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ORIGINAL ARTICLE – Conservation of Nature

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 (Mendonça 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).

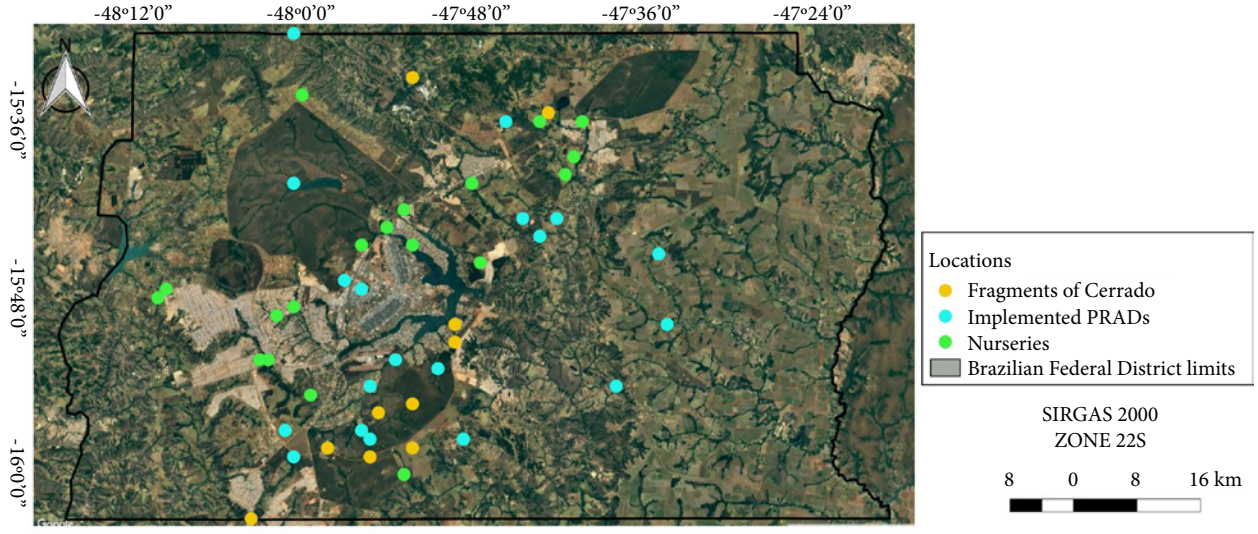

Figure 1. Location of surveyed nurseries, implemented restoration plans (PRADs) and fragments of native Cerrado in the Brazilian Federal District.

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). Bootsrap 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).

