




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

Willian Barros Gomes¹  0000-0002-9832-1982
Rodrigo Studart Corrêa¹  0000-0002-9422-2629
Alexander Paulo do Carmo Balduino¹  0000-0003-4285-2685

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.

¹ Universidade de Brasília (UnB), Planaltina, DF, Brasil

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 & Pomper Mayer, 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 phytophysognomies 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).

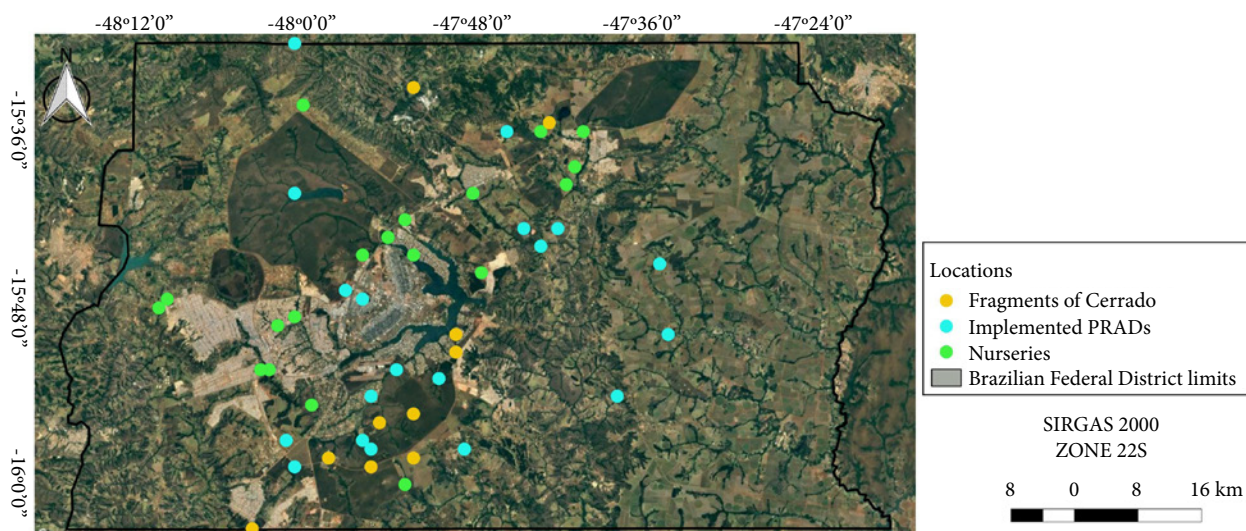


Figure 1. Location of surveyed nurseries, implemented restoration plans (PRADs) and fragments of native Cerrado in the Brazilian Federal District.

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 Uglund 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 phytophysognomies (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).

