and 18.8% by forest formations, from which 5% were gallery forests (UNESCO, 2002).

2.2. Data gathering

Data were gathered from (1) plant nurseries, (2) restoration plans (PRADs), (3) academic works on plant species introduced in areas under restoration, and (4) species naturally present in preserved fragments of Cerrado. These four categories of sources were surveyed until sampling sufficiency was achieved for each category. Names of Cerrado woody species from 21 nurseries, 35 PRADs, 21 implemented PRADs, and 10 fragments of Cerrado were organized for this work (Figure 1). Lists of woody species recommended in PRADs were compiled at the local environmental agency library (Instituto Brasília Ambiental – IBRAM) and at the website Biblioteca Digital (IBRAM, 2018). Taxa names were updated online as per the nomenclature of the Missouri Botanical Garden (MOBOT, 2016). Botanical families were organized according to The Angiosperm Phylogeny Group et al. (2016).

2.3. Data analysis

Rarefaction curves (Colwell et al., 2012) periodically tested sampling sufficiency for each of the four surveyed categories by using the software R Core Team version 3.5.1 (2017). Plant species within surveyed categories were compared by using Vegan package, according to Ugland et al. (2003), Colwell et al. (2004), and Kindt et al. (2006). Interpolated and extrapolated estimates of species richness were run at 95% confidence level as permutation allows drawing average curves of species accumulation and their empirical confidence intervals (Schilling et al., 2012). Bootstrap species richness estimator was used for species analysis and categorical data matrices were generated from the occurrence of the presence of species in each surveyed category.

Species origin was checked according to Mendonça et al. (2008) and Cerrado native species were categorized according to their natural occurrence in Cerrado phytophysiognomies (Ribeiro & Walter, 2008). Data were organized on a table for summarizing the total number and the percentage number of Cerrado woody species engaged in each of the four surveyed categories.
3. RESULTS AND DISCUSSION

The survey of Cerrado woody species in 21 nurseries, 35 PRADs, 21 implemented PRADs, and ten preserved fragments of Cerrado in the Brazilian Federal District (BFD) were enough for reaching stability tendency on rarefaction curves (Figure 2). Procedure on sampling sufficiency adopted in this study emphasizes the asymptotic response to successive samplings (Figure 2) since plant species data from tropical ecosystems do not usually achieve inflection points on rarefaction curves (Corrêa et al., 2015; Schilling et al., 2012) as also shown in our work (Figure 2).

This survey summed 566 Cerrado species from 80 botanical families, which account for 13.2% of the Cerrado’s vascular plant species identified so far (Mendonça et al., 2008). There were 171 species from 45 families traded by local nurseries, 277 species from 64 families recommended in PRADs, 190 species from 52 families effectively used in restoration projects, and 434 species from 72 families were sampled in fragments from native Cerrado (Table 1).

Figure 2. Rarefaction curves of Cerrado native woody species for the four surveyed categories: (a): nurseries; (b): restoration plans (PRADs); (c): implemented PRADs, and (d): preserved fragments of Cerrado. Bootstrap confidence intervals of 95% by interpolation and extrapolation. Error bars indicate estimated errors of means and unfilled dots represent sampling units.
Table 1. Cerrado woody species available in nurseries, recommended in the restoration plans, effectively used in restoration plans, and present in preserved fragments of Cerrado in the Brazilian Federal District.

| Botanical family/species         | Successional stage | Nursery | PRADs | Implemented PRADs | Native Cerrado |
|---------------------------------|--------------------|---------|-------|-------------------|---------------|
| **Anacardiaceae**               |                    |         |       |                   |               |
| Anacardium humile A. St.-Hil.*   | sec.               | 1       | 2     | 1                 | 2             |
| Anacardium occidentale L.*       | pio.               | 5       | 3     | 2                 | 2             |
| Astronium fraxinifolium Schott   | sec.               | 7       | 8     | 8                 | 4             |
| Astronium graveolens Jacq.*     | sec.               | 0       | 0     | 0                 | 1             |
| Lithraea molleoides (Vell.) Engl. | pio.               | 0       | 1     | 0                 | 1             |
| Myracrodruon urundeuva Allemão   | sec.               | 10      | 7     | 9                 | 1             |
| Schinopsis brasiliensis Engl.    | pio.               | 4       | 3     | 0                 | 0             |
| Schinus terebinthifolia Raddi    | pio.               | 4       | 0     | 4                 | 0             |
| Spondias mombin L.*             | sec.               | 2       | 0     | 0                 | 1             |
| Spondias purpurea L.             | –                  | 3       | 1     | 0                 | 0             |
| Spondias tuberosa Arruda         | pio.               | 0       | 0     | 0                 | 0             |
| Tapirira guianensis Aubl.*      | pio.               | 6       | 10    | 6                 | 1             |
| Tapirira obtusa (Benth.) J.D. Mitch. | sec.           | 0       | 1     | 0                 | 0             |
| **Annonaceae**                   |                    |         |       |                   |               |
| Annona cacans Warm.             | sec.               | 0       | 1     | 0                 | 0             |
| Annona coriacea Mart.           | sec.               | 1       | 0     | 0                 | 2             |
| Annona crassiflora Mart.        | sec.               | 3       | 10    | 2                 | 4             |
| Annona neoiserica H. Rainer     | sec.               | 0       | 0     | 0                 | 1             |
| Annona tomentosa R.E. Fr.*      | –                  | 0       | 0     | 0                 | 1             |
| Cardiopetalum calophyllum Schltdl. | sec.         | 0       | 1     | 0                 | 2             |
| Dugetia furfuracea (A. St.-Hil.) Saff.* | sec.   | 0       | 0     | 1                 | 2             |
| Guatteria australis A. St.-Hil. | cli.               | 0       | 1     | 0                 | 0             |
| Guatteria sellowiana Schltdl.    | –                  | 0       | 0     | 0                 | 3             |
| Xylopia aromatica (Lam.) Mart.  | pio.               | 2       | 5     | 0                 | 2             |
| Xylopia brasiliensis Spreng.    | sec.               | 0       | 0     | 0                 | 2             |
| Xylopia emarginata Mart.        | sec.               | 1       | 3     | 1                 | 2             |
| Xylopia sericea A. St.-Hil.     | sec.               | 1       | 0     | 0                 | 3             |
| **Apocynaceae**                  |                    |         |       |                   |               |
| Aspidosperma cylindrocarpon Müll. Arg. | sec.       | 0       | 0     | 0                 | 1             |
| Aspidosperma discolor A. DC.     | sec.               | 2       | 0     | 0                 | 2             |
| Aspidosperma eburneum Allemão ex Saldanha | –        | 0       | 0     | 0                 | 1             |
| Aspidosperma macrorcapon Mart.  | sec.               | 4       | 5     | 2                 | 5             |
| Aspidosperma parvifolium A. DC. | sec.               | 2       | 0     | 2                 | 1             |
| Aspidosperma polyneuron Müll. Arg. | cli.       | 3       | 1     | 0                 | 0             |
| Aspidosperma pyrrofolium Mart.  | sec.               | 4       | 2     | 0                 | 0             |
| Aspidosperma spruceanum Benth. ex Müll. Arg. | sec. | 2       | 0     | 0                 | 2             |
| Aspidosperma subincanum Mart. ex A. DC. | sec. | 1       | 2     | 1                 | 4             |
| Aspidosperma tomentosum Mart.   | sec.               | 2       | 5     | 1                 | 4             |
| Hancornia speciosa Gomes         | sec.               | 7       | 7     | 3                 | 5             |
| Himatanthus obovatus (Müll. Arg.) Woodson* | sec. | 0       | 2     | 1                 | 1             |
| Tabernaemontana catharinensis A. DC. | pio.       | 0       | 0     | 0                 | 0             |
| **Aquifoliaceae**                |                    |         |       |                   |               |
| Ilex affinis Gardner            | sec.               | 0       | 0     | 0                 | 1             |
| Ilex asperula Mart. ex Reissek  | –                  | 0       | 1     | 0                 | 0             |
| Ilex conocarpa Reissek          | –                  | 0       | 0     | 0                 | 2             |
| **Araliaceae**                   |                    |         |       |                   |               |
| Dendropanax cuneatus (DC.) Decne. & Planch. | sec. | 0       | 0     | 0                 | 1             |
| Schefflera macrocarpa (Cham. & Schltdl.) Frodin | pio. | 0       | 9     | 3                 | 6             |
| Schefflera morototoni (Aubl.) Maguire, Steyerm. & Frodin | pio. | 0       | 3     | 0                 | 2             |
## Table 1. Continued...