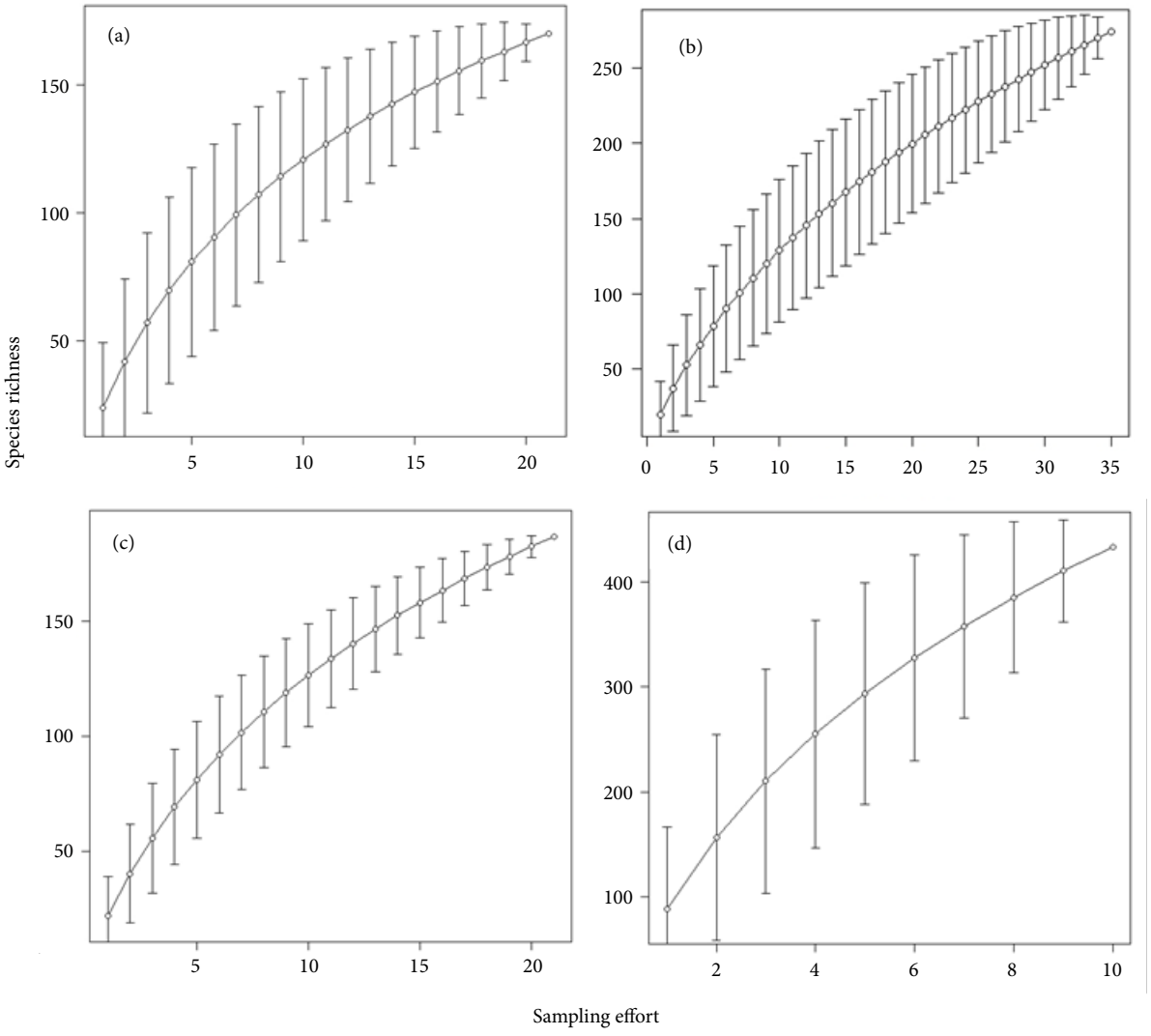

Figure 2. Rarefaction curves of Cerrado native woody species for the four surveyed categories: (a): nurseries; (b): restoration plans (PRADs); (c): implemented PRADs, and (d): preserved fragments of Cerrado. Bootstrap confidence intervals of 95% by interpolation and extrapolation. Error bars indicate 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 neosericea H. Rainer	sec.	0	0	0	1
Annona tomentosa R.E. Fr.*	–	0	0	0	1
Cardiopetalum calophyllum Schltdl.	sec.	0	1	0	2
Duguetia 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 macrocarpon 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 pyrifolium 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	0
Butia capitata (Mart.) Becc.	–	0	1	0	0
Butia purpurascens Glassman	–	0	1	0	0
Euterpe edulis Mart.	sec.	5	1	1	0
Mauritia flexuosa L. f.*	pio.	6	1	0	0
Syagrus comosa (Mart.) Mart.	–	0	1	0	1
Syagrus flexuosa (Mart.) Becc.	sec.	0	0	0	2
Syagrus oleracea (Mart.) Becc.	sec.	3	1	1	0
Syagrus romanzoffiana (Cham.) Glassman	sec.	2	0	0	0
Asteraceae					
Baccharis retusa DC.	pio.	0	0	0	1
Chromolaena laevigata (Lam.) R.M. King & H. Rob.	pio.	0	0	0	2
Eremanthus capitatus (Spreng.) MacLeish	–	0	1	0	0
Eremanthus glomerulatus Less.	–	0	1	1	5
Eremanthus goyazensis (Gardner) Sch. Bip.	–	0	0	0	2
Eremanthus mollis Sch. Bip.	–	0	0	0	1
Moquiniastrum floribundum (Cabrera) G. Sancho	pio.	0	0	0	1
Moquiniastrum polymorphum (Less.) G. Sancho	pio.	0	1	0	0
Piptocarpha macropoda (DC.) Baker*	pio.	0	0	0	3
Piptocarpha rotundifolia (Less.) Baker	sec.	0	3	2	5