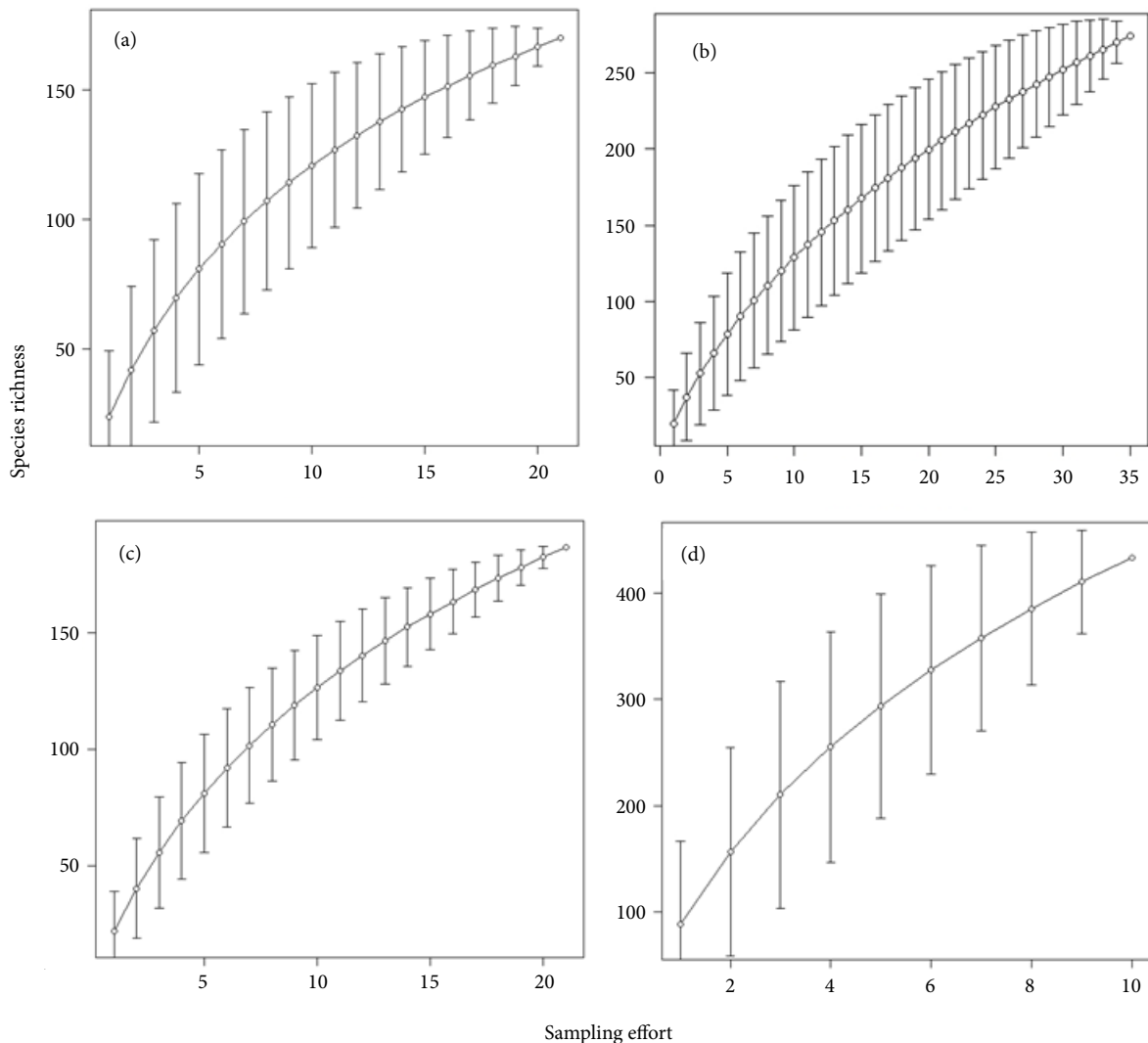


Figure 2. Rarefaction curves of Cerrado native woody species for the four surveyed categories: (a): nurseries; (b): restoration plans (PRADs); (c): implemented PRADs, and (d): preserved fragments of Cerrado. Bootstrap confidence intervals of 95% by interpolation and extrapolation. Error bars indicate 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					
<i>Anacardium humile</i> A. St.-Hil.*	sec.	1	2	1	2
<i>Anacardium occidentale</i> L.*	pio.	5	3	2	2
<i>Astronium fraxinifolium</i> Schott	sec.	7	8	8	4
<i>Astronium graveolens</i> Jacq.*	sec.	0	0	0	1
<i>Lithraea molleoides</i> (Vell.) Engl.	pio.	0	1	0	1
<i>Myracrodruon urundeuva</i> Allemão	sec.	10	7	9	1
<i>Schinopsis brasiliensis</i> Engl.	pio.	4	3	0	0
<i>Schinus terebinthifolia</i> Raddi	pio.	4	0	4	0
<i>Spondias mombin</i> L.*	sec.	2	0	0	1
<i>Spondias purpurea</i> L.	-	3	1	0	0
<i>Spondias tuberosa</i> Arruda	pio.	0	0	0	0
<i>Tapirira guianensis</i> Aubl.*	pio.	6	10	6	1
<i>Tapirira obtusa</i> (Benth.) J.D. Mitch.	sec.	0	1	0	0
Annonaceae					
<i>Annona cacans</i> Warm.	sec.	0	1	0	0
<i>Annona coriacea</i> Mart.	sec.	1	0	0	2
<i>Annona crassiflora</i> Mart.	sec.	3	10	2	4
<i>Annona neosericea</i> H. Rainer	sec.	0	0	0	1
<i>Annona tomentosa</i> R.E. Fr.*	-	0	0	0	1
<i>Cardiopetalum calophyllum</i> Schltld.	sec.	0	1	0	2
<i>Duguetia furfuracea</i> (A. St.-Hil.) Saff.*	sec.	0	0	1	2
<i>Guatteria australis</i> A. St.-Hil.	cli.	0	1	0	0
<i>Guatteria sellowiana</i> Schltld.	-	0	0	0	3
<i>Xylopia aromatica</i> (Lam.) Mart.	pio.	2	5	0	2
<i>Xylopia brasiliensis</i> Spreng.	sec.	0	0	0	2
<i>Xylopia emarginata</i> Mart.	sec.	1	3	1	2
<i>Xylopia sericea</i> A. St.-Hil.	sec.	1	0	0	3
Apocynaceae					
<i>Aspidosperma cylindrocarpon</i> Müll. Arg.	sec.	0	0	0	1
<i>Aspidosperma discolor</i> A. DC.	sec.	2	0	0	2
<i>Aspidosperma eburneum</i> Allemão ex Saldanha	-	0	0	0	1
<i>Aspidosperma macrocarpon</i> Mart.	sec.	4	5	2	5
<i>Aspidosperma parvifolium</i> A. DC.	sec.	2	0	2	1
<i>Aspidosperma polyneuron</i> Müll. Arg.	cli.	3	1	0	0
<i>Aspidosperma pyriforme</i> Mart.	sec.	4	2	0	0
<i>Aspidosperma spruceanum</i> Benth. ex Müll. Arg.	sec.	2	0	0	2
<i>Aspidosperma subincanum</i> Mart. ex A. DC.	sec.	1	2	1	4
<i>Aspidosperma tomentosum</i> Mart.	sec.	2	5	1	4
<i>Hancornia speciosa</i> Gomes	sec.	7	7	3	5
<i>Himatanthus obovatus</i> (Müll. Arg.) Woodson*	sec.	0	2	1	1
<i>Tabernaemontana catharinensis</i> A. DC.	pio.	0	0	0	0
Aquifoliaceae					
<i>Ilex affinis</i> Gardner	sec.	0	0	0	1
<i>Ilex asperula</i> Mart. ex Reissek	-	0	1	0	0
<i>Ilex conocarpa</i> Reissek	-	0	0	0	2
Araliaceae					
<i>Dendropanax cuneatus</i> (DC.) Decne. & Planch.	sec.	0	0	0	1
<i>Schefflera macrocarpa</i> (Cham. & Schltld.) Frodin	pio.	0	9	3	6
<i>Schefflera morototoni</i> (Aubl.) Maguire, Steyerf. & Frodin	pio.	0	3	0	2

Table 1. Continued...