| Botanical family/species                              | Successional stage | Nursery PRADs | Implemented PRADs | Native Cerrado |
|-------------------------------------------------------|--------------------|---------------|-------------------|---------------|
| **Arecaceae**                                         |                    |               |                   |               |
| *Acrocomia aculeata* (Jacq.) Lodd. ex Mart.           | pio.               | 2             | 3                 | 0             |
| *Butia capitata* (Mart.) Becc.                        | –                  | 0             | 1                 | 0             |
| *Butia purpurascens* Glassman                         | –                  | 0             | 1                 | 0             |
| *Euterpe edulis* Mart.                                | sec.               | 5             | 1                 | 1             |
| *Mauritia flexuosa* L. f.*                           | pio.               | 6             | 1                 | 0             |
| *Syagrus comosa* (Mart.) Mart.                        | –                  | 0             | 1                 | 0             |
| *Syagrus flexuosa* (Mart.) Becc.                      | sec.               | 0             | 0                 | 0             |
| *Syagrus oleracea* (Mart.) Becc.                      | sec.               | 3             | 1                 | 1             |
| *Syagrus romanzoffiana* (Cham.) Glassman              | sec.               | 2             | 0                 | 0             |
| **Asteraceae**                                         |                    |               |                   |               |
| *Baccharis retusa* DC.                                | pio.               | 0             | 0                 | 1             |
| *Chromolaena laevigata* (Lam.) R.M. King & H. Rob.    | pio.               | 0             | 0                 | 2             |
| *Eremanthus capitatus* (Spreng.) MacLeish              | –                  | 0             | 1                 | 0             |
| *Eremanthus glomerulatus* Less.                        | –                  | 0             | 1                 | 1             |
| *Eremanthus goyazensis* (Gardner) Sch. Bip.           | –                  | 0             | 0                 | 2             |
| *Eremanthus mollis* Sch. Bip.                         | –                  | 0             | 0                 | 1             |
| *Moquiniastrum floribundum* (Cabrera) G. Sancho       | pio.               | 0             | 0                 | 0             |
| *Moquiniastrum polymorphone* (Less.) G. Sancho        | pio.               | 0             | 1                 | 0             |
| *Piptocarpa macropoda* (DC.) Baker*                   | pio.               | 0             | 0                 | 3             |
| *Piptocarpa rotundifolia* (Less.) Baker               | sec.               | 0             | 3                 | 2             |
| *Vernonanthura ferruginea* (Less.) H. Rob.            | pio.               | 0             | 0                 | 1             |
| *Vernonanthura membranacea* (Gardner) H. Rob.         | –                  | 0             | 0                 | 1             |
| *Vernonanthura polyanthes* (Spreng.) A.J. Vega & M. Dematt. | pio.               | 0             | 1                 | 0             |
| **Bignoniaceae**                                      |                    |               |                   |               |
| *Cybistax antisyphilitica* (Mart.) Mart.*             | sec.               | 9             | 2                 | 7             |
| *Handroanthus chrysotrichus* (Mart. ex A. DC.) Mattos  | sec.               | 5             | 1                 | 2             |
| *Handroanthus impetiginosus* (Mart. ex DC.) Mattos     | sec.               | 16            | 9                 | 6             |
| *Handroanthus ochraceus* (Cham.) Mattos               | sec.               | 7             | 8                 | 5             |
| *Handroanthus serratifolius* (Vahl) S.O. Grose        | sec.               | 8             | 2                 | 10            |
| *Handroanthus umbellatus* (Sond.) Mattos              | sec.               | 0             | 0                 | 0             |
| *Jacaranda brasiliana* (Lam.) Pers.*                  | –                  | 1             | 2                 | 1             |
| *Jacaranda caroba* (Vell.) A. DC.*                    | pio.               | 0             | 1                 | 2             |
| *Jacaranda copaia* (Aubl.) D. Don.*                   | pio.               | 0             | 0                 | 1             |
| *Jacaranda cuspiàfolia* Mart.                         | pio.               | 2             | 1                 | 0             |
| *Jacaranda macrantha* Cham.                           | pio.               | 0             | 0                 | 1             |
| *Jacaranda micrantha* Cham.                           | sec.               | 0             | 0                 | 1             |
| *Jacaranda puberula* Cham.                            | cli.               | 0             | 0                 | 1             |
| *Jacaranda ulei* Bureu & K. Schum.                    | –                  | 0             | 0                 | 1             |
| *Spathodea campanulata* P. Beauv.*                    | –                  | 0             | 1                 | 1             |
| *Tabebuia aurea* (Silva Manso) Benth. & Hook. f. ex S. Moore | pio.               | 8             | 3                 | 5             |
| *Tabebuia rosea* (Ridl.) Sandwith                     | pio.               | 18            | 7                 | 7             |
| *Zeyheria montana* Mart.                              | sec.               | 0             | 3                 | 2             |
| *Zeyheria tuberculosa* (Vell.) Bureau                 | sec.               | 0             | 1                 | 0             |
| Botanical family/species | Successional stage | Nursery | PRADs | Implemented PRADs | Native Cerrado |
|--------------------------|--------------------|---------|-------|-------------------|---------------|
| **Bixaceae**             |                    |         |       |                   |               |
| *Bixa orellana* L.*      | pio.               | 1       | 1     | 0                 | 0             |
| *Cochlospermum regium* (Schrank) Pilg. | sec.               | 0       | 1     | 0                 | 0             |
| **Boraginaceae**         |                    |         |       |                   |               |
| *Cordia sellowiana* Cham.* | sec.               | 0       | 1     | 1                 | 2             |
| *Cordia trichotoma* (Vell.) Arráé. ex Steud. | sec.               | 1       | 0     | 1                 | 1             |
| **Burseraceae**          |                    |         |       |                   |               |
| *Commiphora leptophloeos* (Mart.) J.B. Gillett | pio.               | 0       | 2     | 0                 | 0             |
| *Protium heptaphyllum* (Aubl.) Marchand | sec.               | 0       | 1     | 0                 | 2             |
| *Protium ovatum* Engl.*   | sec.               | 0       | 0     | 1                 | 1             |
| *Protium spruceanum* (Benth.) Engl. | sec.               | 0       | 1     | 0                 | 2             |
| *Protium unifoliatum* Engl. | –                 | 0       | 0     | 0                 | 1             |
| *Tetragastris altissima* (Aubl.) Swart* | –                 | 0       | 1     | 0                 | 0             |
| **Calophyllaceae**       |                    |         |       |                   |               |
| *Calophyllum brasiliense* Cambess. | cli.           | 7       | 11    | 8                 | 2             |
| *Kielmeyera coriacea* Mart. & Zucc.* | sec.               | 3       | 9     | 4                 | 6             |
| *Kielmeyera lathrophyton* Saddi | sec.               | 0       | 0     | 0                 | 2             |
| *Kielmeyera speciosa* A. St.-Hil.* | –                 | 0       | 1     | 1                 | 3             |
| *Kielmeyera variabilis* Mart. & Zucc. | sec.               | 0       | 0     | 0                 | 2             |
| **Cannabaceae**          |                    |         |       |                   |               |
| *Celtis iquanea* (Jacq.) Sarg. | pio.               | 1       | 0     | 0                 | 1             |
| *Trema micrantha* (L.) Blume | pio.               | 0       | 0     | 0                 | 1             |
| **Cardiopteridaceae**    |                    |         |       |                   |               |
| *Citronella gongonha* (Mart.) R.A. Howard | sec.               | 0       | 0     | 0                 | 1             |
| **Caricaceae**           |                    |         |       |                   |               |
| *Jacaratia spinosa* (Aubl.) A. DC.* | pio.               | 1       | 0     | 0                 | 0             |
| **Caryocaraceae**        |                    |         |       |                   |               |
| *Caryocar brasiliense* Cambess. | pio.             | 10      | 17    | 3                 | 6             |
| **Celastraceae**         |                    |         |       |                   |               |
| *Cheiloclinium cognatum* (Miers) A.C. Sm. | sec.           | 2       | 1     | 0                 | 3             |
| *Maytenus floribunda* Reissek* | sec.       | 0       | 0     | 0                 | 1             |
| *Maytenus gonooclada* Mart.* | sec.             | 0       | 0     | 0                 | 1             |
| *Plenckia populnea* Reissek | sec.           | 0       | 1     | 2                 | 5             |
| *Salacia crassifolia* (Mart. ex Schult.) G. Don* | –               | 4       | 4     | 2                 | 5             |
| *Salacia elliptica* (Mart.) G. Don* | sec.         | 0       | 0     | 3                 | 5             |
| **Chloranthaceae**       |                    |         |       |                   |               |
| *Hedyosmum brasiliense* Miq. | sec.               | 0       | 1     | 0                 | 2             |
| **Chrysobalanaceae**     |                    |         |       |                   |               |
| *Couepia grandiflora* (Mart. & Zucc.) Benth. ex Hook. f. | sec.       | 0       | 1     | 0                 | 3             |
| *Hirtella ciliata* Mart. & Zucc. | –               | 0       | 1     | 0                 | 0             |
| *Hirtella glandulos a Spreng.* | sec.        | 1       | 1     | 0                 | 1             |
| *Hirtella gracilipes* (Hook. f.) Prance* | sec.       | 0       | 0     | 0                 | 1             |
| *Hirtella martiana* Hook. f.* | –               | 0       | 0     | 0                 | 1             |
| *Licania apetala* (E. Mey.) Fritsch | –               | 0       | 1     | 0                 | 2             |
| Botanical family/species | Successional stage | Nursery PRADs | Implemented PRADs | Native Cerrado |
|-------------------------|--------------------|---------------|-------------------|---------------|
| Chrysobalanaceae        |                    |               |                   |               |
| *Licania dealbata* Hook. f. | –                  | 0             | 1                 | 0             |
| *Licania octandra* (Hoffmanns. ex Roem. & Schult.) Kuntze | –                  | 0             | 0                 | 1             |
| *Licania rigida* Benth.* | –                  | 7             | 0                 | 0             |
| Parinari obtusifolia Hook. f. | –                  | 0             | 0                 | 1             |
| Clusiaceae              |                    |               |                   |               |
| *Clusia burchellii* Engl. | –                  | 0             | 1                 | 0             |
| *Clusia criuva* Cambess.* | pio.              | 0             | 0                 | 1             |
| *Garcinia brasiliensis* Mart. | sec.              | 1             | 0                 | 1             |
| *Garcinia macrophylla* Mart. | –                 | 0             | 0                 | 1             |
| Combretaceae            |                    |               |                   |               |
| *Buchenavia tetraphylla* (Aubl.) R.A. Howard | pio.              | 0             | 1                 | 0             |
| *Buchenavia tomentosa* Eichler | sec.              | 4             | 2                 | 4             |
| *Terminalia argentea* Mart. | pio.              | 4             | 3                 | 3             |
| *Terminalia fagifolia* Mart. | –                 | 0             | 0                 | 1             |
| *Terminalia glabrescens* Mart. | sec.              | 0             | 2                 | 0             |
| *Terminalia phaeocarpa* Eichler | sec.              | 0             | 0                 | 1             |
| Connaraceae             |                    |               |                   |               |
| *Connarus suberosus* Planch. | sec.              | 0             | 2                 | 1             |
| *Rourea induta* Planch. | sec.              | 0             | 1                 | 0             |
| Cunoniaceae             |                    |               |                   |               |
| *Lamanonia ternata* Vell. | sec.              | 0             | 2                 | 0             |
| Dichapetalaceae         |                    |               |                   |               |
| *Tapura amazonica* Poepp.* | –                 | 1             | 1                 | 0             |
| Dilleniaceae            |                    |               |                   |               |
| *Curatella americana* L. | –                  | 1             | 1                 | 1             |
| *Davilla elliptica* A. St.-Hil.* | –                 | 0             | 1                 | 2             |
| Ebenaceae               |                    |               |                   |               |
| *Diospyros guianensis* (Aubl.) Gürke | –                 | 0             | 0                 | 1             |
| *Diospyros hispida* A. DC. | sec.              | 0             | 3                 | 2             |
| *Diospyros sericea* A. DC. | –                 | 0             | 0                 | 1             |
| Elaeocarpaceae          |                    |               |                   |               |
| *Sloanea guianensis* (Aubl.) Benth.* | sec.              | 0             | 0                 | 0             |
| Ericaceae               |                    |               |                   |               |
| *Agarista chapadensis* (Kin.-Gouv.) Judd* | –                 | 0             | 1                 | 0             |
| Erythroxylaceae         |                    |               |                   |               |
| *Erythroxylum daphnites* Mart. | sec.              | 0             | 1                 | 0             |
| *Erythroxylum deciduam* A. St.-Hil.* | pio.              | 0             | 2                 | 1             |
| *Erythroxylum suberosum* A. St.-Hil. | sec.              | 0             | 2                 | 2             |
| *Erythroxylum tortuosum* Mart. | sec.              | 0             | 0                 | 1             |
| *Erythroxylum vaccinifolium* Mart.* | pio.              | 0             | 0                 | 1             |
Table 1. Continued...