Vernonanthura ferruginea (Less.) H. Rob.	pio.	0	0	0	1
Vernonanthura membranacea (Gardner) H. Rob.	–	0	0	1	1
Vernonanthura polyanthes (Spreng.) A.J. Vega & M. Dematt.	pio.	0	1	0	0
Bignoniaceae					
Cybistax antisyphilitica (Mart.) Mart.*	sec.	9	2	7	3
Handroanthus chrysotrichus (Mart. ex A. DC.) Mattos	sec.	5	1	2	1
Handroanthus impetiginosus (Mart. ex DC.) Mattos	sec.	16	9	6	2
Handroanthus ochraceus (Cham.) Mattos	sec.	7	8	5	5
Handroanthus serratifolius (Vahl) S.O. Grose	sec.	8	2	10	4
Handroanthus umbellatus (Sond.) Mattos	sec.	0	0	0	1
Jacaranda brasiliana (Lam.) Pers.*	–	1	2	1	1
Jacaranda caroba (Vell.) A. DC.*	pio.	0	1	0	2
Jacaranda copaia (Aubl.) D. Don*	pio.	0	0	0	1
Jacaranda cuspidifolia Mart.	pio.	2	1	0	0
Jacaranda macrantha Cham.	pio.	0	0	0	1
Jacaranda micrantha Cham.	sec.	0	0	1	0
Jacaranda puberula Cham.	cli.	0	0	0	1
Jacaranda ulei Bureau & K. Schum.	–	0	0	0	1
Spathodea campanulata P. Beauv.*	–	0	1	1	0
Tabebuia aurea (Silva Manso) Benth. & Hook. f. ex S. Moore	pio.	8	3	5	3
Tabebuia roseoalba (Ridl.) Sandwith	pio.	18	7	7	2
Zeyheria montana Mart.	sec.	0	3	2	4
Zeyheria tuberculosa (Vell.) Bureau	sec.	0	1	0	0

Table 1. Continued...

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.) Arráb. 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 unifoliolatum 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 iguanaea (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 gonoclada 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 glandulosa 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

Table 1. Continued...

