LEANDRO TAVARES VIEIRA

PADRÕES DE DIVERSIDADE DA FLORA LENHOSA DOS CERRADOS DO NORDESTE DO BRASIL

Campinas
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UNIVERSIDADE ESTADUAL DE CAMPINAS
INSTITUTO DE BIOLOGIA

LEANDRO TAVARES VIEIRA

PADRÕES DE DIVERSIDADE DA FLORA LENHOSA DOS CERRADOS DO NORDESTE DO BRASIL

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Fernando R. Martins
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Orientador: Prof. Dr. Fernando Roberto Martins
Co-Orientador: Prof. Dr. Antonio Alberto Jorge Farias Castro

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“*O fato de as coisas acontecerem nada significa.*
Que sejam conhecidas é o que significa tudo”.

Egon Friedell (1878-1938)

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RESUMO

O Cerrado é um domínio fitogeográfico que apresenta diversas fitofisionomias que vão do campestre (campo limpo), passando pelo savânico (campo sujo, campo cerrado e cerrado *sensu stricto*) até o florestal (cerradão). Cerrado com inicial maiúscula refere-se ao domínio fitogeográfico enquanto com inicial minúscula às diferentes fitofisionomias. O Cerrado é o segundo maior domínio fitogeográfico do Brasil e abrange vários estados em sua área central, além de diversas áreas disjuntas na Amazônia, Caatinga e Mata Atlântica. Conhecido por sua grande biodiversidade e endemismo, o Cerrado é um dos 25 "hotspots" de biodiversidade com prioridade para conservação devido à sua baixa porcentagem de área protegida em unidades de conservação. Além disso, a destruição dos ecossistemas que constituem o Cerrado continua de forma muito acelerada, resultado da expansão econômica da região central do Brasil iniciada nos anos de 1970, restando hoje 51,54% de sua vegetação. A flora do Cerrado pode ser dividida em seis províncias fitogeográficas distintas. O Cerrado do nordeste, uma dessas províncias, faz fronteiras com outros domínios fitogeográficos: Caatinga a leste, Amazônia a oeste-noroeste, Mata Atlântica a sudeste e com cerrado central ao sul-sudoeste. A pressão antrópica por novas áreas de cultivos de grãos e oleaginosas em direção ao norte do Cerrado faz com que os cerrados nordestinos sejam foco de atenção conservacionista e pesquisa para que se garanta sua diversidade biológica e funcionalidade ecossistêmica em longo prazo. O primeiro capítulo desta tese introduz ao banco de dados FLORACENE (FLORA do CErrado do nordeste - NE), também utilizado nos demais capítulos, em que foram reunidos 160 levantamentos florísticos. Foram contabilizadas 936 espécies de plantas lenhosas em 376 gêneros e 84 famílias, mostrando que o cerrado nordestino é muito mais rico do que se pensava e diferente do cerrado central. Mostramos como a estrutura florística encontrada para o cerrado nordestino pode ser fruto da história evolutiva do Cerrado. No segundo capítulo, foi avaliado áreas de endemismo locais dentro dos cerrados do nordeste, que por sua vez, é uma área de endemismo regional dentro do domínio fitogeográfico Cerrado, também endêmico. Cinco áreas de endemismo foram determinadas: cerrados litorâneos, Chapada do Araripe, Chapada Diamantina, região norte do estado do Piauí e região sudoeste do cerrado nordestino (oeste da Bahia e sudoeste do Maranhão). A flora de cada uma das áreas de endemismo sofreu influências diferentes dos domínios fitogeográficos adjacentes. As características e semelhanças ambientais de cada área, além da história evolutiva, poderia ter causado tal padrão. No terceiro e último capítulo, foi testado se a severidade ambiental do nordeste poderia causar um agrupamento filogenético nas plantas do cerrado, ou se a competição por recursos limitados ou a influência dos domínios fitogeográficos adjacentes teriam causado uma dispersão filogenética. Através do índice de parentesco líquido (*net relatedness index* - NRI) e do índice do táxon mais próximo (*nearest taxon index* - NTI) verificou-se uma leve indicação para o agrupamento filogenético como um todo, e um padrão geral de que severidade climática e condições de solo relacionadas à seca podem agir como filtros abióticos.

Palavras-chave: Áreas de endemismo, conservação da biodiversidade, domínio fitogeográfico, estrutura filogenética, estrutura florística.

ABSTRACT

The Cerrado is a phytogeographic domain which has many different physiognomies, ranging from pure grassland ("campo limpo”), through savanna ("campo sujo", "campo cerrado", "cerrado *sensu stricto*"), to pure forest ("cerradão"). The Cerrado is the second largest phytogeographic domain of Brazil, covering several states in the central area, as well as several disjunct areas in the Amazon, Caatinga and Atlantic Forest. Widely known for its high biodiversity and endemism, the Cerrado is one of 25 "hotspots" of biodiversity with priority for conservation due to its low percentage of protected area in conservation units. Furthermore, the destruction rate of the Cerrado´s ecosystems remains high as a result of the economic expansion in central Brazil that started early 1970s. Today, there are 51.54% of the Cerrado vegetation remnants. The flora of the Cerrado can be divided into six distinct phytogeographic provinces. The Northeast Cerrado, one of these provinces, is located in an area under influence from others phytogeographic domains: Caatinga at east, Amazonia at west-northwest, Atlantic Forest at southeast and Cerrado central at south-southwest. The anthropic pressure for new areas for grain and oilseed crops makes the northeastern cerrados a focus for conservation actions and scientific research to ensure that its biological diversity and ecosystem function be guaranteed in the long term. The first chapter of this thesis introduces the database FLORACENE (flora of the cerrado of northeast), also used in the other chapters, which 160 floristic surveys were gathered. We recorded 936 species of woody plants in 376 genera and 84 families, showing that the northeastern cerrado is much richer than previously thought and different from the core cerrado. The floristic structure found for northeastern cerrado may be an outcome of the evolutionary history of the Cerrado. In the second chapter, we evaluate local areas of endemism within northeastern cerrado, which, in its turn, is a regional area of endemism within the Cerrado phytogeographical domain, also endemic. We found five areas of endemism: coastal cerrados, Araripe plateau, Diamantina plateau, the northern state of Piauí and southwestern of northeast region (western Bahia and southwestern Maranhão). The flora of each area of endemism was differently influenced by its adjacent phytogeographic domains. We discuss the similarities and environmental characteristics of each area, and evolutionary history that could have produced such a pattern. In the third and last chapter, we tested whether the environmental severity of the northeast region could have produced a phylogenetic clustering, or if the competition for limited resources or the influences of adjacent phytogeographic domains have produced a phylogenetic overdispersion in the cerrado wood species analyzed. Using the net relatedness index (NRI) and nearest taxon index (NTI) there was a slight overall indication for the phylogenetic clustering, and a general pattern that harsh climate and soil conditions related to drought may act as abiotic filters, leading to phylogenetic clustering.

Keywords: Areas of endemism, conservation of biodiversity, phytogeographic domain, phylogenetic structure, floristic structure.

SUMÁRIO

INTRODUÇÃO GERAL

O Cerrado

O Cerrado é amplamente conhecido por sua grande biodiversidade, sendo considerado um dos 25 "*hotspots*" em biodiversidade do mundo, tendo cerca de 10.000 espécies de plantas, 161 de mamíferos, 837 de pássaros, 120 de répteis e 150 espécies de anfíbios (Myers et al. 2000). Terceiro *hotspots* em extensão do mundo (Fig. 1), o Cerrado detém cerca de 4.400 espécies vegetais endêmicas, isto é, 1,5% de todas as plantas endêmicas do mundo (Myers et al. 2000).

O cerrado *sensu lato* não tem uma fisionomia única e uniforme, mas variações fisionômicas que podem ser incluídas em três grupos: o campestre (campo limpo), o savânico (campo sujo, campo cerrado e cerrado *sensu stricto*) e o florestal (cerradão; Coutinho 1978). Ribeiro e Walter (2008) descrevem 11 fisionomias principais adicionando aos anteriores o campo rupestre (campestre); parque cerrado, palmeiral e vereda (savânico); mata ciliar, mata de galeria e mata seca (florestal). Considerando ainda os subtipos, o cerrado pode ter 25 fitofisionomias diferentes (Ribeiro e Walter 2008). Um bioma é delimitado por uma única fisionomia vegetacional e inclui além da flora a fauna associada (Coutinho 2006, Batalha 2011). Portanto, o Cerrado seria um complexo de biomas, formado por um mosaico de comunidades pertencentes a um gradiente de formações ecologicamente relacionadas (Coutinho 2006, Batalha 2011). Assim, concordamos com Fiaschi e Pirani (2009) e Batalha (2011) considerando o Cerrado como um domínio fitogeográfico, se referindo essencialmente à flora relacionada às características morfoclimáticas, em que os diversos tipos ou fisionomias vegetacionais estão incluídas, nesse caso "Cerrado" com inicial maiúscula (Batalha 2011). Com inicial minúscula, "cerrado" refere-se aos tipos vegetacionais ou fisionomias, isto é, da vegetação do campo limpo ao cerradão (Batalha 2011), podendo também ser flexionado no plural. O uso de “domínios fitogeográficos” também é empregado pela recente compilação da flora do Brasil (Forzza et al. 2010), entretanto, muitos autores e o governo brasileiro tratam o Cerrado como bioma (Ribeiro e Walter 2008, MMA 2011a).