| Botanical family/species | Successional stage | Nursery | PRADs | Implemented PRADs | Native Cerrado |
|--------------------------|--------------------|---------|-------|-------------------|---------------|
| **Euphorbiaceae**        |                    |         |       |                   |               |
| Alchornea glandulosa Poepp. | pio.               | 0       | 1     | 1                 | 2             |
| Croton urucurana Baill.  | pio.               | 1       | 0     | 3                 | 1             |
| Mabea fistulifera Mart.  | pio.               | 0       | 1     | 0                 | 0             |
| Maprounea guianensis Aubl.* | sec.           | 0       | 2     | 0                 | 4             |
| Sapium obovatum Klotzsch ex Müll. Arg. | –          | 0       | 0     | 1                 | 1             |
| Sebastiania brasiliensis Spreng.* | pio.       | 0       | 0     | 0                 | 1             |
| **Fabaceae**             |                    |         |       |                   |               |
| Aeosnium lenticifolium Schott ex Spreng. | –          | 0       | 1     | 0                 | 0             |
| Albizia niopoides (Spruce ex Benth.) Burkart | sec.       | 2       | 0     | 1                 | 0             |
| Albizia polypepaha (Benth.) Killip | sec.       | 0       | 0     | 0                 | 1             |
| Amburana caearensis (Allemão) A.C. Sm. | pio.       | 5       | 0     | 3                 | 0             |
| Anadenanthera colubrina (Vell.) Brenan | sec.       | 6       | 8     | 8                 | 2             |
| Anadenanthera peregrina (L.) Speg. | sec.       | 2       | 3     | 4                 | 2             |
| Andira cuyabensis Benth.  | –                 | 0       | 1     | 0                 | 0             |
| Andira fraxinifolia Benth. | sec.       | 0       | 0     | 1                 | 1             |
| Andira humilis Mart. ex Benth.* | sec.       | 0       | 1     | 0                 | 0             |
| Andira vermisiega Mart. ex Benth.* | –             | 0       | 2     | 1                 | 3             |
| Apuleia leiocarpa (Vogel) J.F. Macbr. | sec.       | 2       | 2     | 0                 | 2             |
| Bauhinia cupulata Benth.* | –                 | 0       | 1     | 0                 | 0             |
| Bauhinia dumosa Benth.    | –                 | 0       | 0     | 0                 | 1             |
| Bauhinia forfica Benth.   | sec.             | 0       | 1     | 1                 | 0             |
| Bauhinia longifolia (Bong.) Steud. | pio.       | 0       | 0     | 0                 | 1             |
| Bauhinia rafa (Bong.) Steud. | –             | 0       | 2     | 0                 | 2             |
| Bowdichia virgilioides Kunth* | sec.       | 3       | 7     | 2                 | 4             |
| Calliandra brevipes Benth. | –             | 0       | 0     | 1                 | 0             |
| Cassia ferruginea (Schradt.) Schrader ex DC.* | sec.       | 0       | 0     | 0                 | 0             |
| Cassia grandis L. f.     | pio.             | 1       | 0     | 0                 | 0             |
| Centostigma macrophyllum TuL.* | –             | 0       | 1     | 0                 | 1             |
| Centrolobium tomentosum Guillemin ex Benth.* | sec.       | 1       | 0     | 0                 | 1             |
| Chamaecrista clausenii (Benth.) H.S. Irwin & Barneby* | –             | 0       | 0     | 1                 | 0             |
| Chamaecrista dentata (Vogel) H.S. Irwin & Barneby | –             | 0       | 1     | 0                 | 0             |
| Chamaecrista orbiculata (Benth.) H.S. Irwin & Barneby* | –             | 0       | 0     | 2                 | 1             |
| Chloroleucon tortum (Mart.) Pittier ex Barneby & J.W. Grimes | pio.       | 1       | 0     | 0                 | 0             |
| Clitoria fairchildiana R.A. Howard | –             | 1       | 0     | 0                 | 0             |
| Copaifera langsdorffii Desf.* | sec.       | 13      | 14    | 13                | 4             |
| Copaifera malmei Harms | –                 | 0       | 1     | 0                 | 0             |
| Dalbergia densiflora Benth. | –             | 1       | 0     | 0                 | 1             |
| Dalbergia foliolosa Benth. | –             | 1       | 0     | 0                 | 1             |
| Dalbergia miscolobium Benth. | pio.       | 2       | 12    | 9                 | 5             |
| Dimorphandra mollis Benth. | sec.       | 1       | 9     | 0                 | 5             |
| Dipteryx alata Vogel | sec.             | 7       | 9     | 7                 | 0             |
| Enterolobium contortisiliquum (Vell.) Morong | sec.       | 7       | 7     | 4                 | 2             |
Richness of Cerrado Woody Species Engaged in...

| Botanical family/species | Successional stage | Nursery | PRADs | Implemented PRADs | Native Cerrado |
|--------------------------|--------------------|---------|-------|-------------------|----------------|
| **Fabaceae**              |                    |         |       |                   |                |
| *Enterolobium gummiferum* (Mart.) J.F. Macbr. | sec. | 0 | 6 | 5 | 5 |
| *Enterolobium schomburgkii* (Benth.) Benth | – | 0 | 2 | 0 | 0 |
| *Erythrina crista-galli* L.* | pio. | 0 | 1 | 0 | 0 |
| *Erythrina fusca* Lour.* | – | 0 | 0 | 1 | 0 |
| *Erythrina speciosa* Andrews | sec. | 0 | 1 | 2 | 0 |
| *Erythrina velutina* Willd. | pio. | 2 | 0 | 0 | 0 |
| *Holocalyx balansae* Micheli | sec. | 1 | 0 | 0 | 0 |
| *Hymenaea courbaril* L. | sec. | 5 | 8 | 7 | 3 |
| *Hymenaea martiana* Hayne | – | 0 | 1 | 0 | 0 |
| *Hymenaea stigonocarpa* Mart. ex Hayne | sec. | 6 | 11 | 8 | 4 |
| *Hymenolobium heringeranum* Rizzini | – | 1 | 0 | 0 | 2 |
| *Inga alba* (Sw.) Willd. | sec. | 3 | 1 | 0 | 2 |
| *Inga cylindrica* (Vell.) Mart. | sec. | 1 | 3 | 5 | 1 |
| *Inga edulis* Mart. | sec. | 2 | 2 | 3 | 0 |
| *Inga ingoides* (Rich.) Willd.* | – | 0 | 0 | 0 | 1 |
| *Inga lateriflora* Miq. | – | 0 | 1 | 0 | 0 |
| *Inga laurina* (Sw.) Willd. | pio. | 4 | 1 | 3 | 1 |
| *Inga marginata* Willd. | pio. | 2 | 1 | 1 | 1 |
| *Inga nobilis* Willd. | – | 0 | 2 | 1 | 1 |
| *Inga sessilis* (Vell.) Mart.* | sec. | 1 | 0 | 0 | 0 |
| *Inga vera* Willd. | sec. | 4 | 2 | 1 | 0 |
| *Leptolobium dasycarpum* Vogel | sec. | 2 | 3 | 2 | 6 |
| *Leptolobium elegans* Vogel | sec. | 0 | 3 | 0 | 1 |
| *Lonchocarpus cultratus* (Vell.) A.M.G. Azevedo & H.C. Lima | sec. | 1 | 0 | 0 | 1 |
| *Luetzelburgia auriculata* (Allemão) Ducke | – | 0 | 1 | 0 | 0 |
| *Machaerium acutifolium* Vogel* | sec. | 0 | 0 | 0 | 5 |
| *Machaerium amplum* Benth. | – | 0 | 0 | 0 | 1 |
| *Machaerium nyctitans* (Vell.) Benth. | pio. | 0 | 0 | 1 | 0 |
| *Machaerium opacum* Vogel | – | 0 | 7 | 4 | 4 |
| *Martiodendron mediterraneum* (Mart. ex Benth.) R.C. Koeppen | – | 0 | 1 | 0 | 1 |
| *Mimosa adnetricha* Benth. | – | 0 | 1 | 0 | 0 |
| *Mimosa albolanata* Taub. | – | 0 | 0 | 0 | 1 |
| *Mimosa bimucronata* (DC.) Kuntze | pio. | 0 | 0 | 1 | 0 |
| *Mimosa caesalpinifolia* Benth. | pio. | 0 | 1 | 1 | 1 |
| *Mimosa claussenii* Benth.* | – | 0 | 2 | 3 | 2 |
| *Mimosa foliosa* Benth. | – | 0 | 0 | 0 | 0 |
| *Mimosa heringeri* Barneby | – | 0 | 0 | 0 | 1 |
| *Myroxylon peruiferum* L. f. | sec. | 3 | 0 | 3 | 1 |
| *Ormosia arborea* (Vell.) Harms | sec. | 2 | 0 | 0 | 0 |
| *Parkia pendula* (Willd.) Benth. ex Walp. | sec. | 3 | 0 | 0 | 0 |
| *Parkia platycephala* Benth. | pio. | 0 | 1 | 0 | 1 |
| *Peltophorum dubium* (Spreng.) Taub. | sec. | 1 | 2 | 3 | 0 |