Botanical family/species	Successional stage	Nursery	PRADs	Implemented PRADs	Native Cerrado
Arecaceae					
<i>Acrocomia aculeata</i> (Jacq.) Lodd. ex Mart.	pio.	2	3	0	0
<i>Butia capitata</i> (Mart.) Becc.	–	0	1	0	0
<i>Butia purpurascens</i> Glassman	–	0	1	0	0
<i>Euterpe edulis</i> Mart.	sec.	5	1	1	0
<i>Mauritia flexuosa</i> L. f.*	pio.	6	1	0	0
<i>Syagrus comosa</i> (Mart.) Mart.	–	0	1	0	1
<i>Syagrus flexuosa</i> (Mart.) Becc.	sec.	0	0	0	2
<i>Syagrus oleracea</i> (Mart.) Becc.	sec.	3	1	1	0
<i>Syagrus romanzoffiana</i> (Cham.) Glassman	sec.	2	0	0	0
Asteraceae					
<i>Baccharis retusa</i> DC.	pio.	0	0	0	1
<i>Chromolaena laevigata</i> (Lam.) R.M. King & H. Rob.	pio.	0	0	0	2
<i>Eremanthus capitatus</i> (Spreng.) MacLeish	–	0	1	0	0
<i>Eremanthus glomerulatus</i> Less.	–	0	1	1	5
<i>Eremanthus goyazensis</i> (Gardner) Sch. Bip.	–	0	0	0	2
<i>Eremanthus mollis</i> Sch. Bip.	–	0	0	0	1
<i>Moquiniastrum floribundum</i> (Cabrera) G. Sancho	pio.	0	0	0	1
<i>Moquiniastrum polymorphum</i> (Less.) G. Sancho	pio.	0	1	0	0
<i>Piptocarpha macropoda</i> (DC.) Baker*	pio.	0	0	0	3
<i>Piptocarpha rotundifolia</i> (Less.) Baker	sec.	0	3	2	5
<i>Vernonanthura ferruginea</i> (Less.) H. Rob.	pio.	0	0	0	1
<i>Vernonanthura membranacea</i> (Gardner) H. Rob.	–	0	0	1	1
<i>Vernonanthura polyanthes</i> (Spreng.) A.J. Vega & M. Dematt.	pio.	0	1	0	0
Bignoniaceae					
<i>Cybistax antisyphilitica</i> (Mart.) Mart.*	sec.	9	2	7	3
<i>Handroanthus chrysotrichus</i> (Mart. ex A. DC.) Mattos	sec.	5	1	2	1
<i>Handroanthus impetiginosus</i> (Mart. ex DC.) Mattos	sec.	16	9	6	2
<i>Handroanthus ochraceus</i> (Cham.) Mattos	sec.	7	8	5	5
<i>Handroanthus serratifolius</i> (Vahl) S.O. Grose	sec.	8	2	10	4
<i>Handroanthus umbellatus</i> (Sond.) Mattos	sec.	0	0	0	1
<i>Jacaranda brasiliana</i> (Lam.) Pers.*	–	1	2	1	1
<i>Jacaranda caroba</i> (Vell.) A. DC.*	pio.	0	1	0	2
<i>Jacaranda copaia</i> (Aubl.) D. Don*	pio.	0	0	0	1
<i>Jacaranda cuspidifolia</i> Mart.	pio.	2	1	0	0
<i>Jacaranda macrantha</i> Cham.	pio.	0	0	0	1
<i>Jacaranda micrantha</i> Cham.	sec.	0	0	1	0
<i>Jacaranda puberula</i> Cham.	cli.	0	0	0	1
<i>Jacaranda ulei</i> Bureau & K. Schum.	–	0	0	0	1
<i>Spathodea campanulata</i> P. Beauv.*	–	0	1	1	0
<i>Tabebuia aurea</i> (Silva Manso) Benth. & Hook. f. ex S. Moore	pio.	8	3	5	3
<i>Tabebuia roseoalba</i> (Ridl.) Sandwith	pio.	18	7	7	2
<i>Zeyheria montana</i> Mart.	sec.	0	3	2	4
<i>Zeyheria tuberculosa</i> (Vell.) Bureau	sec.	0	1	0	0

Table 1. Continued...