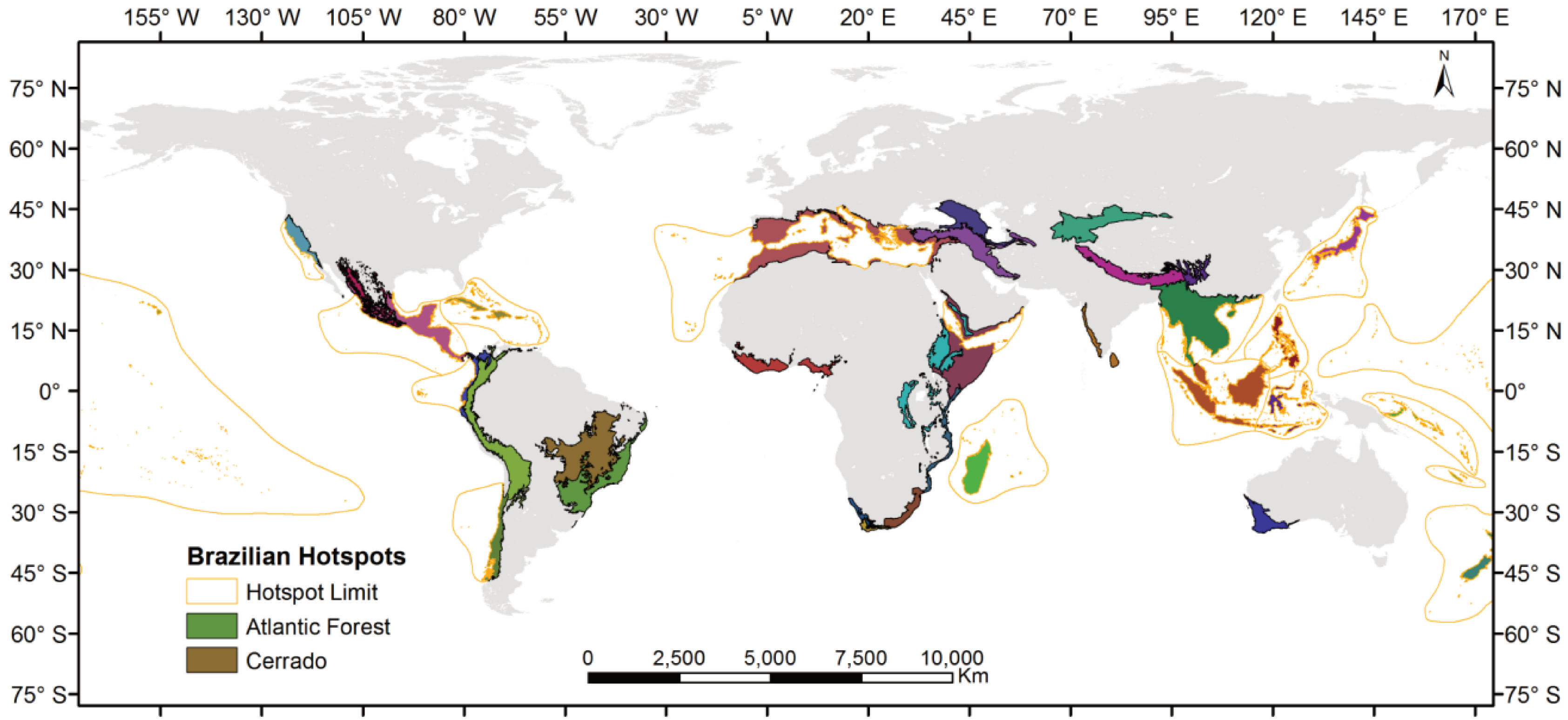

Fig.1 Mapa indicando os 25 hotspots de biodiversidade do mundo evidenciando os hotspots brasileiros. O Cerrado é o terceiro em maior em extensão, ficando atrás da Bacia do Mediterrâneo (entre a África e a Europa) e da região Indonésia-Burma (entre Oceania e Ásia). Figura adaptada de Mittermeier et al. (2004).

Os limites geográficos do Cerrado

A primeira aproximação sobre os limites dos domínios fitogeográficos brasileiros foi realizada por Martius (1824) no qual denominou a área central do Brasil como Oreades, nome dado à ninfa da mitologia grega conhecida como ninfa dos campos de caça (Joly et al. 1999), se referindo ao aspecto de campos do cerrado. Hoje, estima-se que o Cerrado central ocupe uma área de 204,7 milhões de hectares (IBGE 2004) englobando os estados da Bahia, Goiás, Maranhão, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Paraná, Piauí, São Paulo e Tocantins, além do Distrito Federal. Entretanto, o mapa base para esta estimativa (Fig. 2) não considera áreas disjuntas de cerrado como a Chapada Diamantina ou os conhecidos enclaves de cerrado na Amazônia (Prance 1996, Pennington et al. 2006, Ratter et al. 2006), assim como

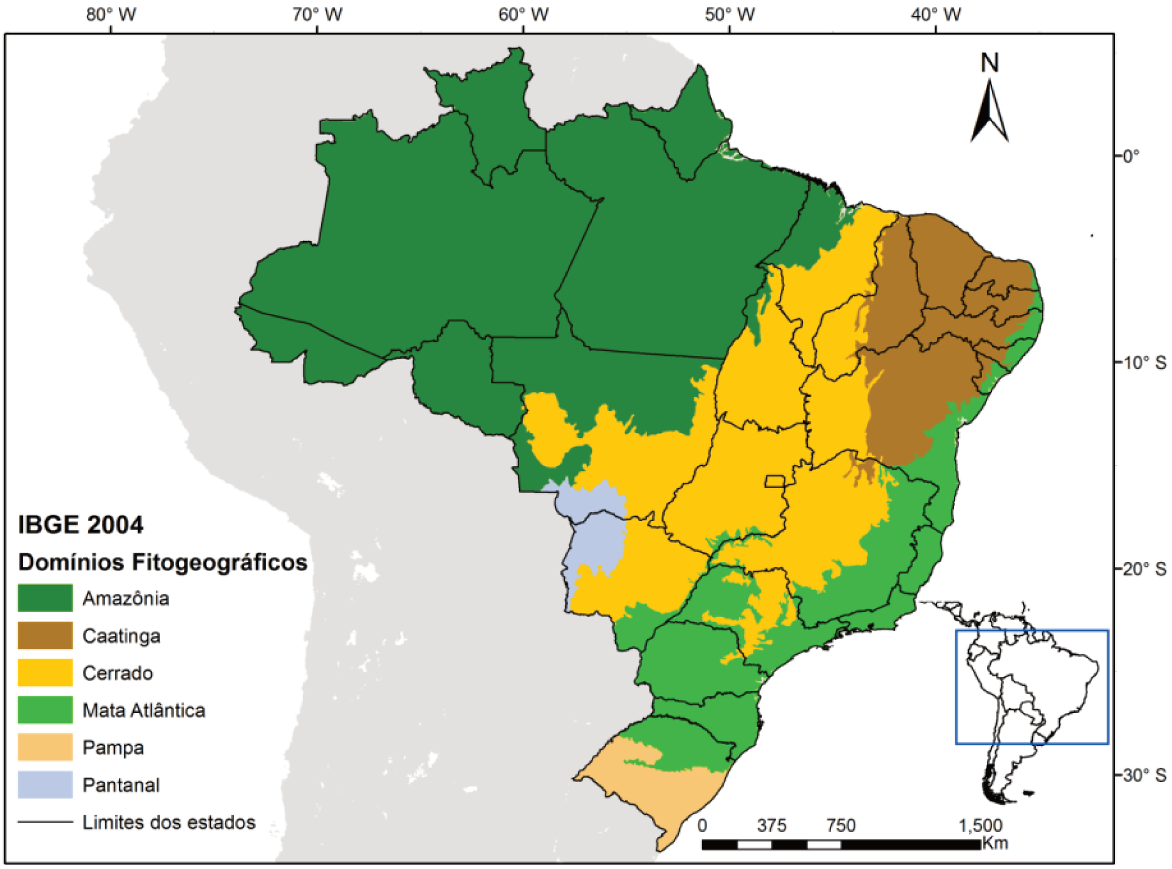

Fig. 2. Mapa oficial dos domínios fitogeográficos brasileiros adotado pelas diversas instituições governamentais brasileiras (IBGE 2004).

algumas áreas marginais como o norte do Piauí.

Olson et al. (2001) propuseram um mapa com 867 "ecorregiões" terrestres pelo mundo distribuídos em 14 biomas mundiais que nortearia as ações de conservação da biodiversidade. Uma ecorregião é uma unidade relativamente grande de terra contendo um conjunto distinto de comunidades naturais e de espécies, com limites que se aproximam da extensão original das comunidades naturais antes da grande mudança do uso da terra (Olson et al. 2001). Tanto as ecorregiões como os biomas se referem a toda biota, diferindo do nosso uso de "domínio fitogeográfico". A base de dados deste mapa foi utilizada, por exemplo, em Myers et al. (2000) e Olson e Dinerstein (2002), além das organizações não governamentais como World Wildlife Fund (WWF) e The Nature Conservancy (TNC). Cinco dos 14 biomas mundiais estão presentes no Brasil (Fig. 3, Olson et al. 2001). Especificamente para o Brasil, este estudo leva em consideração algumas áreas disjuntas de cerrado na Amazônia nos estados do Amapá, Pará e Roraima. Por outro lado, há muita floresta tropical no centro do Cerrado e considera florestas secas como um bioma separado, além de juntar as savanas (cerrado) com os campos de grama (pampas) em um único bioma (Fig. 3). Os autores afirmam: "*a more diverse set of sources was used for Neotropics, including habitat classifications for Brazil from the Instituto Brasileiro de Geografia e Estatística (IBGE 1993)...*", se referindo à falta de conformidade na delimitação dos domínios fitogeográficos brasileiros com quais os autores se basearam. A área do Cerrado do mapa do IBGE de 1993 é muito parecida com a do mapa proposto pela Embrapa Cerrados na década de 1980 (Adámoli et al. 1986), que é o mesmo mapa usado por diversos autores (Bridgewater et al. 2004, Ratter et al. 2006, Sano et al. 2008). Neste mapa há quase total exclusão dos cerrados do estado de São Paulo, não coloca os cerrados disjuntos, mas evidencia áreas no estado de Rondônia e, em alguns casos, as áreas da porção do norte do estado do Piauí.