Table 1. Continued...
### Table 1. Continued...

| Botanical family/species | Successional stage | Nursery | PRADs | Implemented PRADs | Native Cerrado |
|--------------------------|--------------------|---------|------|-------------------|----------------|
| **Fabaceae**             |                    |         |      |                   |                |
| *Piptadenia gonoacantha* (Mart.) J.F. Macbr. | pio.   | 2   | 3   | 2                 | 3              |
| *Piptadenia viridiflora* (Kunth) Benth. | pio. | 0 | 1 | 0               | 0              |
| *Plathymenia reticulata* Benth. | sec. | 2 | 4 | 4                 | 5              |
| *Platycamus regnellii* Benth. | sec. | 0 | 0 | 0                 | 1              |
| *Platymiscium floribundum* Vogel | sec. | 0 | 0 | 1                 | 1              |
| *Platypodium elegans* Vogel | sec. | 5 | 2 | 1                 | 3              |
| *Poeclanthae parviflora* Benth. | cli. | 1 | 1 | 1                 | 0              |
| *Poeclanthae subcordata* Benth. | sec. | 0 | 1 | 0                 | 0              |
| *Poincianella pluviosa* (DC.) L.P. Queiroz | – | 0 | 1 | 0                 | 0              |
| *Pterocarpus rohrii* Vahl | sec. | 1 | 1 | 0                 | 1              |
| *Pterodon abruptus* (Moric.) Benth. | – | 0 | 1 | 0                 | 0              |
| *Pterodon emarginatus* Vogel | pio. | 3 | 6 | 2                 | 5              |
| *Pterogyne nitens* Tul. | sec. | 1 | 2 | 2                 | 0              |
| *Senegalia polypylla* (DC.) Britton | pio. | 2 | 0 | 4                 | 2              |
| *Senegalia tenuifolia* (L.) Britton & Rose | – | 0 | 0 | 3                 | 0              |
| *Senna alata* (L.) Roxb. | pio. | 0 | 0 | 0                 | 0              |
| *Senna macranthera* (DC. ex Collad.) H.S. Irwin & Barneby* | pio. | 1 | 1 | 0                 | 1              |
| *Senna multiagua* (Rich.) H.S. Irwin & Barneby | sec. | 2 | 0 | 0                 | 1              |
| *Senna pendula* (Humb. & Bonpl. ex Willd.) H.S. Irwin & Barneby | – | 0 | 0 | 1                 | 0              |
| *Sennea rugosa* (G. Don) H.S. Irwin & Barneby | pio. | 1 | 1 | 0                 | 0              |
| *Stryphnodendron adstringens* (Mart.) Coville* | sec. | 1 | 11 | 3 | 6 |
| *Swartzia apetala* Raddi | – | 0 | 0 | 0                 | 1              |
| *Swartzia macrostachya* Benth. | – | 0 | 1 | 0                 | 0              |
| *Tachigali aurea* Tul. | sec. | 0 | 4 | 1                 | 2              |
| *Tachigali guianensis* (Benth.) Zarucchi & Herend.* | – | 0 | 0 | 1                 | 2              |
| *Tachigali rubiginosa* (Mart. Ex Tul.) Oliveira-Filho | – | 0 | 0 | 0                 | 1              |
| *Tachigali subvelutina* (Benth.) Oliveira-Filho | – | 0 | 0 | 0                 | 2              |
| *Tachigali vulgaris* L.F. Gomes da Silva & H.C. Lima* | sec. | 1 | 5 | 3                 | 3              |
| *Vatairea macrocarpa* (Benth.) Ducke | sec. | 0 | 0 | 1                 | 4              |
| *Zollernia ilicifolia* (Brongn.) Vogel | sec. | 0 | 1 | 0                 | 0              |
| **Humiriaceae**           |                    |         |      |                   |                |
| *Humiria balsamifera* Aubl. | – | 0 | 1 | 0                 | 0              |
| *Sacoglottis guianensis* Benth. | – | 0 | 0 | 0                 | 2              |
| *Sacoglottis mattoensiss* Malme | – | 0 | 0 | 0                 | 1              |
| **Hypericaceae**          |                    |         |      |                   |                |
| *Visma gracilis* Hieron. | – | 0 | 0 | 0                 | 2              |
| *Visma guianensis* (Aubl.) Pers. | pio. | 0 | 1 | 0                 | 1              |
| **Lacistemataceae**       |                    |         |      |                   |                |
| *Lacistema hasslerianum* Chodat* | sec. | 0 | 0 | 0                 | 1              |
| **Lamiaceae**             |                    |         |      |                   |                |
| *Aegiphila integrifolia* (Jacq.) B.D. Jacks. | pio. | 1 | 1 | 1                 | 1              |
| *Aegiphila verticillata* Vell.* | pio. | 0 | 3 | 4                 | 4              |
| *Hyiptidendron canum* (Pohl ex Benth.) Harley | – | 0 | 1 | 0                 | 1              |
| *Vitex polygama* Cham.* | sec. | 1 | 1 | 0                 | 1              |
| Botanical family/species | Successional stage | Nursery PRADs | Implemented PRADs | Native Cerrado |
|--------------------------|--------------------|---------------|-------------------|---------------|
| **Lauraceae**             |                    |               |                   |               |
| Aniba heringeri Vattimo-Gil* | sec.              | 0             | 0                 | 1             |
| Cryptocarya aschersoniana Mez* | sec.              | 0             | 0                 | 2             |
| Endlicheria paniculata (Spreng.) J.F. Macbr.* | sec. | 0 | 0 | 2 |
| Licaria armeniaca (Nees) Kosterm. | sec. | 0 | 0 | 1 |
| Nectandra cissiflora Nees | sec.              | 0             | 0                 | 1             |
| Nectandra gardneri Meisn. | –                 | 0             | 0                 | 1             |
| Nectandra lanceolata Nees & Mart. | sec. | 1 | 0 | 0 |
| Nectandra nitidula Nees & Mart. | sec. | 0 | 1 | 0 |
| Nectandra reticulata (Ruiz & Pav.) Mez | sec. | 0 | 0 | 3 |
| Ocotea aciphylla (Nees & Mart.) Mez | sec. | 0 | 0 | 1 |
| Ocotea corymbosa (Meisn.) Mez* | sec. | 0 | 0 | 2 |
| Ocotea densiflora (Meisn.) Mez | – | 0 | 0 | 1 |
| Ocotea diospyrifolia (Meisn.) Mez | sec. | 0 | 0 | 1 |
| Ocotea glaziiovii Mez | sec.              | 0             | 0                 | 1             |
| Ocotea pomaderroides (Meisn.) Mez | – | 0 | 1 | 2 |
| Ocotea pulchella (Nees & Mart.) Mez* | cli. | 2 | 1 | 5 |
| Ocotea spixiana (Nees) Mez | sec.              | 0             | 0                 | 3             |
| Ocotea velloziana (Meisn.) Mez | sec. | 0 | 0 | 1 |
| Persea fusca Mez* | –                 | 0             | 0                 | 2             |
| **Lecythidaceae**          |                    |               |                   |               |
| Cariniana estrellensis (Raddi) Kuntze* | sec. | 4 | 2 | 3 | 2 |
| Lecythis brancoensis (R. Knuth) S.A. Mori | – | 0 | 1 | 0 | 0 |
| **Loganiaceae**            |                    |               |                   |               |
| Antonia ovata Pohl | sec. | 0 | 0 | 0 | 1 |
| Strychnos pseudoquina A. St.-Hil. | sec. | 1 | 2 | 1 | 5 |
| **Lythraceae**             |                    |               |                   |               |
| Diplasodon virgatus Pohl | sec. | 0 | 1 | 0 | 1 |
| Lactoensia glyptocarpa Koehne | sec. | 1 | 0 | 0 | 0 |
| Lactoensia pacari A. St.-Hil. | sec. | 2 | 3 | 2 | 5 |
| Physocalymna scaberrimum Pohl | pio. | 3 | 1 | 2 | 0 |
| **Magnoliaceae**           |                    |               |                   |               |
| Magnolia ovata (A. St.-Hil.) Spreng. | sec. | 4 | 0 | 0 | 2 |
| **Malpighiaceae**          |                    |               |                   |               |
| Banisteriopsis megaphylla (A. Juss.) B. Gates* | – | 0 | 0 | 0 | 1 |
| Banisteriopsis stellaris (Griseb.) B. Gates | – | 0 | 0 | 1 | 1 |
| Byrsonima coccolobifolia Kunth | sec. | 0 | 2 | 2 | 5 |
| Byrsonima crassifolia (L.) Kunth* | pio. | 1 | 2 | 1 | 2 |
| Byrsonima guileminiana A. Juss.* | – | 0 | 0 | 0 | 1 |
| Byrsonima intermedia A. Juss. | pio. | 0 | 0 | 0 | 3 |
| Byrsonima laxiflora Griseb. | sec. | 0 | 1 | 0 | 2 |
| Byrsonima ligustrifolia A. Juss.* | cli. | 0 | 0 | 0 | 1 |
| Byrsonima pachyphylla A. Juss. | – | 0 | 3 | 1 | 3 |
| Byrsonima rotunda Griseb.* | – | 0 | 0 | 0 | 1 |
| Botanical family/species                  | Successional stage | Nursery | PRADs | Implemented PRADs | Native Cerrado |
|----------------------------------------|--------------------|---------|-------|-------------------|---------------|
| **Malpighiaceae**                      |                    |         |       |                   |               |
| Byrsonima sericea DC.*                 | sec.               | 0       | 0     | 0                 | 1             |
| Byrsonima umbellata Mart. ex A. Juss.* | sec.               | 0       | 0     | 0                 | 1             |
| Byrsonima verbascifolia (L.) DC.       | sec.               | 1       | 1     | 1                 | 5             |
| Heteropterys perrepetala A. Juss.      | –                  | 0       | 0     | 0                 | 1             |
| Peixotoa reticulata Griseb.            | sec.               | 0       | 0     | 0                 | 2             |
| **Malvaceae**                          |                    |         |       |                   |               |
| Apeiba tibourbou Aubl.                 | pio.               | 0       | 0     | 0                 | 2             |
| Basiloxylon brasiliensis (Allemão) K. Schum. | –               | 2       | 0     | 0                 | 0             |
| Ceiba pentandra (L.) Gaertn.           | pio.               | 1       | 0     | 0                 | 0             |
| Ceiba pubiflora (A. St.-Hil.) K. Schum. | sec.             | 0       | 2     | 0                 | 1             |
| Ceiba speciosa (A. St.-Hil.) Ravenna   | sec.               | 3       | 5     | 6                 | 0             |
| Eriotheca candolleana (K. Schum.) A. Robyns | sec.         | 0       | 0     | 0                 | 1             |
| Eriotheca globosa (Aubl.) A. Robyns    | –                  | 0       | 1     | 0                 | 0             |
| Eriotheca gracilipes (K. Schum.) A. Robyns* | sec.     | 0       | 0     | 1                 | 2             |
| Eriotheca pubescens (Mart. & Zucc.) Schott & Endl.* | sec. | 6       | 11    | 5                 | 6             |
| Guazuma crinita Mart.*                 | pio.               | 0       | 1     | 0                 | 0             |
| Guazuma ulmifolia Lam.                 | pio.               | 7       | 3     | 5                 | 1             |
| Luehea candicans Mart.*                | sec.               | 0       | 1     | 0                 | 1             |
| Luehea divaricata Mart.                | sec.               | 0       | 1     | 2                 | 1             |
| Luehea grandiflora Mart.               | pio.               | 0       | 0     | 1                 | 1             |
| Luehea paniculata Mart.                | pio.               | 1       | 0     | 0                 | 2             |
| Pseudobombax grandiflorum (Cav.) A. Robyns | pio.           | 2       | 1     | 0                 | 0             |
| Pseudobombax longiflorum (Mart.) A. Robyns | sec.       | 3       | 2     | 0                 | 3             |
| Pseudobombax marginatum (A. St.-Hil., Juss. & Cambess.) A. Robyns | sec. | 0 | 0 | 0 | 1 |
| Pseudobombax tomentosum (Mart.) Robyns* | sec. | 0 | 1 | 3 | 2 |
| Sterculia apetala (Jacq.) H. Karst.    | sec.               | 1       | 0     | 1                 | 0             |
| Sterculia striata A. St.-Hil. & Naudin | pio.               | 6       | 3     | 6                 | 1             |
| **Melastomataceae**                    |                    |         |       |                   |               |
| Leandra aurea (Cham.) Cogn.            | sec.               | 0       | 0     | 0                 | 1             |
| Leandra melastomoides Raddi            | sec.               | 0       | 0     | 0                 | 1             |
| Macairea radula (Bonpl.) DC.           | –                  | 0       | 1     | 0                 | 0             |
| Miconia albicans (Sw.) Steud.          | pio.               | 1       | 1     | 1                 | 3             |
| Miconia burchellii Triana*             | –                  | 0       | 2     | 0                 | 4             |
| Miconia chamissonis Naudin             | pio.               | 1       | 0     | 1                 | 2             |
| Miconia chartacea Triana               | pio.               | 0       | 0     | 0                 | 1             |
| Miconia cubatanensis Hoehne            | pio.               | 0       | 0     | 0                 | 2             |
| Miconia cuspidata Mart. ex Naudin      | sec.               | 0       | 0     | 0                 | 3             |
| Miconia dodecandra Cogn.*             | sec.               | 0       | 1     | 0                 | 1             |
| Miconia elegans Cogn.*                 | sec.               | 0       | 0     | 0                 | 1             |
| Miconia fallax DC.                     | sec.               | 0       | 0     | 0                 | 1             |
| Miconia ferruginata DC.*               | pio.               | 0       | 1     | 0                 | 6             |
| Miconia hirtella Cogn.*                | –                  | 0       | 0     | 0                 | 1             |
### Table 1. Continued...