Botanical family/species	Successional stage	Nursery	PRADs	Implemented PRADs	Native Cerrado
Bixaceae					
<i>Bixa orellana</i> L.*	pio.	1	1	0	0
<i>Cochlospermum regium</i> (Schrank) Pilg.	sec.	0	1	0	0
Boraginaceae					
<i>Cordia sellowiana</i> Cham.*	sec.	0	1	1	2
<i>Cordia trichotoma</i> (Vell.) Arráb. ex Steud.	sec.	1	0	1	1
Burseraceae					
<i>Commiphora leptophloeos</i> (Mart.) J.B. Gillett	pio.	0	2	0	0
<i>Protium heptaphyllum</i> (Aubl.) Marchand	sec.	0	1	0	2
<i>Protium ovatum</i> Engl.*	sec.	0	0	1	1
<i>Protium spruceanum</i> (Benth.) Engl.	sec.	0	1	0	2
<i>Protium unifoliolatum</i> Engl.	–	0	0	0	1
<i>Tetragastris altissima</i> (Aubl.) Swart*	–	0	1	0	0
Calophyllaceae					
<i>Calophyllum brasiliense</i> Cambess.	cli.	7	11	8	2
<i>Kielmeyera coriacea</i> Mart. & Zucc.*	sec.	3	9	4	6
<i>Kielmeyera lathrophyton</i> Saggi	sec.	0	0	0	2
<i>Kielmeyera speciosa</i> A. St.-Hil.*	–	0	1	1	3
<i>Kielmeyera variabilis</i> Mart. & Zucc.	sec.	0	0	0	2
Cannabaceae					
<i>Celtis iguanaea</i> (Jacq.) Sarg.	pio.	1	0	0	1
<i>Trema micrantha</i> (L.) Blume	pio.	0	0	0	1
Cardiopteridaceae					
<i>Citronella gongonha</i> (Mart.) R.A. Howard	sec.	0	0	0	1
Caricaceae					
<i>Jacaratia spinosa</i> (Aubl.) A. DC.*	pio.	1	0	0	0
Caryocaraceae					
<i>Caryocar brasiliense</i> Cambess.	pio.	10	17	3	6
Celastraceae					
<i>Cheiloclinium cognatum</i> (Miers) A.C. Sm.	sec.	2	1	0	3
<i>Maytenus floribunda</i> Reissek*	sec.	0	0	0	1
<i>Maytenus gonoclada</i> Mart.*	sec.	0	0	0	1
<i>Plenckia populnea</i> Reissek	sec.	0	1	2	5
<i>Salacia crassifolia</i> (Mart. ex Schult.) G. Don*	–	4	4	2	5
<i>Salacia elliptica</i> (Mart.) G. Don*	sec.	0	0	3	5
Chloranthaceae					
<i>Hedyosmum brasiliense</i> Miq.	sec.	0	1	0	2
Chrysobalanaceae					
<i>Couepia grandiflora</i> (Mart. & Zucc.) Benth. ex Hook. f.	sec.	0	1	0	3
<i>Hirtella ciliata</i> Mart. & Zucc.	–	0	1	0	0
<i>Hirtella glandulosa</i> Spreng.*	sec.	1	1	0	1
<i>Hirtella gracilipes</i> (Hook. f.) Prance*	sec.	0	0	0	1
<i>Hirtella martiana</i> Hook. f.*	–	0	0	0	1
<i>Licania apetala</i> (E. Mey.) Fritsch	–	0	1	0	2

Table 1. Continued...

Botanical family/species	Successional stage	Nursery	PRADs	Implemented PRADs	Native Cerrado
Chrysobalanaceae					
<i>Licania dealbata</i> Hook. f.	–	0	1	0	0
<i>Licania octandra</i> (Hoffmanns. ex Roem. & Schult.) Kuntze	–	0	0	0	1
<i>Licania rigida</i> Benth.*	–	7	0	0	0
<i>Parinari obtusifolia</i> Hook. f.	–	0	0	0	1
Clusiaceae					
<i>Clusia burchellii</i> Engl.	–	0	1	0	0
<i>Clusia criuva</i> Cambess.*	pio.	0	0	1	0
<i>Garcinia brasiliensis</i> Mart.	sec.	1	0	0	1
<i>Garcinia macrophylla</i> Mart.	–	0	0	0	1
Combretaceae					
<i>Buchenavia tetraphylla</i> (Aubl.) R.A. Howard	pio.	0	1	0	1
<i>Buchenavia tomentosa</i> Eichler	sec.	4	2	4	0
<i>Terminalia argentea</i> Mart.	pio.	4	3	3	3
<i>Terminalia fagifolia</i> Mart.	–	0	0	1	3
<i>Terminalia glabrescens</i> Mart.	sec.	0	2	0	2
<i>Terminalia phaeocarpa</i> Eichler	sec.	0	0	1	1
Connaraceae					
<i>Connarus suberosus</i> Planch.	sec.	0	2	1	4
<i>Rourea induta</i> Planch.	sec.	0	1	0	3
Cunoniaceae					
<i>Lamanonia ternata</i> Vell.	sec.	0	2	0	2
Dichapetalaceae					
<i>Tapura amazonica</i> Poepp.*	–	1	1	0	2
Dilleniaceae					
<i>Curatella americana</i> L.	–	1	1	1	2
<i>Davilla elliptica</i> A. St.-Hil.*	–	0	1	2	4
Ebenaceae					
<i>Diospyros guianensis</i> (Aubl.) Gürke	–	0	0	0	1
<i>Diospyros hispida</i> A. DC.	sec.	0	3	2	7
<i>Diospyros sericea</i> A. DC.	–	0	0	0	1
Elaeocarpaceae					
<i>Sloanea guianensis</i> (Aubl.) Benth.*	sec.	0	0	0	2
Ericaceae					
<i>Agarista chapadensis</i> (Kin.-Gouv.) Judd*	–	0	1	0	0
Erythroxylaceae					
<i>Erythroxylum daphnites</i> Mart.	sec.	0	1	0	3
<i>Erythroxylum deciduum</i> A. St.-Hil.*	pio.	0	2	1	4
<i>Erythroxylum suberosum</i> A. St.-Hil.	sec.	0	2	2	6
<i>Erythroxylum tortuosum</i> Mart.	sec.	0	0	1	3
<i>Erythroxylum vacciniifolium</i> Mart.*	pio.	0	0	0	1

Table 1. Continued...