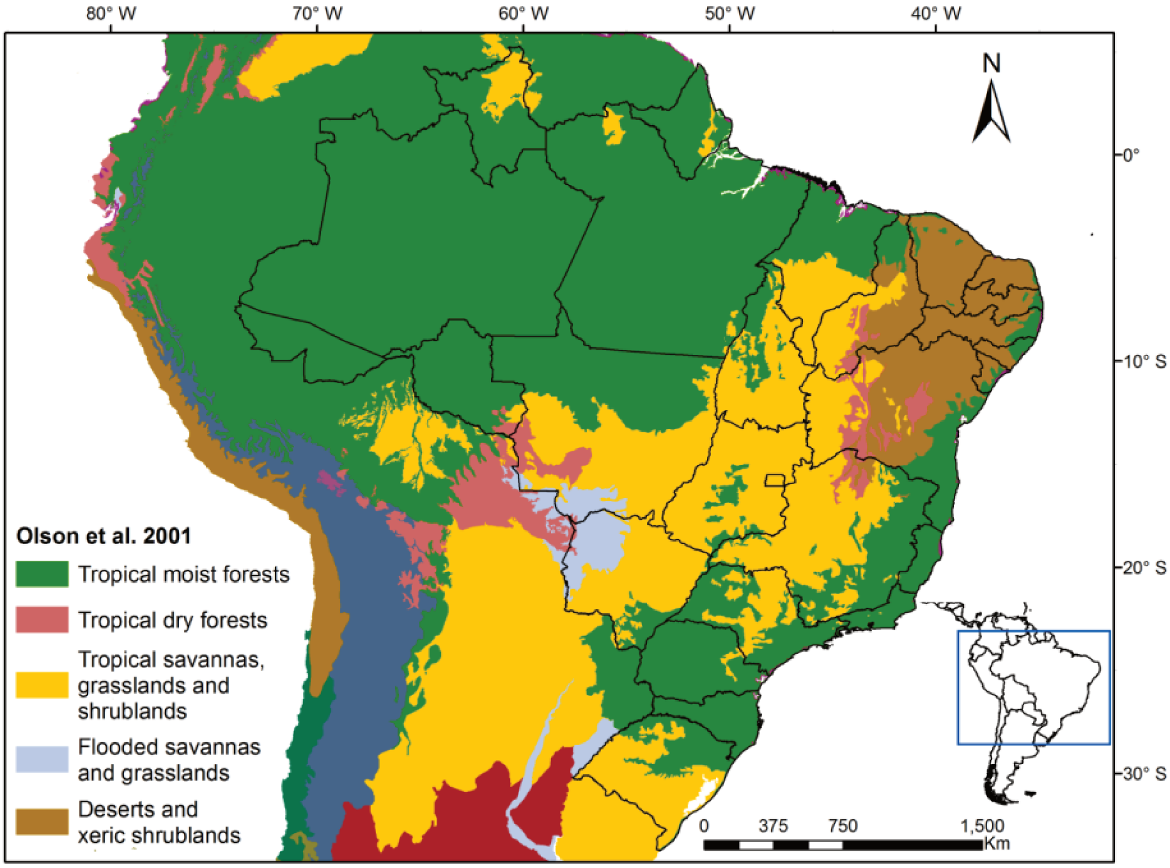

Fig. 3. Mapa de biomas proposto por Olson et al. (2001), evidenciando os que ocorrem no Brasil. Tradução livre: tropical moist forest: florestas tropicais úmidas; tropical dry forest: florestas tropicais secas; tropical savannas, grasslands e shrublands: savanas, campos de grama e campos arbustivos tropicais; flooded savannas and grasslands: savanas e campos inundáveis; deserts and xeric shrublands: desertos e campos arbustivos xéricos.

Quando observado cada ecorregião na base de dados do mapa de Olson et al. (2001), é possível observar que existem várias áreas definidas neste estudo como enclaves ou transição. Classificamos algumas dessas áreas como sendo cerrado e chegamos a um mapa que considera várias pequenas áreas disjuntas na Amazônia, na Caatinga e na Mata Atlântica, a porção norte do Piauí, as áreas do estado de São Paulo e a Chapada Diamantina, porém não existem delimitações de ecorregiões nos cerrados litorâneos nos estados do Ceará, Rio Grande do Norte e Pernambuco, e nos cerrados de Rondônia (Fig. 4). Regiões que eram definidas como florestas secas em Olson et al. (2001), nós classificamos como Mata Atlântica conforme determinado pela Lei Federal 11.428 de 2006 e pelo Decreto 6660 de 2008. Por mais que a definição dos limites do Cerrado seja difícil devido à complexidade dos ambientes e fitofisionomias e às inúmeras áreas de transição ou ecótonos, a exclusão de algumas áreas bem conhecidas como sendo do domínio fitogeográfico Cerrado leva a algumas complicações em relação à conservação da biodiversidade, como por exemplo, sobre a evolução do uso e ocupação do solo (Sano et al. 2007) além de questões administrativas e implantação de Unidades de Conservação.

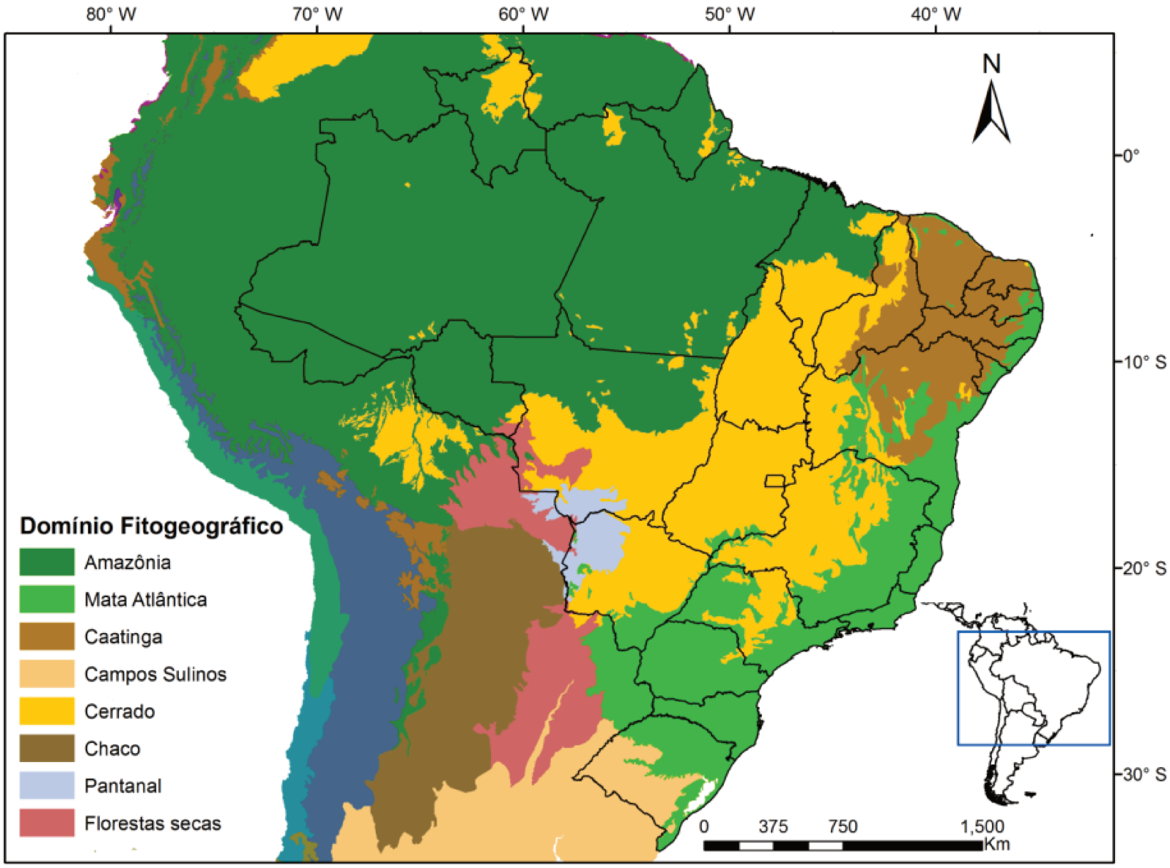

Fig. 4. Mapa dos domínios fitogeográficos brasileiros, adaptado de Olson et al. (2001).

Conservação do Cerrado

Devido à alta complexidade de seus habitats e pelos altos níveis de endemismo e beta diversidade de plantas, o Cerrado também foi incorporado à lista das duzentas ecorregiões do mundo com prioridade para conservação (Olson e Dinerstein 2002). Além de sua riqueza biológica e alto nível de endemismo, o Cerrado está seriamente ameaçado pela grande perda de habitat, que o faz ser considerado um *hotspots* de biodiversidade para conservação (Myers et al. 2000).

Segundo Myers et al. (2000), restam apenas 20% de sua vegetação natural e apenas 6% de área protegida em unidades de conservação, a mais baixa proporção de todos os 25 *hotspots* mundiais. Arruda et al. (2008) apontam que o Cerrado possuí 2,51% de área protegida em unidades de conservação, porém considerando terras indígenas esse valor sobe para 6,48%. Em 2006 o governo brasileiro estabeleceu a meta de 10% da área do Cerrado protegida em unidades de conservação até 2010, porém foi atingido apenas 7,44% (MMA 2011a), enquanto, por exemplo, a Amazônia possui 25 % de área protegida tendo com meta de 30% (MMA 2011b). Este percentual foi calculado com base na área das unidades de conservação federais, estaduais e municipais com Cadastro Nacional de Unidades de Conservação (CNUC) até maio de 2011. A meta para o Cerrado até 2020 é agora de 17% de áreas protegidas em unidades de conservação (MMA 2011b). Vale ressaltar que a estimativa de Arruda et al. (2008) se baseia na área de Cerrado de Olson et al. (2001) (Fig. 3), enquanto a do Ministério do Meio Ambiente (MMA 2011a, b) se baseia no mapa oficial do IBGE (2004) (Fig. 2). Isto exemplifica uma das complicações para o uso de diferentes limites geográficos do Cerrado. A Fig. 5 mostra as unidades de conservação estabelecidas até maio de 2012 de acordo com o Ministério do Meio Ambiente, mas utilizando o mapa com algumas áreas de cerrado incluídas, como já discutido (Fig. 4).