| Botanical family/species | Successional stage | Nursery | PRADs | Implemented PRADs | Native Cerrado |
|--------------------------|--------------------|---------|-------|-------------------|----------------|
| *Miconia ibaguensis* (Bonpl.) Triana | pio. | 1 | 0 | 1 | 0 |
| *Miconia leucocarpa* DC. | – | 0 | 0 | 1 | 6 |
| *Miconia nervosa* (Sm.) Triana | – | 0 | 0 | 0 | 1 |
| *Miconia pepericarpa* DC.* | pio. | 0 | 0 | 0 | 2 |
| *Miconia prasina* (Sw.) DC. | pio. | 0 | 0 | 0 | 1 |
| *Miconia punctata* (Desr.) D. Don ex DC. | – | 0 | 0 | 0 | 2 |
| *Miconia sellowiana* Naudin | pio. | 0 | 1 | 0 | 4 |
| *Mouriri glazioviana* Cogn. | sec. | 0 | 0 | 0 | 1 |
| *Mouriri pusa* Gardner ex Hook. | – | 0 | 1 | 0 | 0 |
| *Ossaea congestiflora* (Naudin) Cogn. | – | 0 | 0 | 0 | 1 |
| *Tibouchina candolleana* Cogn.* | – | 7 | 3 | 1 | 2 |
| *Tibouchina frigidula* (DC.) Cogn.* | – | 0 | 0 | 1 | 0 |
| *Tibouchina granulosa* (Desr.) Cogn. | sec. | 2 | 1 | 0 | 0 |
| *Tibouchina stenocarpa* (DC.) Cogn. | – | 2 | 0 | 5 | 1 |
| *Tococa guianensis* Aubl. | – | 0 | 0 | 1 | 0 |
| *Trembleya parviflora* (D. Don) Cogn.* | pio. | 0 | 0 | 1 | 2 |
| *Trembleya phlogifomis* DC. | – | 0 | 0 | 0 | 1 |

**Meliaceae**

| *Cabralea canjerana* (Vell.) Mart.* | sec. | 0 | 1 | 1 | 2 |
| *Cedrela fissilis* Vell. | sec. | 3 | 4 | 3 | 0 |
| *Cedrela odorata* L. | sec. | 0 | 0 | 0 | 1 |
| *Guarea guidonia* (L.) Sleumer | sec. | 3 | 0 | 0 | 1 |
| *Guarea kunthiana* A. Juss.* | sec. | 0 | 0 | 1 | 1 |
| *Guarea macrophylla* Vahl | sec. | 0 | 1 | 0 | 1 |
| *Trichilia catigua* A. Juss.* | sec. | 0 | 0 | 0 | 1 |
| *Trichilia elegans* A. Juss. | sec. | 0 | 0 | 0 | 1 |
| *Trichilia pallida* Sw. | sec. | 0 | 0 | 0 | 1 |

**Metteniusiaceae**

| *Emmotum nitens* (Benth.) Miers | – | 1 | 5 | 0 | 5 |

**Monimiaceae**

| *Macropelus ligustrinus* (Tul.) Perkins | – | 0 | 0 | 0 | 1 |
| *Mollinedia oligantha* Perkins* | – | 0 | 0 | 0 | 1 |