Botanical family/species	Successional stage	Nursery	PRADs	Implemented PRADs	Native Cerrado
Euphorbiaceae					
<i>Alchornea glandulosa</i> Poepp.	pio.	0	1	1	2
<i>Croton urucurana</i> Baill.	pio.	1	0	3	1
<i>Mabea fistulifera</i> Mart.	pio.	0	1	0	0
<i>Maprounea guianensis</i> Aubl.*	sec.	0	2	0	4
<i>Sapium obovatum</i> Klotzsch ex Müll. Arg.	–	0	0	1	1
<i>Sebastiania brasiliensis</i> Spreng.*	pio.	0	0	0	1
Fabaceae					
<i>Acosmium lentiscifolium</i> Schott ex Spreng.	–	0	1	0	0
<i>Albizia niopoides</i> (Spruce ex Benth.) Burkart	sec.	2	0	1	0
<i>Albizia polycephala</i> (Benth.) Killip	sec.	0	0	0	1
<i>Amburana cearensis</i> (Allemão) A.C. Sm.	pio.	5	0	3	0
<i>Anadenanthera colubrina</i> (Vell.) Brenan	sec.	6	8	8	2
<i>Anadenanthera peregrina</i> (L.) Speng.	sec.	2	3	4	2
<i>Andira cujabensis</i> Benth.	–	0	1	0	0
<i>Andira fraxinifolia</i> Benth.	sec.	0	0	1	1
<i>Andira humilis</i> Mart. ex Benth.*	sec.	0	1	0	0
<i>Andira vermifuga</i> Mart. ex Benth.*	–	0	2	1	3
<i>Apuleia leiocarpa</i> (Vogel) J.F. Macbr.	sec.	2	2	0	2
<i>Bauhinia cupulata</i> Benth.*	–	0	1	0	0
<i>Bauhinia dumosa</i> Benth.	–	0	0	0	1
<i>Bauhinia forficata</i> Link	sec.	0	1	1	0
<i>Bauhinia longifolia</i> (Bong.) Steud.	pio.	0	0	0	1
<i>Bauhinia rufa</i> (Bong.) Steud.	–	0	2	0	2
<i>Bowdichia virgilioides</i> Kunth*	sec.	3	7	2	4
<i>Calliandra brevipes</i> Benth.	–	0	0	1	0
<i>Cassia ferruginea</i> (Schrad.) Schrader ex DC.*	sec.	0	0	0	0
<i>Cassia grandis</i> L. f.	pio.	1	0	0	0
<i>Cenostigma macrophyllum</i> Tul.*	–	0	1	0	1
<i>Centrolobium tomentosum</i> Guillemin ex Benth.*	sec.	1	0	0	1
<i>Chamaecrista clausenii</i> (Benth.) H.S. Irwin & Barneby*	–	0	0	1	0
<i>Chamaecrista dentata</i> (Vogel) H.S. Irwin & Barneby	–	0	1	0	0
<i>Chamaecrista orbiculata</i> (Benth.) H.S. Irwin & Barneby*	–	0	0	2	1
<i>Chloroleucon tortum</i> (Mart.) Pittier ex Barneby & J.W. Grimes	pio.	1	0	0	0
<i>Clitoria fairchildiana</i> R.A. Howard	–	1	0	0	0
<i>Copaifera langsdorffii</i> Desf.*	sec.	13	14	13	4
<i>Copaifera malmei</i> Harms	–	0	1	0	0
<i>Dalbergia densiflora</i> Benth.	–	1	0	0	1
<i>Dalbergia foliolosa</i> Benth.	–	1	0	0	1
<i>Dalbergia miscolobium</i> Benth.	pio.	2	12	9	5
<i>Dimorphandra mollis</i> Benth.	sec.	1	9	0	5
<i>Dipteryx alata</i> Vogel	sec.	7	9	7	0
<i>Enterolobium contortisiliquum</i> (Vell.) Morong	sec.	7	7	4	2

Table 1. Continued...

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

Table 1. Continued...

Botanical family/species	Successional stage	Nursery	PRADs	Implemented PRADs	Native Cerrado
Fabaceae					
<i>Piptadenia gonoacantha</i> (Mart.) J.F. Macbr.	pio.	2	3	2	3
<i>Piptadenia viridiflora</i> (Kunth) Benth.	pio.	0	1	0	0
<i>Plathymenia reticulata</i> Benth.	sec.	2	4	4	5
<i>Platycyamus regnellii</i> Benth.	sec.	0	0	0	1
<i>Platymiscium floribundum</i> Vogel	sec.	0	0	1	1
<i>Platypodium elegans</i> Vogel	sec.	5	2	1	3
<i>Poecilanthe parviflora</i> Benth.	cli.	1	1	1	0
<i>Poecilanthe subcordata</i> Benth.	sec.	0	1	0	0
<i>Poincianella pluviosa</i> (DC.) L.P. Queiroz	-	0	1	0	0
<i>Pterocarpus rohrii</i> Vahl	sec.	1	1	0	1
<i>Pterodon abruptus</i> (Moric.) Benth.	-	0	1	0	0
<i>Pterodon emarginatus</i> Vogel	pio.	3	6	2	5
<i>Pterogyne nitens</i> Tul.	sec.	1	2	2	0
<i>Senegalia polyphylla</i> (DC.) Britton	pio.	2	0	4	2
<i>Senegalia tenuifolia</i> (L.) Britton & Rose	-	0	0	3	0
<i>Senna alata</i> (L.) Roxb.	pio.	0	0	0	0
<i>Senna macranthera</i> (DC. ex Collad.) H.S. Irwin & Barneby*	pio.	1	1	0	1
<i>Senna multijuga</i> (Rich.) H.S. Irwin & Barneby	sec.	2	0	0	1
<i>Senna pendula</i> (Humb. & Bonpl. ex Willd.) H.S. Irwin & Barneby	-	0	0	1	0
<i>Senna rugosa</i> (G. Don) H.S. Irwin & Barneby	pio.	1	1	0	0
<i>Stryphnodendron adstringens</i> (Mart.) Coville*	sec.	1	11	3	6
<i>Swartzia apetala</i> Raddi	-	0	0	0	1
<i>Swartzia macrostachya</i> Benth.	-	0	1	0	0
<i>Tachigali aurea</i> Tul.	sec.	0	4	1	2
<i>Tachigali guianensis</i> (Benth.) Zarucchi & Herend.*	-	0	0	1	2
<i>Tachigali rubiginosa</i> (Mart. Ex Tul.) Oliveira-Filho	-	0	0	0	1
<i>Tachigali subvelutina</i> (Benth.) Oliveira-Filho	-	0	0	0	2
<i>Tachigali vulgaris</i> L.F. Gomes da Silva & H.C. Lima*	sec.	1	5	3	3
<i>Vatairea macrocarpa</i> (Benth.) Ducke	sec.	0	0	1	4
<i>Zollernia ilicifolia</i> (Brongn.) Vogel	sec.	0	1	0	0
Humiriaceae					
<i>Humiria balsamifera</i> Aubl.	-	0	1	0	0
<i>Sacoglottis guianensis</i> Benth.	-	0	0	0	2
<i>Sacoglottis mattogrossensis</i> Malme	-	0	0	0	1
Hypericaceae					
<i>Vismia gracilis</i> Hieron.	-	0	0	0	2
<i>Vismia guianensis</i> (Aubl.) Pers.	pio.	0	1	0	1
Lacistemataceae					
<i>Lacistema hasslerianum</i> Chodat*	sec.	0	0	0	1
Lamiaceae					
<i>Aegiphila integrifolia</i> (Jacq.) B.D. Jacks.	pio.	1	1	1	1
<i>Aegiphila verticillata</i> Vell.*	pio.	0	3	4	4
<i>Hyptidendron canum</i> (Pohl ex Benth.) Harley	-	0	1	0	1
<i>Vitex polygama</i> Cham.*	sec.	1	1	0	1