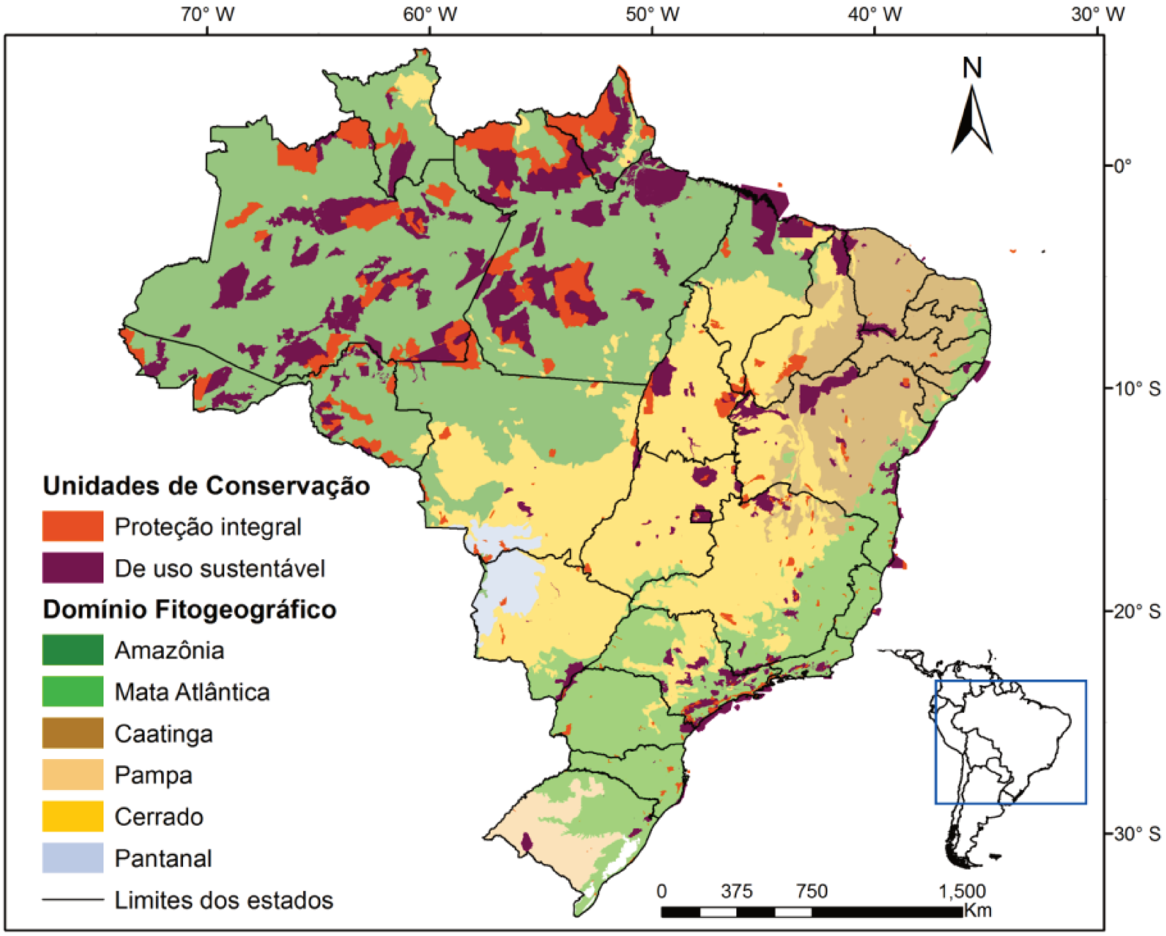

Fig. 5. Unidades de Conservação (UC) de acordo com categoria previstas pelo Sistema Nacional de Unidades de Conservação (SNUC, Lei 9.985 de 2000). UCs federais, estaduais e municipais com Cadastro Nacional de Unidades de Conservação (CNUC 2012) até maio de 2012. Figura adaptada de Olson et al. (2001).

Além do déficit de unidades de conservação no Cerrado, há severa falta de representatividade das paisagens e fitofisionomias presentes nas áreas selecionadas para preservação no domínio fitogeográfico (Arruda et al. 2008). Algumas das unidades de conservação que existem para o Cerrado estão mal localizadas e/ou têm tamanho insuficiente (Dias 1990), não garantindo a manutenção da diversidade biológica e genética e a integridade dos ecossistemas (Arruda et al. 2008).

A destruição dos ecossistemas que constituem o Cerrado continua de forma muito acelerada (Klink e Machado 2005), resultado da expansão econômica da região central do Brasil iniciada nos anos de 1970 (Dias 1990). Já na década de 1990 quase 40% do cerrado já haviam sido substituídos, principalmente por plantações de soja, feijão, milho, eucalipto e pastagem (Dias 1990) e pela retirada do carvão vegetal utilizado pelas indústrias siderúrgicas sem que qualquer medida governamental fosse tomada para assegurar a produção sustentável em áreas de cerrado (Felfili e Silva Jr 1993). Em 2002 a taxa de ocupação antrópica chegou a 55% do Cerrado (Machado et al. 2004), embora a Embrapa tenha chegado um uma taxa de 39.5% de uso antrópico (Sano et al. 2007). Essa diferença pode estar relacionada à definição de cobertura natural e da resolução das imagens de satélite entre os dois estudos (Sano et al. 2007). Os dados oficiais mais recentes indicam que os remanescentes de vegetação do Cerrado passaram de 55,73% em 2002 para 51,54% em 2008 (MMA 2009) (Fig. 6) e 50,84% em 2010, ou seja, 48,54% de ocupação antrópica em 2010 (MMA 2011a).

Um dos pontos preocupantes em que o relatório do Ministério do Meio Ambiente (MMA 2009) aponta é o crescimento no desmatamento de áreas da região norte do Cerrado entre 2002 e 2008, uma vez que é onde possui maior porcentagem de remanescentes vegetais. Os estados que lideram esse crescimento são: Maranhão (7%), Bahia (6,1%), Mato Grosso (4,9%), Tocantins (4,8%) e Piauí (4,5%). Novamente, a definição dos limites geográficos do Cerrado causa complicações, pois estes dados são baseados nos limites oficiais dos domínios fitogeográficos (IBGE 2004), ficando sem avaliação áreas disjuntas de Cerrado, bem como as áreas marginais como a do norte do Piauí.

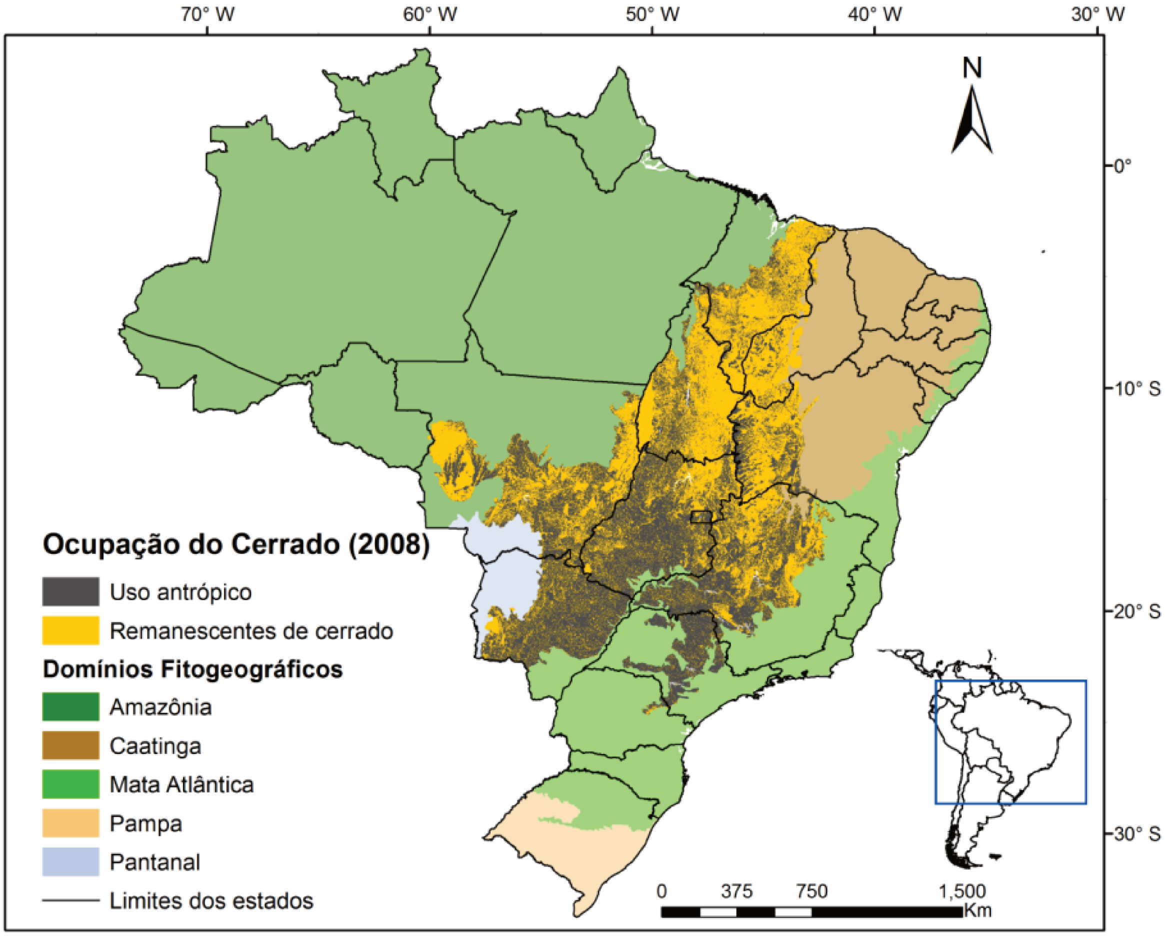

Fig. 6. Ocupação do Cerrado até o ano de 2008 de acordo com o Ministério do Meio Ambiente (MMA 2009) usando o mapa oficial dos domínios fitogeográficos (IBGE 2004)