**Moraceae**

| *Brosimum gaudichaudii* Trécul* | pio. | 2 | 3 | 2 | 3 |
| *Ficus citrifolia* Mill. | pio. | 0 | 0 | 0 | 1 |
| *Ficus enormis* (Mart. ex Miq.) Mart. | sec. | 0 | 0 | 0 | 1 |
| *Ficus insipida* Willd.* | sec. | 0 | 0 | 0 | 1 |
| *Ficus obtusiuscula* (Miq.) Miq. | sec. | 0 | 0 | 0 | 1 |
| *Ficus pertusa* L. f. | pio. | 0 | 0 | 0 | 1 |
| *Ficus trigona* L. f. | sec. | 0 | 0 | 0 | 1 |
| *Maclura tinctoria* (L.) D. Don ex Steud. | sec. | 0 | 0 | 2 | 0 |
| *Pseudolmedia laevigata* Trécul* | sec. | 0 | 2 | 0 | 2 |
| *Sorocea bonplandii* (Baill.) W.C. Burger, Lanj. & Wess. Boer | sec. | 0 | 0 | 0 | 1 |
| Botanical family/species | Successional stage | Nursery | PRADs | Implemented PRADs | Native Cerrado |
|--------------------------|--------------------|---------|-------|------------------|----------------|
| Myristicaceae             |                    |         |       |                  |                |
| *Virola sebifera* Aubl.   | pio.               | 1       | 2     | 0                | 3              |
| *Virola urbaniana* Warb.  |                    | 0       | 0     | 0                | 1              |
| Myrtaceae                 |                    |         |       |                  |                |
| *Blepharocalyx salicifolius* (Kunth) O. Berg* | cli. | 0 | 1 | 2 | 4 |
| *Calyptanthus brasiliensis* Spreng. | sec. | 0 | 0 | 0 | 0 |
| *Calyptanthus clusiifolia* (Miq.) O. Berg* | sec. | 0 | 1 | 0 | 2 |
| *Calyptanthus lucida* Mart. ex DC. | sec. | 0 | 0 | 0 | 1 |
| *Campomanesia aromatica* (Aubl.) Griseb. | – | 0 | 0 | 0 | 2 |
| *Campomanesia eugenioides* (Cambess.) D.Legrand ex Landrum* | sec. | 0 | 0 | 0 | 2 |
| *Campomanesia pubescens* (DC.) O. Berg | sec. | 0 | 0 | 0 | 1 |
| *Campomanesia rufa* (O. Berg) Nied. | – | 0 | 0 | 0 | 1 |
| *Campomanesia velutina* (Cambess.) O. Berg | pio. | 1 | 0 | 0 | 1 |
| *Campomanesia xanthocarpa* Mart. ex O. Berg* | sec. | 0 | 0 | 0 | 1 |
| *Eugenia aurata* O. Berg | sec. | 0 | 1 | 0 | 1 |
| *Eugenia bimarginata* DC. | sec. | 0 | 0 | 0 | 1 |
| *Eugenia complicata* O. Berg* | – | 0 | 0 | 0 | 1 |
| *Eugenia dyssenterica* DC. | sec. | 8 | 15 | 7 | 3 |
| *Eugenia florida* DC.* | sec. | 0 | 0 | 0 | 1 |
| *Eugenia involucrata* DC. | sec. | 1 | 0 | 0 | 2 |
| *Eugenia pyriformis* Cambess. | sec. | 1 | 0 | 0 | 0 |
| *Eugenia uruguayensis* Cambess. | – | 1 | 0 | 0 | 1 |
| *Marlierea clausseniana* (O. Berg) Kiaersk. | – | 0 | 1 | 0 | 0 |
| *Myrcia albomentosa* DC. | – | 0 | 1 | 0 | 0 |
| *Myrcia bracteata* (Rich.) DC. | – | 0 | 0 | 0 | 1 |
| *Myrcia eriocalyx* DC. | – | 0 | 0 | 0 | 1 |
| *Myrcia fenzliana* O. Berg* | – | 0 | 0 | 0 | 2 |
| *Myrcia lasiantha* DC.* | – | 0 | 0 | 0 | 1 |
| *Myrcia nivea* Cambess. | – | 0 | 0 | 0 | 1 |
| *Myrcia pubipetala* Miq. | sec. | 0 | 0 | 0 | 1 |
| *Myrcia splendidens* (Sw.) DC. | pio. | 0 | 2 | 1 | 4 |
| *Myrcia tomentosa* (Aubl.) DC. | pio. | 0 | 2 | 0 | 5 |
| *Myrcia venulosa* DC. | – | 0 | 0 | 0 | 1 |
| *Myraciaria floribunda* (H. West ex Willd.) O. Berg | sec. | 0 | 1 | 0 | 0 |
| *Myraciaria glanduliflora* (Kiaersk.) Mattos & D. Legrand | – | 0 | 0 | 0 | 1 |
| *Pimenta pseudocaryophyllus* (Gomes) Landrum* | sec. | 0 | 0 | 0 | 2 |
| *Psidium firmum* O. Berg* | – | 0 | 0 | 0 | 1 |
| *Psidium guineense* Sw. | sec. | 3 | 0 | 1 | 1 |
| *Psidium longipetiolatum* D. Legrand | – | 1 | 0 | 0 | 0 |
| *Psidium myrsinites* Mart. ex DC.* | – | 0 | 0 | 0 | 1 |
| *Psidium myrtoides* O. Berg* | – | 0 | 2 | 3 | 1 |
| *Psidium oligospermum* DC.* | – | 0 | 0 | 0 | 1 |
| *Siphoneugena densiflora* O. Berg | sec. | 3 | 2 | 0 | 2 |
### Table 1. Continued...

| Botanical family/species | Successional stage | Nursery | PRADs | Implemented PRADs | Native Cerrado |
|--------------------------|--------------------|---------|-------|-------------------|---------------|
| **Nyctaginaceae**        |                    |         |       |                   |               |
| *Guapira graciliflora* (Mart. ex J.A. Schmidt) Lundell | sec. | 0 | 1 | 0 | 5 |
| *Guapira noxia* (Netto) Lundell | sec. | 0 | 2 | 3 | 5 |
| *Guapira opposita* (Vell.) Reitz | sec. | 0 | 0 | 0 | 1 |
| *Neea macrophylla* Poepp. & Endl.* | – | 0 | 0 | 0 | 1 |
| *Neea oppositifolia* Ruiz & Pav. | – | 0 | 0 | 0 | 1 |
| *Neea theifera* Oerst.* | – | 0 | 3 | 2 | 2 |
| **Ochnaceae**            |                    |         |       |                   |               |
| *Ouratea castanifolia* (DC.) Engl. | sec. | 0 | 1 | 0 | 2 |
| *Ouratea hexasperma* (A. St.-Hil.) Baill. | – | 0 | 1 | 3 | 4 |
| *Ouratea parviflora* Engl. | sec. | 0 | 1 | 0 | 1 |
| **Olacaceae**            |                    |         |       |                   |               |
| *Heisteria ovata* Benth. | sec. | 0 | 1 | 0 | 2 |
| **Oleaceae**             |                    |         |       |                   |               |
| *Chionanthus trichotomus* (Vell.) P.S. Green* | – | 0 | 0 | 0 | 1 |
| **Opiliaceae**           |                    |         |       |                   |               |
| *Agonandra brasiliensis* Miers ex Benth. & Hook. f. | sec. | 0 | 1 | 0 | 3 |
| **Peraceae**             |                    |         |       |                   |               |
| *Pera glabrata* (Schott) Poepp. ex Baill. | pio. | 0 | 0 | 0 | 3 |
| **Phyllanthaceae**       |                    |         |       |                   |               |
| *Hieronyma alchorneoides* Allemão | sec. | 0 | 0 | 0 | 1 |
| *Margarturia nobilis* L. f.* | sec. | 0 | 0 | 1 | 1 |
| *Richeria grandis* Vahl | sec. | 0 | 1 | 1 | 1 |
| **Picramniaceae**        |                    |         |       |                   |               |
| *Picramnia sellowii* Planch. | sec. | 0 | 0 | 0 | 1 |
| **Piperaceae**           |                    |         |       |                   |               |
| *Piper aduncum* L. | sec. | 0 | 0 | 1 | 2 |
| *Piper arboeum* Aubl. | – | 0 | 0 | 0 | 1 |
| *Piper crassinervium* Kunth | sec. | 0 | 0 | 1 | 1 |
| *Piper hispidum* Sw. | – | 0 | 0 | 0 | 1 |
| *Piper luctonifolium* Kunth | – | 0 | 0 | 0 | 1 |
| *Piper tuberculatum* Jacq. | – | 0 | 0 | 1 | 0 |
| **Polygonaceae**         |                    |         |       |                   |               |
| *Triplaris americana* L.* | pio. | 1 | 4 | 2 | 0 |
| *Triplaris gardneriana* Wedd. | – | 4 | 2 | 3 | 0 |
| **Primulaceae**          |                    |         |       |                   |               |
| *Cybianthus detergens* Mart.* | – | 0 | 1 | 0 | 3 |
| *Cybianthus gardneri* (A. DC.) G. Agostini | – | 0 | 0 | 0 | 2 |
| *Cybianthus glaber* A. DC. | – | 0 | 0 | 0 | 1 |
| *Myrsine coriacea* (Sw.) R. Br. ex Roem. & Schult. | pio. | 0 | 1 | 0 | 3 |
| *Myrsine gardneriana* A. DC. | pio. | 0 | 0 | 1 | 1 |
| *Myrsine guianensis* (Aubl.) Kuntze | pio. | 1 | 4 | 5 | 6 |
| *Myrsine lancifolia* Mart. | pio. | 0 | 0 | 0 | 1 |
| *Myrsine umbellata* Mart. | pio. | 0 | 0 | 0 | 1 |
Table 1. Continued...

| Botanical family/species | Successional stage | Nursery | PRADs | Implemented PRADs | Native Cerrado |
|--------------------------|--------------------|---------|-------|-------------------|----------------|
| **Proteaceae**           |                    |         |       |                   |                |
| Roupala montana Aubl.    | sec.               | 1       | 3     | 3                 | 7              |
| **Rhamnaceae**           |                    |         |       |                   |                |
| Rhamnidium elaeocarpum Reissek | sec.       | 1       | 0     | 1                 | 1              |
| **Rosaceae**             |                    |         |       |                   |                |
| Prunus brasiliensis (Cham. & Schltdl.) D. Dietr. | sec. | 0 | 0 | 0 | 1 |
| Prunus chamissoana Koehne | –                 | 0       | 0     | 0                 | 1              |
| Prunus myrtifolia (L.) Urb. | cli.    | 0       | 0     | 0                 | 1              |
| **Rubiaceae**            |                    |         |       |                   |                |
| Alibertia edulis (Rich.) A. Rich. ex DC. | sec. | 3 | 0 | 1 | 2 |
| Amaioua guianensis Aubl. | sec.              | 0       | 0     | 0                 | 3              |
| Calycophyllum spruceanum (Benth.) Hook. f. ex K. Schum. | – | 0 | 1 | 0 | 0 |
| Chiococca alba (L.) Hitchc. | sec.     | 0       | 0     | 0                 | 1              |
| Homelia martiana Müll.Arg.* | –            | 0       | 5     | 0                 | 0              |
| Homelia obtusa Cham. & Schltdl. | sec. | 0 | 0 | 0 | 1 |
| Homelia pohliana Müll. Arg.* | sec. | 0 | 0 | 0 | 1 |
| Cordiera elliptica (Cham.) Kuntze | – | 0 | 0 | 0 | 1 |
| Cordiera macrophylla (K. Schum.) Kuntze | sec. | 1 | 1 | 2 | 2 |
| Cordiera myrcifolia (K. Schum.) C.H. Perss. & Delprete | – | 0 | 0 | 0 | 0 |
| Cordiera sessilis (Vell.) Kuntze | sec. | 0 | 0 | 2 | 2 |
| Coussarea hydrangeifolia (Benth.) Müll. Arg. | sec. | 0 | 1 | 0 | 2 |
| Coutarea hexandra (Jacq.) K. Schum. | sec. | 0 | 0 | 0 | 1 |
| Faramea hyacinthina Mart.* | sec. | 0 | 1 | 0 | 2 |
| Ferdinandusa elliptica (Pohl) Pohl | – | 0 | 0 | 0 | 1 |
| Ferdinandusa speciosa (Pohl) Pohl | – | 0 | 0 | 0 | 1 |
| Genipa americana L. | cli.              | 12      | 11    | 8                 | 1              |
| Guettarda pohliana Müll. Arg. | pio. | 0 | 0 | 0 | 1 |
| Guettarda viburnoides Cham. & Schltdl. | sec. | 1 | 3 | 0 | 2 |
| Ixora brevifolia Benth. | sec.               | 0       | 0     | 0                 | 1              |
| Ladenbergia graciliflora K. Schum. | – | 0 | 1 | 0 | 0 |
| Palicourea rigidifolia Kunth | pio. | 0 | 3 | 2 | 5 |
| Posoqueria latifolia (Rudge) Schult. | sec. | 0 | 1 | 0 | 1 |
| Psychotria carthagensis Jacq. | pio. | 0 | 0 | 0 | 1 |
| Psychotria mapourioides DC. | sec. | 0 | 0 | 0 | 1 |
| Rudgea viburnoides (Cham.) Benth. | sec. | 0 | 0 | 0 | 1 |
| Rustia formosa (Cham. & Schltdl.) Klotzsch | sec. | 0 | 1 | 0 | 1 |
| Tocoyena formosa (Cham. & Schltdl.) K. Schum. | pio. | 2 | 1 | 0 | 5 |
| **Rutaceae**             |                    |         |       |                   |                |
| Balfourodendron riedelianum (Engl.) Engl.* | sec. | 1 | 0 | 0 | 0 |
| Dictyoloma vandelianum A. Juss.* | pio. | 1 | 0 | 0 | 0 |
| Esenbeckia grandiflora Mart. | sec. | 0 | 0 | 0 | 1 |
| Esenbeckia pumila Pohl | – | 0 | 0 | 1 | 1 |
| Metrodorea stipularis Mart. | sec. | 0 | 0 | 0 | 1 |
Table 1. Continued...