Table 1. Continued...

Botanical family/species	Successional stage	Nursery	PRADs	Implemented PRADs	Native Cerrado
Lauraceae					
<i>Aniba heringeri</i> Vattimo-Gil*	sec.	0	0	0	1
<i>Cryptocarya aschersoniana</i> Mez*	sec.	0	0	0	2
<i>Endlicheria paniculata</i> (Spreng.) J.F. Macbr.*	sec.	0	0	0	2
<i>Licaria armeniaca</i> (Nees) Kosterm.	sec.	0	0	0	1
<i>Nectandra cissiflora</i> Nees	sec.	0	0	0	1
<i>Nectandra gardneri</i> Meisn.	–	0	0	0	1
<i>Nectandra lanceolata</i> Nees & Mart.	sec.	1	0	0	0
<i>Nectandra nitidula</i> Nees & Mart.	sec.	0	1	0	0
<i>Nectandra reticulata</i> (Ruiz & Pav.) Mez	sec.	0	0	0	3
<i>Ocotea aciphylla</i> (Nees & Mart.) Mez	sec.	0	0	0	1
<i>Ocotea corymbosa</i> (Meisn.) Mez*	sec.	0	0	0	2
<i>Ocotea densiflora</i> (Meisn.) Mez	–	0	0	0	1
<i>Ocotea diospyrifolia</i> (Meisn.) Mez	sec.	0	0	0	1
<i>Ocotea glaziovii</i> Mez	sec.	0	0	0	1
<i>Ocotea pomaderroides</i> (Meisn.) Mez	–	0	1	0	2
<i>Ocotea pulchella</i> (Nees & Mart.) Mez*	cli.	2	1	0	1
<i>Ocotea spixiana</i> (Nees) Mez	sec.	0	0	0	3
<i>Ocotea velloziana</i> (Meisn.) Mez	sec.	0	0	0	1
<i>Persea fusca</i> Mez*	–	0	0	0	2
Lecythidaceae					
<i>Cariniana estrellensis</i> (Raddi) Kuntze*	sec.	4	2	3	2
<i>Lecythis brancoensis</i> (R. Knuth) S.A. Mori	–	0	1	0	0
Loganiaceae					
<i>Antonia ovata</i> Pohl	sec.	0	0	0	1
<i>Strychnos pseudoquina</i> A. St.-Hil.	sec.	1	2	1	5
Lythraceae					
<i>Diplusodon virgatus</i> Pohl	sec.	0	1	0	1
<i>Lafoensia glyptocarpa</i> Koehne	sec.	1	0	0	0
<i>Lafoensia pacari</i> A. St.-Hil.	sec.	2	3	2	5
<i>Physocalymma scaberrimum</i> Pohl	pio.	3	1	2	0
Magnoliaceae					
<i>Magnolia ovata</i> (A. St.-Hil.) Spreng.	sec.	4	0	0	2
Malpighiaceae					
<i>Banisteriopsis megaphylla</i> (A. Juss.) B. Gates*	–	0	0	0	1
<i>Banisteriopsis stellaris</i> (Griseb.) B. Gates	–	0	0	1	1
<i>Byrsonima coccolobifolia</i> Kunth	sec.	0	2	2	5
<i>Byrsonima crassifolia</i> (L.) Kunth*	pio.	1	2	1	2
<i>Byrsonima guilleminiana</i> A. Juss.*	–	0	0	0	1
<i>Byrsonima intermedia</i> A. Juss.	pio.	0	0	0	3
<i>Byrsonima laxiflora</i> Griseb.	sec.	0	1	0	2
<i>Byrsonima ligustrifolia</i> A. Juss.*	cli.	0	0	0	1
<i>Byrsonima pachyphylla</i> A. Juss.	–	0	3	1	3
<i>Byrsonima rotunda</i> Griseb.*	–	0	0	0	1

Table 1. Continued...