Distribuição da flora do Cerrado

A influência da flora de domínios fitogeográficos adjacentes ao Cerrado é de interesse de muitos pesquisadores, que focam principalmente a influência da Mata Atlântica e da Floresta Amazônica (Heringer et al. 1977, Oliveira-Filho e Ratter 1995, Oliveira-Filho e Fontes 2000, Méio et al. 2003). Oliveira-Filho e Ratter (1995) mostraram haver espécies amazônicas e atlânticas que penetraram no Cerrado através das matas de galeria ou florestas estacionais. Méio et al. (2003) analisando a distribuição geográfica de 290 espécies arbóreas e arbustivas do cerrado *sensu stricto*, afirmaram haver um gradiente florístico atlântico-amazônico no sentido sudeste-noroeste do Cerrado e encontraram 41,1% das espécies ocorrendo apenas no Cerrado, 44,8% comuns com a Floresta Atlântica, apenas 1,4% comuns com a Floresta Amazônica e 12.7% ocorrendo nos três domínios fitogeográficos. A similaridade florística das Florestas Atlântica e Amazônica com o Cerrado tende a diminuir com a distância para o interior do domínio fitogeográfico (Oliveira-Filho e Fontes 2000, Méio et al. 2003), havendo então uma máxima expressão fisionômica e florística nas áreas centrais do Cerrado (Rizzini 1963). Portanto, como alegado por Rizzini (1963), em áreas marginais ou disjuntas do Cerrado deveria haver um empobrecimento da flora peculiar ou característica do cerrado em comparação com as áreas centrais e, ao mesmo tempo, um acréscimo de espécies vindas de formações vegetacionais adjacentes (Rizzini 1963, Eiten 1972, Fernandes e Bezerra 1990, Castro et al. 1999), as quais Rizzini (1963) chamou de "espécies acessórias".

A descoberta de padrões de distribuição da vegetação do cerrado vem sendo pesquisada sequencialmente nos últimos anos com um acréscimo de dados e qualidade a cada publicação. Por exemplo, Ratter e Dargie (1992) analisaram 26 áreas de cerrado e constataram uma heterogeneidade em sua composição influenciada pela disponibilidade de nutrientes e por variáveis geográficas como latitude e longitude. Castro (1994a, b) analisou espécies de cerrado arbustivas e arbóreas em 145 listas florísticas em 78 sítios e definiu três "supercentros de biodiversidade": nordeste, planalto central e sudeste meridional. Depois de alguns estudos intermediários (Oliveira-Filho e Ratter 1995, Ratter et al. 1996, Ratter et al. 2001), Ratter et al. (2003) avaliaram 376 áreas de cerrado com 951 espécies arbóreas ou grandes arbustos de áreas de campo cerrado à cerradão, excluindo florestas mesotróficas ou de galeria. Neste estudo Ratter et al. (2003), definiram seis províncias fitogeográficas distintas (Fig. 7) (Sul, Centro-Sudeste, Centro-Oeste, Nordeste, Extremo Oeste e Amazônica Disjunta), sendo cada província caracterizada por um numero significativo de espécies exclusivas (Ratter et al. 2003).

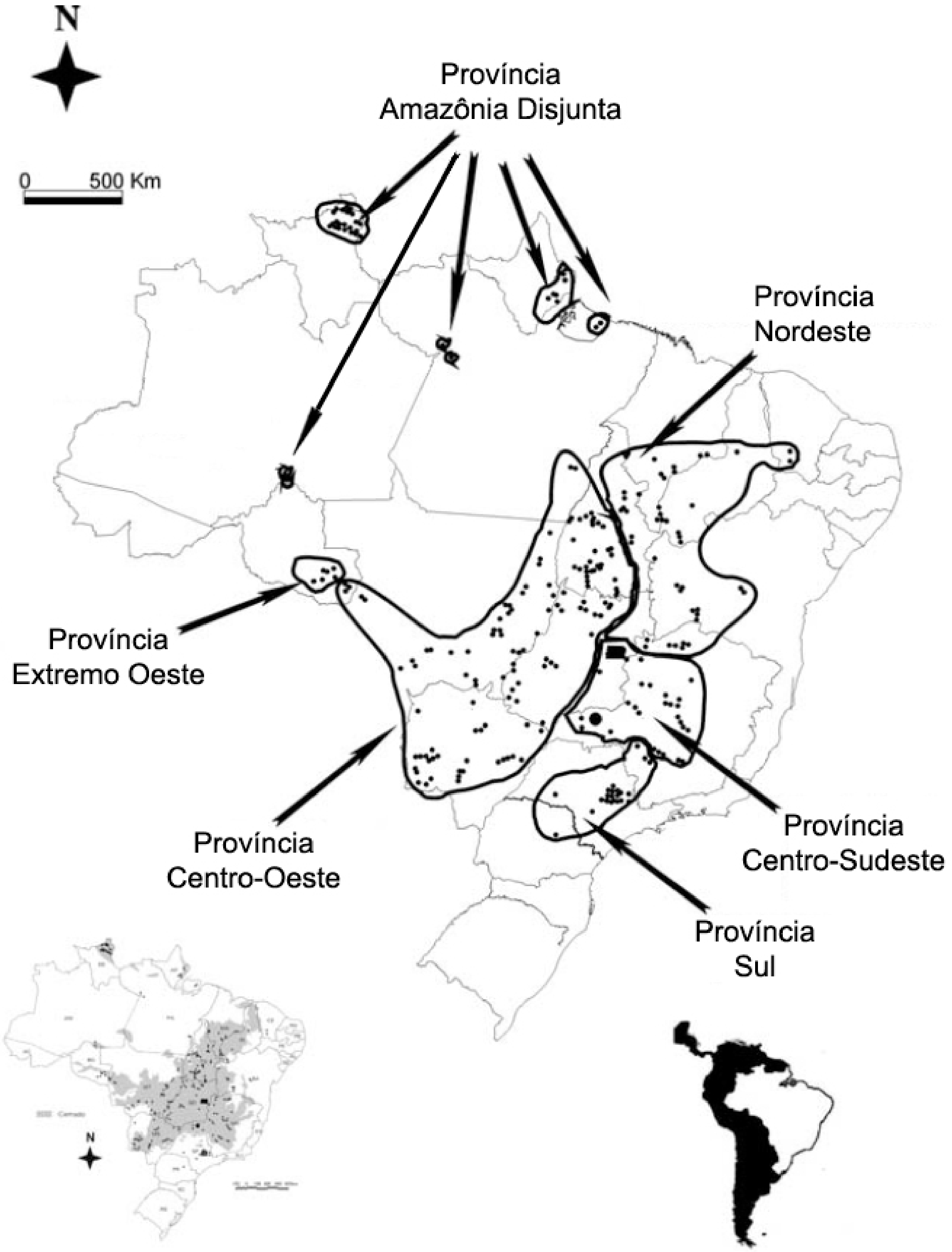

Fig. 7. Mapa mostrando as seis províncias florísticas definidas por Ratter et al. (2003) e os locais dos levantamentos florísticos usado no estudo. Extraído de Bridgewater et al. (2004).

Bridgewater et al. (2004) analisaram o mesmo conjunto de dados de Ratter et al. (2003) e encontraram apenas 121 espécies "oligárquicas", generalistas e de ampla distribuição geográfica, que dominam a vegetação arbórea do cerrado sentido restrito, tendo as demais espécies distribuições muito restritas, evidenciando um elevado grau de β-diversidade (Bridgewater et al. 2004) que é definido como o grau de diferenciação de comunidades ao longo de um gradiente ambiental (Whittaker 1972). Esse entendimento é fundamental para a seleção de áreas para a conservação. Se, por exemplo, a composição das espécies de um domínio fitogeográfico tão abrangente geograficamente não varia com a distância, então a localização das áreas de conservação não é importante. Se, entretanto, há uma considerável diferença florística no espaço, um estudo cuidadoso da composição dos sítios é essencial para assegurar que a seleção das áreas de conservação protegerá todas as espécies adequadamente (Castro 1994a, b, Bridgewater et al. 2004).

Os cerrados nordestinos

Os cerrados nordestinos refere-se ao complexo de formações vegetais que ocorrem na região nordeste do Brasil, diferenciando da Província Nordeste do Cerrado de Ratter et al. (2003) que não se trata de uma delimitação geográfico-administrativa, e que foi definida com base no cerrado sentido restrito. A área dos cerrados nordestinos está localizada sob influência de outros domínios fitogeográficos como da Caatinga a leste, da Amazônia a oeste-noroeste, da Mata Atlântica a sudeste e além do cerrado central ao sul-sudoeste (Fig. 8). Sua flora é tida como bastante diferente da flora do cerrado central (Rizzini 1976, Heringer et al. 1977) com algumas espécies comuns às demais áreas de cerrado (Bridgewater et al. 2004). Além disso, os cerrados nordestinos de um modo geral se encontram em altitudes, tipo de solos e condições climáticas também diferentes dos cerrados centrais (Castro et al. 1998, Castro 1999, Castro et al. 2007). A pressão antrópica por novas áreas de cultivos de grãos e oleaginosas em direção ao norte do Cerrado faz com que os cerrados nordestinos sejam foco de atenção conservacionista e pesquisa para que se garanta sua diversidade biológica e funcionalidade ecossistêmica em longo prazo.