| Botanical family/species | Successional stage | Nursery | PRADs | Implemented PRADs | Native Cerrado |
|--------------------------|--------------------|---------|-------|-------------------|----------------|
| **Rutaceae**             |                    |         |       |                   |                |
| *Spiranthera odoratissima* A. St.-Hil.* | – | 0 | 0 | 0 | 1 |
| *Zanthoxylum fagara* (L.) Sarg. | sec. | 0 | 1 | 0 | 0 |
| *Zanthoxylum rhoifolium* Lam. | sec. | 0 | 0 | 0 | 3 |
| *Zanthoxylum riedelianum* Engl. | sec. | 1 | 2 | 0 | 1 |
| **Salicaceae**           |                    |         |       |                   |                |
| *Casearia gossypiosperma* Briq. | sec. | 0 | 0 | 0 | 1 |
| *Casearia grandiflora* Cambess. | sec. | 0 | 1 | 0 | 2 |
| *Casearia rupestris* Eichler* | pio. | 0 | 0 | 0 | 1 |
| *Casearia sylvestris* Sw. | sec. | 1 | 1 | 2 | 5 |
| *Casearia lasiophylla* Eichler | sec. | 0 | 0 | 0 | 1 |
| *Xylosma benthamii* (Tul.) Triana & Planch. | – | 0 | 0 | 0 | 2 |
| *Xylosma pseudosalzmanii* Sleumer | sec. | 0 | 0 | 0 | 1 |
| *Allophylus edulis* (A. St.-Hil., A. Juss. & Cambess.) Hieron. ex Niederl. | sec. | 0 | 0 | 0 | 1 |
| *Cupania vernalis* Cambess. | sec. | 0 | 1 | 0 | 1 |
| *Dilodendron bipinnatum* Radlk. | pio. | 2 | 1 | 3 | 0 |
| *Magonia pubescens* A. St.-Hil. | sec. | 3 | 2 | 4 | 1 |
| *Matayba elaegnoides* Radlk.* | sec. | 0 | 0 | 0 | 1 |
| *Matayba guianensis* Aubl.* | sec. | 0 | 3 | 1 | 4 |
| *Sapindus saponaria* L.* | sec. | 3 | 4 | 2 | 0 |
| *Talisia esculenta* (A. St.-Hil.) Radlk. | – | 3 | 0 | 1 | 1 |
| **Sapotaceae**           |                    |         |       |                   |                |
| *Chrysophyllum marginatum* (Hook. & Arn.) Radlk. | pio. | 0 | 0 | 0 | 1 |
| *Ecclinusa ramiflora* Mart.* | sec. | 0 | 1 | 0 | 0 |
| *Manilkara triflora* (Allemão) Monach. | – | 0 | 1 | 0 | 0 |
| *Micropholis venulosa* (Mart. & Eichler) Pierre | pio. | 0 | 0 | 0 | 2 |
| *Pouteria gardneri* (Mart. & Miq.) Baehni* | pio. | 0 | 0 | 0 | 1 |
| *Pouteria ramiflora* (Mart.) Radlk. | sec. | 2 | 5 | 4 | 7 |
| *Pouteria torta* (Mart.) Radlk. | sec. | 1 | 4 | 2 | 5 |
| **Simaroubaceae**        |                    |         |       |                   |                |
| *Simarouba amara* Aubl. | sec. | 4 | 2 | 0 | 1 |
| *Simarouba versicolor* A. St.-Hil. | sec. | 0 | 1 | 1 | 3 |
| *Siparuna brasiliensis* (Spreng.) A. DC. | sec. | 0 | 0 | 0 | 1 |
| *Siparuna guianensis* Aubl. | sec. | 0 | 0 | 0 | 3 |
| *Solanum argenteum* Dunal | – | 0 | 1 | 0 | 0 |
| *Solanum crinitum* Lam. | sec. | 0 | 0 | 1 | 0 |
| *Solanum lycocarpum* A. St.-Hil. | pio. | 0 | 8 | 4 | 3 |
| *Solanum paniculatum* L. | pio. | 0 | 1 | 1 | 1 |
| **Styracaceae**          |                    |         |       |                   |                |
| *Styrax camporum* Pohl | sec. | 0 | 1 | 0 | 4 |
| *Styrax ferrugineus* Nees & Mart. | pio. | 0 | 4 | 2 | 6 |
| *Styrax guyanensis* A. DC. | – | 0 | 1 | 0 | 1 |
| *Styrax pohlii* A. DC. | sec. | 0 | 0 | 1 | 1 |
Table 1. Continued...

| Botanical family/species | Successional stage | Nursery | PRADs | Implemented PRADs | Native Cerrado |
|--------------------------|--------------------|---------|-------|-------------------|----------------|
| **Sympliocacae**         |                    |         |       |                   |                |
| *Symplocos laxiflora* Benth. | –                  | 0       | 0     | 0                 | 1              |
| *Symplocos nitens* (Pohl) Benth. | sec.               | 0       | 0     | 0                 | 2              |
| *Symplocos revoluta* Casar.* | sec.               | 0       | 0     | 0                 | 2              |
| *Symplocos rhamnifolia* A. DC.* | –                  | 0       | 1     | 1                 | 5              |
| **Theaceae**             |                    |         |       |                   |                |
| *Laplacea fruticosa* (Schrad.) Kobuski | sec.         | 0       | 0     | 0                 | 1              |
| **Thymelaeaceae**        |                    |         |       |                   |                |
| *Daphnopsis fasciculata* (Meisn.) Nevling* | sec.   | 0       | 0     | 0                 | 1              |
| **Urticaceae**           |                    |         |       |                   |                |
| *Cecropia hololeuca* Miq. | pio.               | 0       | 1     | 0                 | 0              |
| *Cecropia pachystachya* Trécul | pio.       | 5       | 10    | 1                 | 2              |
| **Verbenaceae**          |                    |         |       |                   |                |
| *Aloysia virgata* (Ruiz & Pav.) Pers. | pio. | 0       | 1     | 0                 | 0              |
| *Citharexylum myrianthum* Cham. | sec. | 0       | 1     | 1                 | 0              |
| **Vochysiaceae**         |                    |         |       |                   |                |
| *Callisthene fasciculata* Mart. | sec. | 0       | 1     | 0                 | 2              |
| *Callisthene major* Mart. | sec.               | 0       | 2     | 0                 | 3              |
| *Qualea cordata* (Mart.) Spreng. | sec. | 0       | 1     | 0                 | 0              |
| *Qualea dichotoma* (Mart.) Warm. | sec. | 0       | 2     | 0                 | 3              |
| *Qualea grandiflora* Mart.* | sec. | 2       | 11    | 2                 | 8              |
| *Qualea multiflora* Mart.* | sec. | 1       | 1     | 1                 | 7              |
| *Qualea parviflora* Mart.  | sec.               | 1       | 4     | 1                 | 6              |
| *Salvertia convallariodora* A. St.-Hil. | –     | 0       | 1     | 0                 | 2              |
| *Vochysia elliptica* Mart.* | –              | 0       | 2     | 1                 | 4              |
| *Vochysia haenkeana* Mart. | sec.               | 0       | 0     | 0                 | 1              |
| *Vochysia pruinosa* Pohl | –                   | 0       | 0     | 0                 | 1              |
| *Vochysia pyramidalis* Mart. | –                 | 0       | 0     | 0                 | 1              |
| *Vochysia rufa* Mart.     | –                   | 0       | 4     | 1                 | 4              |
| *Vochysia thyrsoides* Pohl | pio.               | 2       | 4     | 2                 | 4              |
| *Vochysia tucanorum* Mart. | sec.               | 1       | 2     | 0                 | 4              |
| **Winteraceae**          |                    |         |       |                   |                |
| *Drimys brasiliensis* Miers | cli. | 0       | 0     | 0                 | 1              |
| **Ximeniaceae**          |                    |         |       |                   |                |
| *Ximenia americana* L.   | –                   | 0       | 2     | 0                 | 1              |

Species frequency (numbers) and species successional stage: pio.: pioneer; sec.: secondary; cli.: climax. PRAD: restoration plan. * Woody species that naturally inhabits Cerrado grasslands formations.