Botanical family/species	Successional stage	Nursery	PRADs	Implemented PRADs	Native Cerrado
Malpighiaceae					
<i>Byrsonima sericea</i> DC.*	sec.	0	0	0	1
<i>Byrsonima umbellata</i> Mart. ex A. Juss.*	sec.	0	0	0	1
<i>Byrsonima verbascifolia</i> (L.) DC.	sec.	1	1	1	5
<i>Heteropterys pteropetala</i> A. Juss.	–	0	0	0	1
<i>Peixotoa reticulata</i> Griseb.	sec.	0	0	0	2
Malvaceae					
<i>Apeiba tibourbou</i> Aubl.	pio.	0	0	0	2
<i>Basiloxylon brasiliensis</i> (Allemão) K. Schum.	–	2	0	0	0
<i>Ceiba pentandra</i> (L.) Gaertn.	pio.	1	0	0	0
<i>Ceiba pubiflora</i> (A. St.-Hil.) K. Schum.	sec.	0	2	0	1
<i>Ceiba speciosa</i> (A. St.-Hil.) Ravenna	sec.	3	5	6	0
<i>Eriotheca candolleana</i> (K. Schum.) A. Robyns	sec.	0	0	0	1
<i>Eriotheca globosa</i> (Aubl.) A. Robyns	–	0	1	0	0
<i>Eriotheca gracilipes</i> (K. Schum.) A. Robyns*	sec.	0	0	1	2
<i>Eriotheca pubescens</i> (Mart. & Zucc.) Schott & Endl.*	sec.	6	11	5	6
<i>Guazuma crinita</i> Mart.*	pio.	0	1	0	0
<i>Guazuma ulmifolia</i> Lam.	pio.	7	3	5	1
<i>Luehea candicans</i> Mart.*	sec.	0	1	0	1
<i>Luehea divaricata</i> Mart.	sec.	0	1	2	1
<i>Luehea grandiflora</i> Mart.	pio.	0	0	1	1
<i>Luehea paniculata</i> Mart.	pio.	1	0	0	2
<i>Pseudobombax grandiflorum</i> (Cav.) A. Robyns	pio.	2	1	0	0
<i>Pseudobombax longiflorum</i> (Mart.) A. Robyns	sec.	3	2	0	3
<i>Pseudobombax marginatum</i> (A. St.-Hil., Juss. & Cambess.) A. Robyns	sec.	0	0	0	1
<i>Pseudobombax tomentosum</i> (Mart.) Robyns*	sec.	0	1	3	2
<i>Sterculia apetala</i> (Jacq.) H. Karst.	sec.	1	0	1	0
<i>Sterculia striata</i> A. St.-Hil. & Naudin	pio.	6	3	6	1
Melastomataceae					
<i>Leandra aurea</i> (Cham.) Cogn.	sec.	0	0	0	1
<i>Leandra melastomoides</i> Raddi	sec.	0	0	0	1
<i>Macairea radula</i> (Bonpl.) DC.	–	0	1	0	0
<i>Miconia albicans</i> (Sw.) Steud.	pio.	1	1	1	3
<i>Miconia burchellii</i> Triana*	–	0	2	0	4
<i>Miconia chamissois</i> Naudin	pio.	1	0	1	2
<i>Miconia chartacea</i> Triana	pio.	0	0	0	1
<i>Miconia cubatanensis</i> Hoehne	pio.	0	0	0	2
<i>Miconia cuspidata</i> Mart. ex Naudin	sec.	0	0	0	3
<i>Miconia dodecandra</i> Cogn.*	sec.	0	1	0	1
<i>Miconia elegans</i> Cogn.*	sec.	0	0	0	1
<i>Miconia fallax</i> DC.	sec.	0	0	0	1
<i>Miconia ferruginata</i> DC.*	pio.	0	1	0	6
<i>Miconia hirtella</i> Cogn.*	–	0	0	0	1

Table 1. Continued...