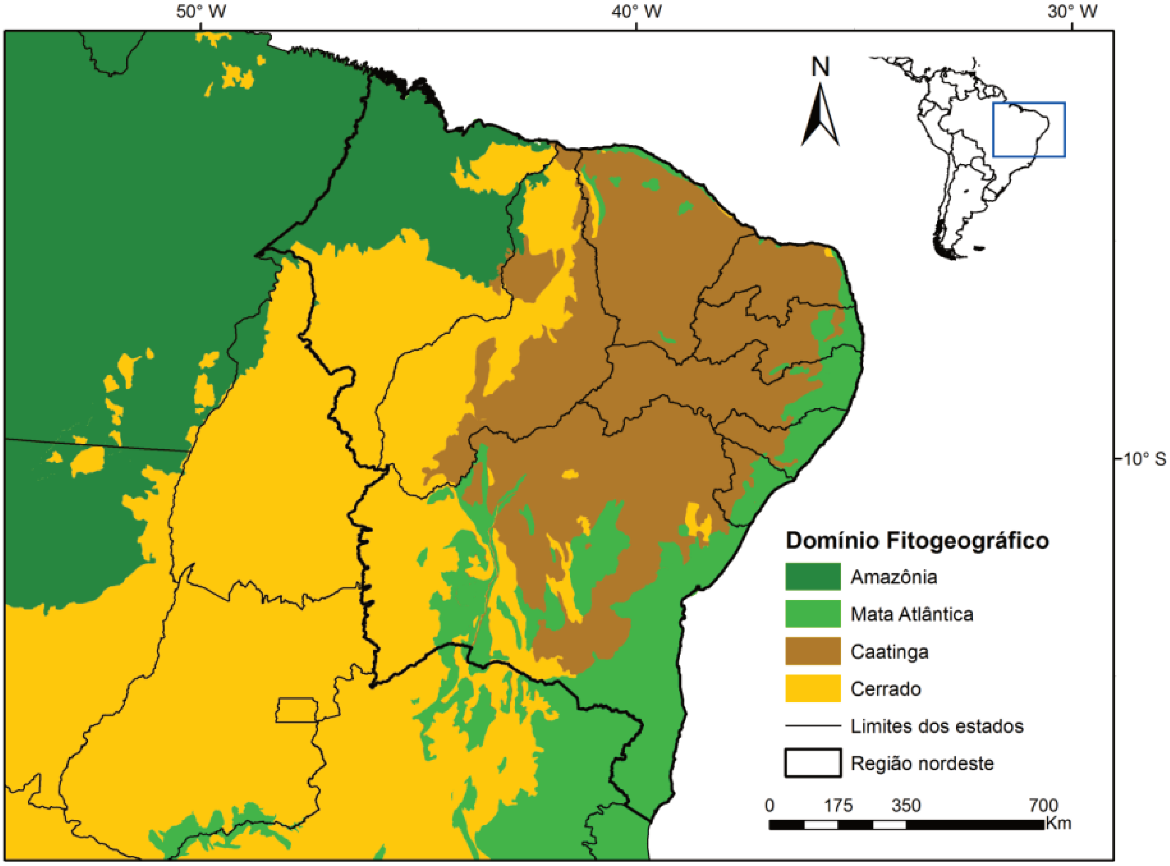

Fig. 8. Região nordeste do Brasil evidenciando os domínios fitogeográficos adjacentes aos cerrados nordestinos. Mapa adaptado de Olson et al. (2001).

Objetivo

Esta tese tem como objetivo geral investigar os padrões de diversidade das espécies lenhosas dos cerrados do nordeste do Brasil e discutir como padrões de riqueza, endemismo e estrutura filogenética estão relacionados aos processos ecológicos e históricos desse domínio fitogeográfico.

Apoio

Esta tese foi desenvolvida junto ao Departamento de Biologia Vegetal do Instituto de Biologia da Universidade Estadual de Campinas (UNICAMP) em parceria com o **Programa de Biodiversidade do Trópico Ecotonal do Nordeste** (BIOTEN) da Universidade Federal do Piauí (UFPI) no âmbito do Programa de Pesquisas Ecológicas de Longa Duração (PELD), como um sub-projeto (ou projeto complementar) do Projeto BASE do Sítio 10 (= Sítio ECOCEM, Ecologia dos Cerrados Marginais do Nordeste e Ecótonos Associados): **Biodiversidade e Fragmentação de Ecossistemas nos Cerrados Marginais do Nordeste** (Processo CNPq Nº 521131/2001-4).

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An analysis of woody flora of the northeastern cerrado of Brazil: a biogeographic meaning and implications for conservation[†]

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[†]Capítulo segue o formato da revista *Flora – Morphology, Distribution, Functional Ecology of Plants*.

Abstract

The Cerrado vegetation has many different physiognomies, which vary from pure grassland to pure forest. Its main area occupies the central Brazilian Plateau and has boundaries with Amazonian and Atlantic forests, Caatinga, Chaco and Pantanal. There are also isolated patches scattered across the Amazon, Atlantic forest and Caatinga. Including these patches, the whole Cerrado woody flora is distributed into six floristic provinces. We investigated the hypothesis that near the limits of a large phytogeographic domain biogeographic processes could produce a different floristic structure in relation to its central area. We gathered 160 floristic surveys from cerrado sites in the Brazilian Northeastern Region, out of which 64 were field surveys from our team work, most inedited. We proceeded simple calculations in order to assess the structure of the cerrado northeastern woody flora on family, genera and species levels. We recorded 936 species in 376 genera and 84 families. Excluding richer families such as Fabaceae, Myrtaceae and Asteraceae, we had high proportion of monogeneric and monospecific families. We recorded 54% of monospecific genera and 30% present in only one site. The more constant species were *Qualea parviflora* (129 sites, 80%), followed by *Anacardium occidentale* (119, 74%), *Bowdichia virgilioides* (117, 73%) and *Qualea grandiflora* (115, 72%), but 443 species (47%) were recorded at one site only. We showed that the woody flora of cerrado northeastern is much richer than supposed by many authors, with characteristics species different from core cerrado. Higher proportion of monospecific families and genera and monogeneric families and the great number of species restricted to few sites advocate a high degree of endemism. We discussed how the evolutionary history of the Cerrado could produce the floristic structure found. We highlight that a fair knowledge of a peripheral flora of a large phytogeographic domain is the start point for understand what factors and processes have rendered a unique flora. Diversity, endemism, and rarity are issues to be investigated in an attempt to underpin the choice of conservation units and the elaboration of policies to ensure that the maximum of biodiversity will persist in the future for the northeastern cerrado of Brazil.

Keywords: Biogeography, Brazilian savanna, core cerrado, phytogeographic domain,vegetation interchange, woody flora.

Resumo

A vegetação do Cerrado tem muitas fisionomias diferentes, que variam de campo à floresta. Sua área principal ocupa o Planalto Central Brasileiro e tem fronteiras com Amazônia e Mata Atlântica, Caatinga, Chaco e Pantanal. Há também manchas isoladas espalhadas por toda a Amazônia, Mata Atlântica e Caatinga. Incluindo essas manchas, toda a flora lenhosa do Cerrado está distribuída em seis províncias florísticas. Foi investigada a hipótese de que perto dos limites de um grande domínio fitogeográfico, processos biogeográficos poderiam produzir uma estrutura florística diferente em relação à sua área central. Reunimos 160 levantamentos florísticos de áreas de cerrado na Região Nordeste do Brasil, dos quais 64 eram pesquisas de campo do nosso trabalho em equipe, a maioria inéditos. Procedeu-se cálculos simples a fim de avaliar a estrutura da flora lenhosa do cerrado nordestino em níveis de gênero, família, e espécie. Foram registradas 936 espécies em 376 gêneros e 84 famílias. Excluindo as famílias mais ricas, como Fabaceae, Myrtaceae e Asteraceae, houve maior proporção de famílias monogenéricas e monoespecíficas. Foram registradas 54% de gêneros monoespecíficos e 30% destes presentes em apenas um sítio. As espécies mais constantes foram *Qualea parviflora* (129 sítios, 80%), seguido por *Anacardium occidentale* (119, 74%), *Bowdichia virgilioides* (117, 73%) e *Qualea grandiflora* (115, 72%), todavia 443 espécies (47%) foram registradas em apenas um local. Os resultados mostram que a flora lenhosa do cerrado nordestino é muito mais rica do que suposta por muitos autores, com espécies características diferentes do cerrado nuclear. Alta proporção de famílias e gêneros monoespecíficos e famílias monogenéricas e o grande número de espécies restritas a poucos locais defendem um alto grau de endemismo do cerrado nordestino. Assim, a estrutura florística encontrada para o cerrado nordestino poderia ser fruto da história evolutiva do Cerrado. Um bom conhecimento de uma flora periférica de um grande domínio fitogeográfico é o ponto de partida para compreender quais os fatores e processos tornam uma flora única. Diversidade, endemismo e raridade são questões a serem investigadas na tentativa de sustentar a escolha das unidades de conservação e para elaboração de políticas públicas para garantir que o máximo de biodiversidade venha a persistir no futuro para o cerrado nordestino do Brasil.

Palavras-chave: Biogeografia, savana brasileira, cerrado nuclear, domínio fitogeográfico, intercâmbio de vegetação, flora lenhosa.

Introduction

The Cerrado vegetation main area occupies the central Brazilian Plateau and extends towards north and northwest to Amazonian forest, south and southeast to Atlantic forest, northeast to Caatinga (Seasonal Dry Tropical Forest – SDTF) and southwest to Chaco and Pantanal (large alluvial plains); there are also isolated patches scattered across the Amazon, Atlantic rainforests and Caatinga (Olson et al. 2001, Prance 1996) (Fig. 1). The Cerrado has many different physiognomies, which can be ordered following growing woody biomass (Coutinho 1978, 1990): pure grassland ("campo limpo"), through savanna ("campo sujo", "campo cerrado", "cerrado *sensu stricto*"), to pure forest ("cerradão"). All these physiognomies together are named cerrado *sensu lato* (s.l.; Oliveira-Filho and Ratter 2002). We according to Fiaschi and Pirani (2009) and Batalha (2011), instead of being a biome (Batalha 2011, Coutinho 2006), the Cerrado, with initial uppercase, is a phytogeographic domain, in which many formations with different physiognomies, structures and floras occur. Although many authors use biome as synonym of phytogeographic domain (Fiaschi and Pirani 2009), the term biome also includes the associated fauna (Coutinho 2006). With lowercase, cerrado, or in plural, refers to vegetation types or to the complex of formations (Batalha 2011).