Botanical family/species	Successional stage	Nursery	PRADs	Implemented PRADs	Native Cerrado
Chrysobalanaceae					
Licania dealbata Hook. f.	–	0	1	0	0
Licania octandra (Hoffmanns. ex Roem. & Schult.) Kuntze	–	0	0	0	1
Licania rigida Benth.*	–	7	0	0	0
Parinari obtusifolia Hook. f.	–	0	0	0	1
Clusiaceae					
Clusia burchellii Engl.	–	0	1	0	0
Clusia criuva Cambess.*	pio.	0	0	1	0
Garcinia brasiliensis Mart.	sec.	1	0	0	1
Garcinia macrophylla Mart.	–	0	0	0	1
Combretaceae					
Buchenavia tetraphylla (Aubl.) R.A. Howard	pio.	0	1	0	1
Buchenavia tomentosa Eichler	sec.	4	2	4	0
Terminalia argentea Mart.	pio.	4	3	3	3
Terminalia fagifolia Mart.	–	0	0	1	3
Terminalia glabrescens Mart.	sec.	0	2	0	2
Terminalia phaeocarpa Eichler	sec.	0	0	1	1
Connaraceae					
Connarus suberosus Planch.	sec.	0	2	1	4
Rourea induta Planch.	sec.	0	1	0	3
Cunoniaceae					
Lamanonia ternata Vell.	sec.	0	2	0	2
Dichapetalaceae					
Tapura amazonica Poepp.*	–	1	1	0	2
Dilleniaceae					
Curatella americana L.	–	1	1	1	2
Davilla elliptica A. St.-Hil.*	–	0	1	2	4
Ebenaceae					
Diospyros guianensis (Aubl.) Gürke	–	0	0	0	1
Diospyros hispida A. DC.	sec.	0	3	2	7
Diospyros sericea A. DC.	–	0	0	0	1
Elaeocarpaceae					
Sloanea guianensis (Aubl.) Benth.*	sec.	0	0	0	2
Ericaceae					
Agarista chapadensis (Kin.-Gouv.) Judd*	–	0	1	0	0
Erythroxylaceae					
Erythroxylum daphnites Mart.	sec.	0	1	0	3
Erythroxylum deciduum A. St.-Hil.*	pio.	0	2	1	4
Erythroxylum suberosum A. St.-Hil.	sec.	0	2	2	6
Erythroxylum tortuosum Mart.	sec.	0	0	1	3
Erythroxylum vaccinifolium Mart.*	pio.	0	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					
Acosmium lentiscifolium Schott ex Spreng.	–	0	1	0	0
Albizia niopoides (Spruce ex Benth.) Burkart	sec.	2	0	1	0
Albizia polycephala (Benth.) Killip	sec.	0	0	0	1
Amburana cearensis (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 cujabensis Benth.	–	0	1	0	0
Andira fraxinifolia Benth.	sec.	0	0	1	1
Andira humilis Mart. ex Benth.*	sec.	0	1	0	0
Andira vermifuga 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 forficata Link	sec.	0	1	1	0
Bauhinia longifolia (Bong.) Steud.	pio.	0	0	0	1
Bauhinia rufa (Bong.) Steud.	–	0	2	0	2
Bowdichia virgilioides Kunth*	sec.	3	7	2	4
Calliandra brevipes Benth.	–	0	0	1	0
Cassia ferruginea (Schrad.) Schrader ex DC.*	sec.	0	0	0	0
Cassia grandis L. f.	pio.	1	0	0	0
Cenostigma macrophyllum Tul.*	–	0	1	0	1
Centrolobium tomentosum Guillemin ex Benth.*	sec.	1	0	0	1
Chamaecrista claussenii (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

Table 1. Continued...

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 adenotricha Benth.	–	0	1	0	0
Mimosa albolanata Taub.	–	0	0	0	1
Mimosa bimucronata (DC.) Kuntze	pio.	0	0	1	0
Mimosa caesalpiniifolia Benth.	pio.	0	1	1	1
Mimosa claussenii Benth.*	–	0	2	3	2
Mimosa foliolosa 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...

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
Platycyamus regnellii Benth.	sec.	0	0	0	1
Platymiscium floribundum Vogel	sec.	0	0	1	1
Platypodium elegans Vogel	sec.	5	2	1	3
Poecilanthe parviflora Benth.	cli.	1	1	1	0
Poecilanthe 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 polyphylla (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 multijuga (Rich.) H.S. Irwin & Barneby	sec.	2	0	0	1
Senna pendula (Humb. & Bonpl. ex Willd.) H.S. Irwin & Barneby	–	0	0	1	0
Senna 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 mattogrossensis Malme	–	0	0	0	1
Hypericaceae					
Vismia gracilis Hieron.	–	0	0	0	2
Vismia 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
Hyptidendron canum (Pohl ex Benth.) Harley	–	0	1	0	1
Vitex polygama Cham.*	sec.	1	1	0	1

Table 1. Continued...