Botanical family/species	Successional stage	Nursery	PRADs	Implemented PRADs	Native Cerrado
<i>Miconia ibaguensis</i> (Bonpl.) Triana	pio.	1	0	1	0
<i>Miconia leucocarpa</i> DC.	–	0	0	1	6
<i>Miconia nervosa</i> (Sm.) Triana	–	0	0	0	1
<i>Miconia pepericarpa</i> DC.*	pio.	0	0	0	2
<i>Miconia prasina</i> (Sw.) DC.	pio.	0	0	0	1
<i>Miconia punctata</i> (Desr.) D. Don ex DC.	–	0	0	0	2
<i>Miconia sellowiana</i> Naudin	pio.	0	1	0	4
<i>Mouriri glazioviana</i> Cogn.	sec.	0	0	0	1
<i>Mouriri pusa</i> Gardner ex Hook.	–	0	1	0	0
<i>Ossaea congestiflora</i> (Naudin) Cogn.	–	0	0	0	1
<i>Tibouchina candolleana</i> Cogn.*	–	7	3	1	2
<i>Tibouchina frigidula</i> (DC.) Cogn.*	–	0	0	1	0
<i>Tibouchina granulosa</i> (Desr.) Cogn.	sec.	2	1	0	0
<i>Tibouchina stenocarpa</i> (DC.) Cogn.	–	2	0	5	1
<i>Tococa guianensis</i> Aubl.	–	0	0	1	0
<i>Trembleya parviflora</i> (D. Don) Cogn.*	pio.	0	0	1	2
<i>Trembleya phlogiformis</i> DC.	–	0	0	0	1
Meliaceae					
<i>Cabralea canjerana</i> (Vell.) Mart.*	sec.	0	1	1	2
<i>Cedrela fissilis</i> Vell.	sec.	3	4	3	0
<i>Cedrela odorata</i> L.	sec.	0	0	0	1
<i>Guarea guidonia</i> (L.) Sleumer	sec.	3	0	0	1
<i>Guarea kunthiana</i> A. Juss.*	sec.	0	0	1	1
<i>Guarea macrophylla</i> Vahl	sec.	0	1	0	1
<i>Trichilia catigua</i> A. Juss.*	sec.	0	0	0	1
<i>Trichilia elegans</i> A. Juss.	sec.	0	0	0	1
<i>Trichilia pallida</i> Sw.	sec.	0	0	0	1
Metteniusaceae					
<i>Emmotum nitens</i> (Benth.) Miers	–	1	5	0	5
Monimiaceae					
<i>Macropeplus ligustrinus</i> (Tul.) Perkins	–	0	0	0	1
<i>Mollinedia oligantha</i> Perkins*	–	0	0	0	1
Moraceae					
<i>Brosimum gaudichaudii</i> Trécul*	pio.	2	3	2	3
<i>Ficus citrifolia</i> Mill.	pio.	0	0	0	1
<i>Ficus enormis</i> (Mart. ex Miq.) Mart.	sec.	0	0	0	1
<i>Ficus insipida</i> Willd.*	sec.	0	0	0	1
<i>Ficus obtusiuscula</i> (Miq.) Miq.	sec.	0	0	0	1
<i>Ficus pertusa</i> L. f.	pio.	0	0	0	1
<i>Ficus trigona</i> L. f.	sec.	0	0	0	1
<i>Maclura tinctoria</i> (L.) D. Don ex Steud.	sec.	0	0	2	0
<i>Pseudolmedia laevigata</i> Trécul*	sec.	0	2	0	2
<i>Sorocea bonplandii</i> (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					
<i>Virola sebifera</i> Aubl.	pio.	1	2	0	3
<i>Virola urbaniana</i> Warb.	-	0	0	0	1
Myrtaceae					
<i>Blepharocalyx salicifolius</i> (Kunth) O. Berg*	cli.	0	1	2	4
<i>Calyptanthes brasiliensis</i> Spreng.	sec.	0	0	0	0
<i>Calyptanthes clusiiifolia</i> (Miq.) O. Berg*	sec.	0	1	0	2
<i>Calyptanthes lucida</i> Mart. ex DC.	sec.	0	0	0	1
<i>Campomanesia aromatica</i> (Aubl.) Griseb.	-	0	0	0	2
<i>Campomanesia eugenioides</i> (Cambess.) D.Legrand ex Landrum*	sec.	0	0	0	2
<i>Campomanesia pubescens</i> (DC.) O. Berg	sec.	0	0	0	1
<i>Campomanesia rufa</i> (O. Berg) Nied.	-	0	0	0	1
<i>Campomanesia velutina</i> (Cambess.) O. Berg	pio.	1	0	0	1
<i>Campomanesia xanthocarpa</i> Mart. ex O. Berg*	sec.	0	0	0	1
<i>Eugenia aurata</i> O. Berg	sec.	0	1	0	1
<i>Eugenia bimarginata</i> DC.	sec.	0	0	1	0
<i>Eugenia complicata</i> O. Berg*	-	0	0	0	1
<i>Eugenia dysenterica</i> DC.	sec.	8	15	7	3
<i>Eugenia florida</i> DC.*	sec.	0	0	0	1
<i>Eugenia involucrata</i> DC.	sec.	1	0	0	2
<i>Eugenia pyriformis</i> Cambess.	sec.	1	0	0	0
<i>Eugenia uruguayensis</i> Cambess.	-	1	0	0	1
<i>Marlierea clauseniana</i> (O. Berg) Kiaersk.	-	0	1	0	0
<i>Myrcia albotomentosa</i> DC.	-	0	1	0	0
<i>Myrcia bracteata</i> (Rich.) DC.	-	0	0	0	1
<i>Myrcia eriocalyx</i> DC.	-	0	0	0	1
<i>Myrcia fenziiana</i> O. Berg*	-	0	0	0	2
<i>Myrcia lasiantha</i> DC.*	-	0	0	0	1
<i>Myrcia nivea</i> Cambess.	-	0	0	0	1
<i>Myrcia pubipetala</i> Miq.	sec.	0	0	0	1
<i>Myrcia splendens</i> (Sw.) DC.	pio.	0	2	1	4
<i>Myrcia tomentosa</i> (Aubl.) DC.	pio.	0	2	0	5
<i>Myrcia venulosa</i> DC.	-	0	0	0	1
<i>Myrciaria floribunda</i> (H. West ex Willd.) O. Berg	sec.	0	1	0	0
<i>Myrciaria glanduliflora</i> (Kiaersk.) Mattos & D. Legrand	-	0	0	0	1
<i>Pimenta pseudocaryophyllus</i> (Gomes) Landrum*	sec.	0	0	0	2
<i>Psidium firmum</i> O. Berg*	-	0	0	0	1
<i>Psidium guineense</i> Sw.	sec.	3	0	1	1
<i>Psidium longipetiolatum</i> D. Legrand	-	1	0	0	0
<i>Psidium myrsinites</i> Mart. ex DC.*	-	0	0	0	1
<i>Psidium myrtoides</i> O. Berg*	-	0	2	3	1
<i>Psidium oligospermum</i> DC.*	-	0	0	0	1
<i>Siphoneugena densiflora</i> O. Berg	sec.	3	2	0	2

Table 1. Continued...

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

Table 1. Continued...

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

Table 1. Continued...

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

Table 1. Continued...

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

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CORRESPONDENCE TO

Willian Barros Gomes

Universidade de Brasília (UnB), Área Universitária, 1, Vila Nossa Senhora de Fátima, CEP 73345-010, Planaltina, DF, Brasil
e-mail: wbgomes@yahoo.com

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