The evolutionary history of the Cerrado and adjacent phytogeographic domains has intensively been discussed for many years. For instance, Cole (1960) reviewed classic works between 1872 and 1956 on the savanna vegetation of Latin America and concluded that they attributed the current savanna distribution to rainfall periodicity, moisture deficiency, soil conditions, influence of fire, or a combination of these factors. Although Cole (1960) made some considerations about the Cerrado origin and the dynamic nature of its vegetation in relation to landscape evolution and climatic change in a purely descriptive way, her opinions are still nowadays discussed, as, for example: (1) She investigated the floristic relationships between the grassy savanna, caatinga and forest, and suggested that these formations are in a constant flux of propagules; (2) Near the limits of their distribution, the composition is subject to dynamic change; therefore, any modification of the local environmental conditions leads to the expansion of one type and the shrink of another; (3) The cerrado s.l. is constituted by species of an ancient flora and was once continuously widespread; and (4) Today, only remnants survive, the large tract in central Brazil represent the centre or core area, and the outliers in eastern Brazil and north of the Amazon representing relict communities, whereas the rainforests and the caatinga seem to have a more recent origin.

Other authors also discussed the floristic relationships between the core cerrado and marginal areas and between the Cerrado and adjacent phytogeographic domains. Rizzini (1963) stated that the core cerrado has the highest proportion of “peculiar” species, which are exclusive to the cerrado, whereas the marginal and disjunct areas have some proportion of “accessory” species, which come from the neighbor formations (Eiten 1972, Fernandes and Bezerra 1990, Rizzini 1963). Rizzini (1963) found a proportion of accessory species about 58%, whereas Heringer et al. (1977), 56%. More recently, Méio et al. (2003) found 59% of cerrado accessory species with a prevalence (45%) of Atlantic species, however, for all cerrado. Sarmiento (1983) analyzed the relationships among South American phytogeographic domains considering the genus level as a more adequate analytical tool for providing a wider evolutionary perspective of floristic changes. He observed that the flora of the neotropical savanna is much more akin to rain than to dry forests, and distinguished peculiar genera, which are exclusive to or have many species in the cerrado and a few in the forest, and accessory genera, which have many species in the forest and a few in the cerrado. He concluded that the occurrence of closely related species both in the savanna and in the neighbor forest suggests a long interplay between these formations (Sarmiento 1983). The interchanges of floristic stocks between phytogeographic domains may be attributed to successive expansions and contractions in their areas during alternating dry and wet climatic phases in the Tertiary and Quaternary (Eiten 1972, Sarmiento 1983).

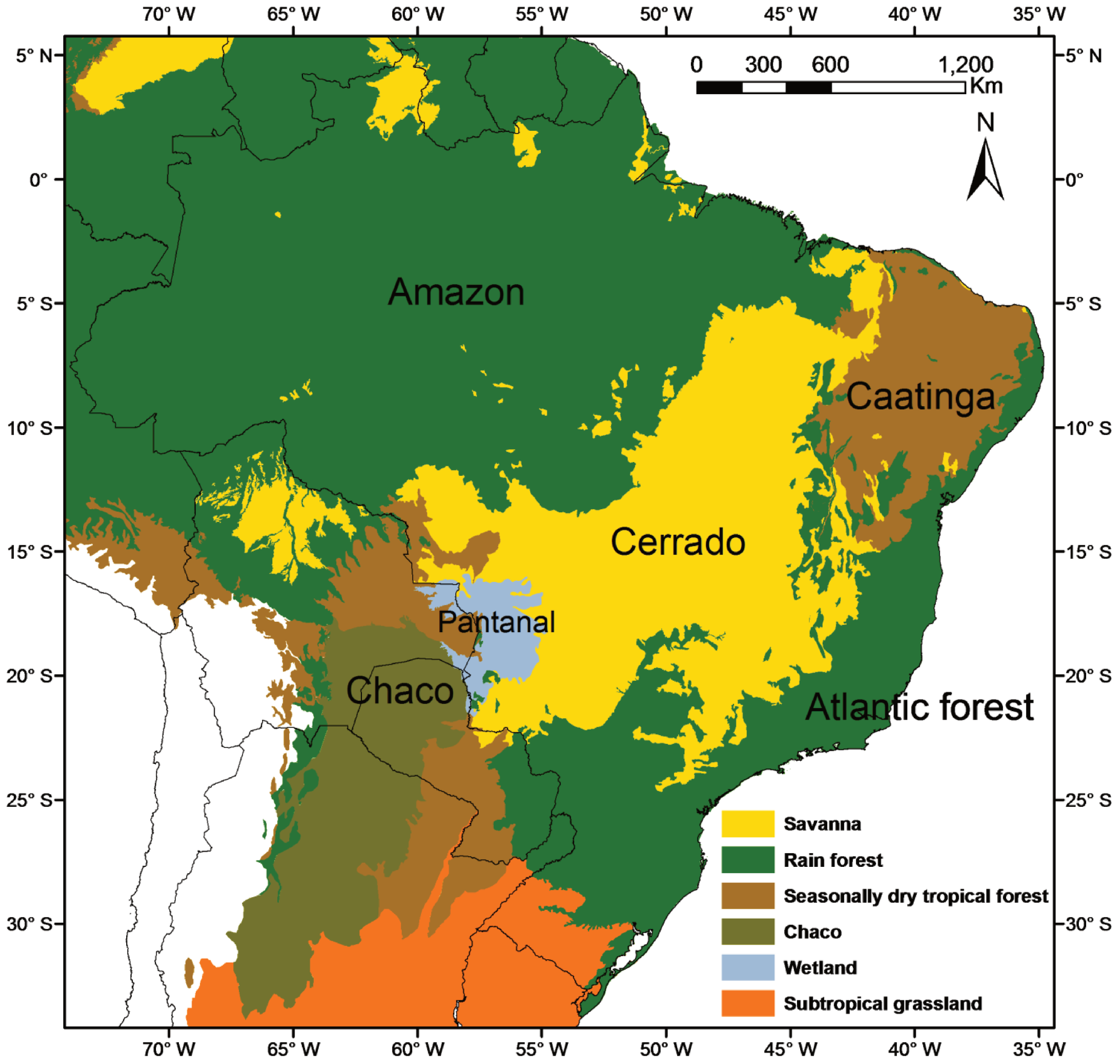

Fig. 1. Map of the major phytogeographic domains of South America, showing the Brazilian Cerrado and their boundaries. Map based on Olson et al. (2001).

Nowadays, the historical biogeography is undergoing a “Renaissance” due to new methods, especially in paleogeography, phylogeography, phylochronology and others (Werneck 2011), which have contributed to investigate the origins of the Cerrado and the complex relationships between the Cerrado and the surrounding phytogeographic domains. It is speculated that the origins of the Cerrado began in prototypic form in the Cretaceous, before the final separation of South America from Africa, ca. 100 mya (Ratter et al. 1997). The isolation of South America during the Tertiary left a strong imprint on the flora of the Neotropics (Burnham and Graham 1999), but the molecular dating of plant phylogenies have shown that the arrival of several lineages in South America happened after its separation from Africa (Fiaschi and Pirani 2009). Families such as Lauraceae, Melastomataceae, Annonaceae, Moraceae, Burseraceae and Malpighiaceae, occur in both Africa and the Neotropics. However, this pattern has been explained not due to the break-up of Gondwana (Pennington et al. 2006), but through migration via ‘boreotropical’ forests that were present at high latitudes during the early Tertiary, a period of high global temperature (Lavin and Luckow 1993, Tiffney 1985a, b, Wolfe 1975). As suggested by phylogenetic and paleontological studies with Arecaceae (Trénel et al. 2007) and Proteaceae (Barker et al. 2007, Morley 2003), some island chains may have permitted dispersal routes for floristic exchanges between the two continents during the Late Cretaceous/Early Tertiary (K/T) boundary, about 65 mya (Fiaschi and Pirani 2009, Morley 2003, Pennington and Dick 2004). A transoceanic long-distance dispersal mechanism it is also plausible for Leguminosae (Lavin et al. 2004), which dominates tropical rain and dry forests and woody savannas of both the Neotropics and Africa (Pennington et al. 2006). Thus, the long period of geographic isolation of South America between the break-up of Gondwana ca. 100 mya and the closure of the Isthmus of Panama ca

3 mya, implies a flora development *in situ* with little contribution of immigrant taxa (Burnham and Graham 1999, Gentry 1982, Raven and Axelrod 1974).

Palynological studies suggest no strong evidence for the existence of neotropical rainforests before the early Tertiary ca. 60 mya. (Burnham and Johnson 2004), although some lineages typical of closed-canopy tropical rainforests could have existed well before the K/T boundary (Davis et al. 2005). However, palaeontological evidences have indicated that neotropical savannas have a more recent origin than rainforests (Pennington et al. 2006), contrasting with Cole (1960) view. The estimated ages of cerrado lineages span the late Miocene to Pliocene from 9.8 to 0.4 mya, most within less than 4 mya (Simon et al. 2009). The cerrado is dominated by C_4 grasses with C_4 photosynthetic pathway, which is an adaptation derived from the more common C_3 photosynthetic pathway and confers a higher productivity under warm temperatures and low atmospheric CO_2 concentrations (Christin et al. 2008, Tipple and Pagani 2007). C_4 grasses have originated and started to diversify between 32–25 mya in several independent lineages as a consequence of past atmospheric CO_2 decline (Christin et al. 2008, Tipple and Pagani 2007). However, C_4 grasses only became ecologically dominant ca. 4–8 mya (Cerling et al. 1997, Jacobs et al. 1999), thus agreeing with the origins of the major cerrado lineages ca. 4 mya (Simon et al. 2009). Thus, the evolution of the cerrado tree flora is synchronous with the expanding dominance of C_4 grasses in the Pliocene and would have occurred as *in situ* adaptations to fire (Simon et al. 2009). This hypothesis is evidenced by the convergent morphological adaptations to fire in the cerrado flora, such as thick corky bark, geoxylic suffruticose growth, developed underground systems and woody shoots, stipules and other structures protecting the shoot apex against fire, and others (Simon et al. 2009).