The number of woody species traded by local nurseries made up 39% of the same found in native fragments of Cerrado and it may be insufficient to meet the demand of restoration plans for achieving rich and diverse plant communities. However, this scenario is better than the one found by Oliveira et al. (2017), who evaluated the availability of native species saplings in nurseries settled in the Rio Grande catchment area, Minas Gerais (Brazil) and found a species richness lower than 10% compared to the regional native vegetation. Cerrado is the species-richest savanna in the world (Mendonça et al., 2008) and the relatively low species richness available in nurseries (39%) is attributed to difficulties in collecting seeds from a wide range of native species and the poor knowledge on germination and growth of many native plant species.
Species richness recommended in the surveyed PRADs achieved 63.8% of that naturally present in fragments of Cerrado. However, restoration plans represent only the intention of setting up highly-diverse plant communities that will trigger ecological succession in degraded areas (Corrêa et al., 2015). Examined PRADs showed superficial and incomplete approaches to the problems intended to tackle, as some plans mostly swerved around real characteristics of sites to be restored and many proposed plant species were not adequate to them. Therefore, some PRADs were rather instruments to comply with environmental laws than to outline effective ecological restoration (Lima et al., 2006). There were lists of activities and plant species in these plans that did not match the availability of sapling species traded in BFD nurseries. Sánchez (2010) pointed out three major problems associated with PRADs: i) they usually are improperly drawn up and it results in unsatisfactory restoration when applied in practice; ii) they should be periodically updated; iii) proposed measures in PRADs are vague, generic, and difficult to check.

Studies on Cerrado phytophysiognomies have found 63 woody species in a hectare of sub-arboreal Cerrado (Cerrado stricto sensu) and 155 woody species in Cerrado’s forest formations (Amaral, 2008; Andrade et al., 2002; Aquino et al., 2014; Brant, 2011; Braga & Rezende, 2007; Haidar, 2007; Nunes et al., 2002; Silva, 2009; Silva & Sarmento, 2009; Silva et al., 2001). Our data show local nurseries traded 26 Cerrado woody species on average, PRADs recommended 20 woody species on average, and executed PRADs used only 24 Cerrado woody species on average (Artioli, 2011; Barbosa, 2008; Carvalheira, 2007; Corrêa et al., 2007; 2015; Cortes, 2012; Ferreira et al., 2015; Fraga, 2016; Leite, 2014; Lima et al., 2016; Monteiro, 2014; Oliveira, 2013; Oliveira, 2014; Oliveira, 2015; Oliveira et al., 2015; Pachêco, 2014; Pinheiro et al., 2009; Sampaio & Pinto, 2007; Sousa, 2016; Souza, 2002; Venturoli et al., 2013).

Low average of species richness recommended in PRADs and in executed PRADs may be a result of low availability of native species in individual nurseries, although the pool of 21 surveyed nurseries in BFD traded 171 Cerrado woody species as a whole. Thus the range of 20–24 species introduced as initial plant communities on restoration sites is not reasonable because plant species for a given PRAD can be purchased from more than one nursery. Surprisingly, we found 190 Cerrado wood species on sites where PRADs had been executed and such figure suggests that some species could have come from elsewhere besides local nurseries. The introduction of species from other populations may lead to genetic contamination, extinction of local populations, and loss of genetic biodiversity, which opposes one of the ecological restoration goals. Yet, introduction of tree saplings from distinct ecological regions brings back genes that natural selection had already banned from the receiving area or genes previously inexistente in it (Durigan et al., 2010).

Species-rich plant communities may guarantee restoration success as some studies point out that increases in ecosystem functions follow increases of species richness (Cardinale et al., 2007; Solan et al., 2009). Barbosa et al. (2003) found 355 native species in 30 plant nurseries in São Paulo State, Brazil, and an average of 30 native woody species in executed PRADs. The authors have attributed the low species richness on sites under restoration to the low availability of species in local nurseries. By comparison with our data, it seems that a low number of plant species available in individual nurseries have translated into low species richness in areas under restoration (Barbosa et al., 2003).

*Qualea grandiflora* Mart. was the most frequent species found in preserved fragments of Cerrado in BFD and it was present in 80% of the surveyed sites. *Tabebuia roseoalba* (Ridl.) Sandwith was the most frequent species available in local nurseries and it was sold by 86% of the surveyed traders. *Caryocar brasiliense* Cambess. was the most recommended species in PRADs and appeared listed in 49% of them. Finally, *Copaifera langsdorffii* Desf. was the most frequent species effectively introduced in degraded areas and it was sampled in 62% of sites under restoration. Such a figure reflects the poor connection between the stages necessary for achieving a sound ecological restoration: reference ecosystem (Cerrado fragments), planning (PRADs), necessary support (nurseries), and execution of restoration projects.

Stepwise management of PRADs is critical for achieving successful ecological restoration (Corrêa et al., 2015). Among the 566 species recorded in this work, only 69 species (12%) were shared in between nurseries, PRADs, executed PRADs, and Cerrado fragments. Nurseries supply plant saplings for restoration projects, and PRADs and environmental agencies cannot overlook plant species that are effectively available in local nurseries (Barbosa et al., 2003; Brancalion et al., 2013; Durigan et al., 2010; Sánchez, 2010). Approximately 37% of the BFD territory was originally covered by sub-arboreal Cerrado (Cerrado stricto sensu) and most of the degraded sites are located in this phytophysiognomy (UNESCO, 2002). But 63.7% of species available in local nurseries, 62.5% of species recommended in PRADs, and 63.7% of species introduced on sites under restoration are from gallery forests (mata de galeria) (Table 2).
Table 2. Percentage of Cerrado woody species and absolute number of species found in the four surveyed categories in the Brazilian Federal District, according to the phytophysiognomy of natural occurrence.

| Phytophysiognomy* | Native Cerrado | Nursery | PRADs | Implemented PRADs |
|-------------------|----------------|---------|-------|-------------------|
| Gallery forest (mata de galeria) | 71.2% (309) | 63.7% (109) | 62.5% (173) | 63.7% (121) |
| Gallery forest (mata ciliar) | 34.3% (149) | 38.0% (65) | 38.3% (106) | 36.8% (70) |
| Dry forest (mata seca) | 30.2% (131) | 38.6% (66) | 29.2% (81) | 30.5% (58) |
| Arboreal Cerrado (Cerradão) | 37.1% (161) | 48.5% (83) | 41.5% (115) | 41.6% (79) |
| Sub-arboreal Cerrado (Cerrado stricto sensu) | 32.7% (142) | 33.9% (58) | 37.9% (105) | 41.1% (78) |
| Cerrado Park (Parque de Cerrado) | 10.45 (45) | 12.9% (22) | 12.3% (34) | 13.2% (25) |
| Palm tree formation (palmeiral) | 0.7% (3) | 1.8% (3) | 1.4% (4) | 3.2% (6) |
| Grassland + palm trees (Vereda) | 11.1% (48) | 9.9% (17) | 12.3% (34) | 12.1% (23) |
| Grassland (campo limpo) | 4.4% (19) | 2.3% (4) | 3.2% (9) | 6.8% (13) |
| Shrubby grassland (campo sujo) | 15.9% (69) | 8.8% (15) | 15.5% (43) | 17.4% (33) |
| Rocky grassland (campo rupestre) | 18.7% (81) | 11.1% (19) | 17.3% (48) | 24.2% (46) |

* According to the classification by Ribeiro & Walter (2008). PRAD: restoration plan

Of the 21 implemented PRADs surveyed in this work, five (23.8%) were executed in areas of gallery forest, six on mining sites (28.6%), and ten (47.6%) in areas of sub-arboreal Cerrado (Cerrado stricto sensu), which is the phytophysiognomy mostly affected by degradation in BFD (UNESCO, 2002). However, the number of plant species from sub-arboreal Cerrado (Cerrado stricto sensu) ranked the third position after gallery forest (mata de galeria) and arboreal Cerrado (Cerradão) in PRADs and implemented PRADs. Only a third of Cerrado woody species available in the surveyed nurseries are from sub-arboreal Cerrado (Cerrado stricto sensu), and it may explain the prevalence of forest species in PRADs and implemented PRADs. According to Silva et al. (2017), many species available in nurseries in Brazil are endemic and require a biome-specific approach for their use in restoration projects. Selection of native woody species for ecological restoration in BFD has shown some deficiencies, such as low species richness. Hence, implemented PRADs applied less than 40% of the species richness present in preserved fragments of Cerrado.

The low number of pioneer species in areas of executed PRADs may also be a problem as only 23.7% of plant species in such areas are pioneer species (Table 1). São Paulo State regulation SMA 32/2014 requires 40% of pioneer species to compose initial plant communities on sites that will undergo ecological restoration. Pioneer species usually grow faster than plant species of advanced ecological stages (Durigan et al., 2010) and it hastens the development of vegetation cover, which is an essential step towards the restoration of ecosystems (Corrêa et al., 2018). Another critical issue on BFD ecological restoration refers to the widespread use of forest species in areas of previously inhabited savanna formations. Such practice will likely lead succession towards the formation of forest ecosystems (Overbeck et al., 2013; Parr et al., 2014; Veldman et al., 2015).

Production of woody saplings from many different native species is a factor that currently limits ecological restoration in many parts of Brazil (Silva et al., 2017). There is currently a lack of knowledge on the production of plant saplings for several Cerrado native species (Barbosa et al., 2003; Oliveira et al., 2016; Oliveira et al., 2017; Santos & Queiroz, 2011). As a result, it is rather difficult to find a broad sort of woody species in commercial nurseries (Oliveira et al., 2016). Seed collection and appropriate germination protocols for Cerrado species are other limitations for ecological restoration (Viani & Rodrigues, 2007), although there are already studies on these issues (Young et al., 2005).

Besides the difficulties to produce plant saplings from Cerrado species and the low species richness in BFD nurseries and PRADs, our study shows the detachment between species composition along the line nurseries, PRADs, and executed-PRADs, as only 22.9% of species were common to these three categories.
4. CONCLUSION

Cerrado woody species available in nurseries established in the Brazilian Federal District (BFD) made up 39% of the species richness found in native fragments of Cerrado as a whole. However, species richness found on sites under restoration falls to 5.5% of it on average. Total number of plant species traded in nurseries (171) can support plant communities richer in species than the ones recommended in PRADs (20 on average) and found in areas under restoration (24 on average). Restoration plans should therefore rely on various nurseries to increase species richness in initial plant communities.

There was a higher number of Cerrado species recommended in PRADs (277) than available in BFD nurseries (171) or growing in areas of executed PRADs (190). Such a figure portraits the unrealistic nature of the surveyed restoration plans.

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