Botanical family/species	Successional stage	Nursery	PRADs	Implemented PRADs	Native Cerrado
Lauraceae					
Aniba heringeri Vattimo-Gil*	sec.	0	0	0	1
Cryptocarya aschersoniana Mez*	sec.	0	0	0	2
Endlicheria paniculata (Spreng.) J.F. Macbr.*	sec.	0	0	0	2
Licaria armeniaca (Nees) Kosterm.	sec.	0	0	0	1
Nectandra cissiflora Nees	sec.	0	0	0	1
Nectandra gardneri Meisn.	–	0	0	0	1
Nectandra lanceolata Nees & Mart.	sec.	1	0	0	0
Nectandra nitidula Nees & Mart.	sec.	0	1	0	0
Nectandra reticulata (Ruiz & Pav.) Mez	sec.	0	0	0	3
Ocotea aciphylla (Nees & Mart.) Mez	sec.	0	0	0	1
Ocotea corymbosa (Meisn.) Mez*	sec.	0	0	0	2
Ocotea densiflora (Meisn.) Mez	–	0	0	0	1
Ocotea diospyrifolia (Meisn.) Mez	sec.	0	0	0	1
Ocotea glaziovii Mez	sec.	0	0	0	1
Ocotea pomaderroides (Meisn.) Mez	–	0	1	0	2
Ocotea pulchella (Nees & Mart.) Mez*	cli.	2	1	0	1
Ocotea spixiana (Nees) Mez	sec.	0	0	0	3
Ocotea velloziana (Meisn.) Mez	sec.	0	0	0	1
Persea fusca Mez*	–	0	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					
Diplusodon virgatus Pohl	sec.	0	1	0	1
Lafoensia glyptocarpa Koehne	sec.	1	0	0	0
Lafoensia pacari A. St.-Hil.	sec.	2	3	2	5
Physocalymma 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 guilleminiana 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

Table 1. Continued...

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 pteropetala 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 chamissois 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 phlogiformis 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
Metteniusaceae					
Emmotum nitens (Benth.) Miers	–	1	5	0	5
Monimiaceae					
Macropeplus 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

Table 1. Continued...

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
Calyptranthes brasiliensis Spreng.	sec.	0	0	0	0
Calyptranthes clusiifolia (Miq.) O. Berg*	sec.	0	1	0	2
Calyptranthes 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	1	0
Eugenia complicata O. Berg*	–	0	0	0	1
Eugenia dysenterica 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 albotomentosa 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 splendens (Sw.) DC.	pio.	0	2	1	4
Myrcia tomentosa (Aubl.) DC.	pio.	0	2	0	5
Myrcia venulosa DC.	–	0	0	0	1
Myrciaria floribunda (H. West ex Willd.) O. Berg	sec.	0	1	0	0
Myrciaria 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 castaneifolia (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
Margaritaria 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 arboreum Aubl.	–	0	0	0	1
Piper crassinervium Kunth	sec.	0	0	1	1
Piper hispidum Sw.	–	0	0	0	1
Piper tectoniifolium 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
Chomelia martiana Müll.Arg.*	–	0	5	0	0
Chomelia obtusa Cham. & Schltdl.	sec.	0	0	0	1
Chomelia 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 myrciifolia (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 rigida Kunth	pio.	0	3	2	5
Posoqueria latifolia (Rudge) Schult.	sec.	0	1	0	1
Psychotria carthagenensis 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 vandellianum 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 elaeagnoides 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
Symplocaceae					
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 thyrsoidea 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

(Oliveira et al., 2016; Oliveira et al., 2017; Santos & Queiroz, 2011). The main obstacles for plant sapling production of Brazilian native species are seed shortage (80%), difficulties in trading plant saplings (75%), and poor training for the management of native species (65%) (Silva et al., 2017).

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 inexistent 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)
Shruby 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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