Considering that most of the cerrado woody flora has evolved only ca. 4mya, then relatively recent diversification and fire adaptation (Simon et al. 2009), probably associated to capability of the cerrado flora to survive in low nutrient levels and high level of aluminum, frequently in toxic levels (Furley and Ratter 1988), must have produced the high percentage of endemic plant species (Pennington et al. 2006), as is fact (e.g. Myers et al. 2000). However, this recent, fast *in situ* evolution does not explain the high proportion of accessory species from Atlantic and Amazonian forests and Caatinga or their closely related species as mentioned above. Thus, if rainforest and savanna species are consistently resolved as pairs of sister species, then switching of habitat must have played a predominant role in the generation of both cerrado and forest diversity (Pennington et al. 2006). During the Tertiary, the geologic and biotic records apparently show long periods of uniform environmental conditions, sporadically interrupted by geologically short but highly disruptive periods of changes (Ortiz-Jaureguizar and Cladera 2006). Contrarily, climatic oscillations with large amplitude seem to have often happened during the Quaternary, imposing chorological changes, expanding or contracting the distribution areas of taxa, communities, and biomes (Ortiz-Jaureguizar and Cladera 2006).

Some authors tried to reconstruct the climatic changes during the Quaternary, especially with palynological records. Sites that today are cerrado probably were dominated by rainforest during humid climatic shifts between 30 and 23 ka B.P., 13 and 11 ka B.P., 9.5 and 5.5 ka B.P., intercalated by dryer periods with absence of rainforest in central Brazil (Ledru 1993). Similar dry phases were recorded in other sites in central Brazil (Salgado-Labouriau et al. 1998), but some sites could show a trend towards delaying dryness to the south of the continent (Salgado-Labouriau et al. 1997). Palynological studies also indicate that in the Holocene, between 7,000 and 4,000 years B.P., climate started to become similar to the present conditions in central Brazil (Behling and Hooghiemstra 2001, Salgado-Labouriau et al. 1998, Salgado-Labouriau et al. 1997). Also, in the Holocene fire was frequent in the cerrado as suggested by many studies (Ledru et al. 2006, Pessenda et al. 2004, Salgado-Labouriau et al. 1997, Salgado-Labouriau and Ferraz-Vicentini 1994). Events of expansion and retraction associated with climatic oscillations were documented in the cerrado southern (Behling 1998) and northeastern limits (Behling et al. 2000, Ledru et al. 2006). Pollen records have also suggested a moderate expansion of the cerrado over the Amazon at the last glacial maximum ca. 25,000-13,000 B.P. (Haberle and Maslin 1999, Hermanowski et al. 2012, van der Hammen and Absy 1994).

This highly dynamic evolutionary history of the Cerrado woody flora is thought to imply a strong geographic pattern. The Cerrado woody flora is distributed into six floristic provinces: southern, central-southeastern, central-western, far-western, northeastern, and disjunct Amazonian patches (Castro 1994a, b, Ratter et al. 1996, Ratter et al. 2001, Ratter et al. 2003, Ratter and Dargie 1992). Each province has a different flora with a significant number of exclusive species (Ratter et al. 2003), which could broadly be the outcome of current climatic factors (Castro 1994a, b, Castro et al. 1999), altitude and soil type (Ratter and Dargie 1992), and biogeographic processes presided by climatic oscillations in the Tertiary and Quaternary periods (Ratter et al. 2003). Bridgewater et al. (2004) analyzed the same databank of Ratter et al. (2003) and found only 121 widespread ‘oligarch’ species, which dominate the arboreal vegetation of most cerrado sites, whereas the other 830 species have restricted distributions. Rizzini (1963, 1979) and Castro and Martins (1999) hypothesized that species richness would be highest in the core cerrado sites, where peculiar species would dominate, whereas marginal sites would have low species richness and the presence of accessory species coming from the neighbor formations.

Here we investigated the hypothesis that near the limits of a large phytogeographic domain biogeographic processes could produce a different floristic structure in relation to its central area. In order to improve our investigation, we posed the following questions as guidelines: (1) Would the flora of the northeastern marginal area be impoverished in relation to that of the core area? (2) Analyzing the current composition of the woody flora, is it possible to infer about the evolutionary history of the northeastern Brazilian cerrado? We hope that answering these questions could contribute a sound background to the elaboration of conservations plans in order to protect the current and the future biodiversity of areas with similar interactions among distinct phytogeographic domains in other parts of the world.

Material and Methods

The cerrado northeastern

According Bridgewater et al. (2004), a total of 333 woody species was sampled in 67 surveys that recorded 57 species exclusive to the northeastern cerrado province, rendering this province the fourth in species number and endemism. Rizzini (1976) and Heringer et al. (1977) had already claimed that the woody flora of the cerrado northeastern, particularly in the states of Maranhão and Piauí, is very different from that of the core area. However, simple calculations of Sørensen similarity indices from the figures of Bridgewater et al. (2004) result that the northeastern province has the highest mean of similarity (0.477) with the other five provinces and the highest similarity with Amazonian disjunct patches (0.363) and far-western provinces (0.458).

The cerrado northeastern has been claimed to be unique due to its particular climate and soil (Castro et al. 1998). Two climatic barriers are thought to influence the distribution of the cerrado woody flora: the frost polygon south of 20º S and the dry polygon north of 15º S (Castro 1994a, b, Castro and Martins 1999). The cerrado northeastern is included in the dry polygon, where the rainy season is short with unpredictable rains, although the yearly average total rainfall is similar to that of most part of the core cerrado (Castro et al. 1998). Also, during the rainy season, the northeastern is frequently affected by long periods of drought, about fifty days without rain (Assad et al. 2001), which could be interpreted as an Indian summer. Annual average temperatures range from 23º C to 27º C, being the highest all over the Cerrado (Silva et al. 2008). According to Castro and Martins (1999), the cerrado northeastern occurs in lower altitudes (0-500 m) than the central plateau (900-1200 m) and southern cerrado (500-900 m). As in the whole Cerrado, Latosols and Arenosols predominate (Reatto et al. 2008), but Castro et al. (1998) observed that the soils show evidence of hydric seasonality with greater presence of concretions, plinthite, and generally lighter colors, which may be interpreted as indicating large fluctuations of the water-table during pedogenesis. Plinthosols are also well represented in the cerrado northeastern, especially in Piauí and Maranhão states (Reatto et al. 2008). These soils are typical of hyperseasonal savannas, which are stressed by a long period of drought during the dry season and by waterlogging in the rainy season (Sarmiento 1983).

Floristic databank

To construct a databank we considered both metadata and new data coming from field surveys we did along a ten-year project (Castro et al. 2007). The metadata were gathered from surveys of cerrado sites in the Brazilian Northeastern Region, provided that the surveyors considered the vegetation as belonging to a cerrado physiognomy. We considered government reports, presentations on symposiums, meetings and congresses, scientific papers, including local publications, theses and dissertations published until November 2011, but kept only the contributions that provided adequate information on the locality and respective geographic coordinates (Appendix A). We also incorporated the databank of the project Conservation and Management of the Biodiversity of the Cerrado Biome (CMBBC; Ratter et al. 2011) used by Ratter et al. (2003) to indicate the six cerrado floristic provinces, available online (http://cerrado.rbge.org.uk/cerrado). We also included five unpublished surveys from Ratter et al. (2011) available online (http://cerrado.rbge.org.uk/cerrado).

Although the cerrado northeastern province includes a narrow belt in the eastern-northeastern Tocantins state and extreme northwestern Minas Gerais state (Ratter et al. 2003), we took into account the political division and considered the states of Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, and Bahia as constituting this floristic province (Fig. 2). We assumed that considering political division rather than the “natural” limits of the northeastern floristic province would be more convenient because policies are elaborated according to the division of the Brazilian territory in geographic regions, of which the Northeastern Region is constituted by the states named above. Besides, sharp political limits are easily distinguishable and comparable.

We selected 160 surveys, out of which 64 were field surveys from our team and 96 were performed by other authors (Fig. 2; Appendix A). The surveys were done using different methods and sampling designs (Appendix A), but following Ratter and Dargie (1992), Ratter et al. (1996) and Ratter et al. (2003) for the cerrado, and Caiafa and Martins (2007) Atlantic Forest, we considered these floristic lists as qualified data for comparison and suitable for statistical analyses. Caiafa and Martins (2007), for instance, showed that the size of the smallest individual sampled has greater influence on the results than the sampling method itself and that the sample size, which should not to be less than 1000 individuals, is more important than the area sampled. There is no similar study for the cerrado, but all available information for each survey we considered in our analysis is in the Appendix A.

After gathering the information, we obtained a raw floristic list, which was synonymized to the original binomials with the aid of the websites Missouri Botanical Garden VAST (W^3Tropicos 2011) and The Species List of Flora of Brazil (Forzza et al. 2010). We prioritized the accepted names found in (Forzza et al. 2010) in order to keep standardized the information in Brazilian system. Taxonomic systematization was arranged according to the Angiosperm Phylogeny Group III (APG APG III 2009) for angiosperms. With the aid of literature (e.g. Mendonça et al. 1998, Mendonça et al. 2008), herbarium collections (speciesLink 2011), and field observation we classified each binomial as liana, palm, herb, subshrub, shrub, treelet and tree. According to its ontogenetic stage and the environmental

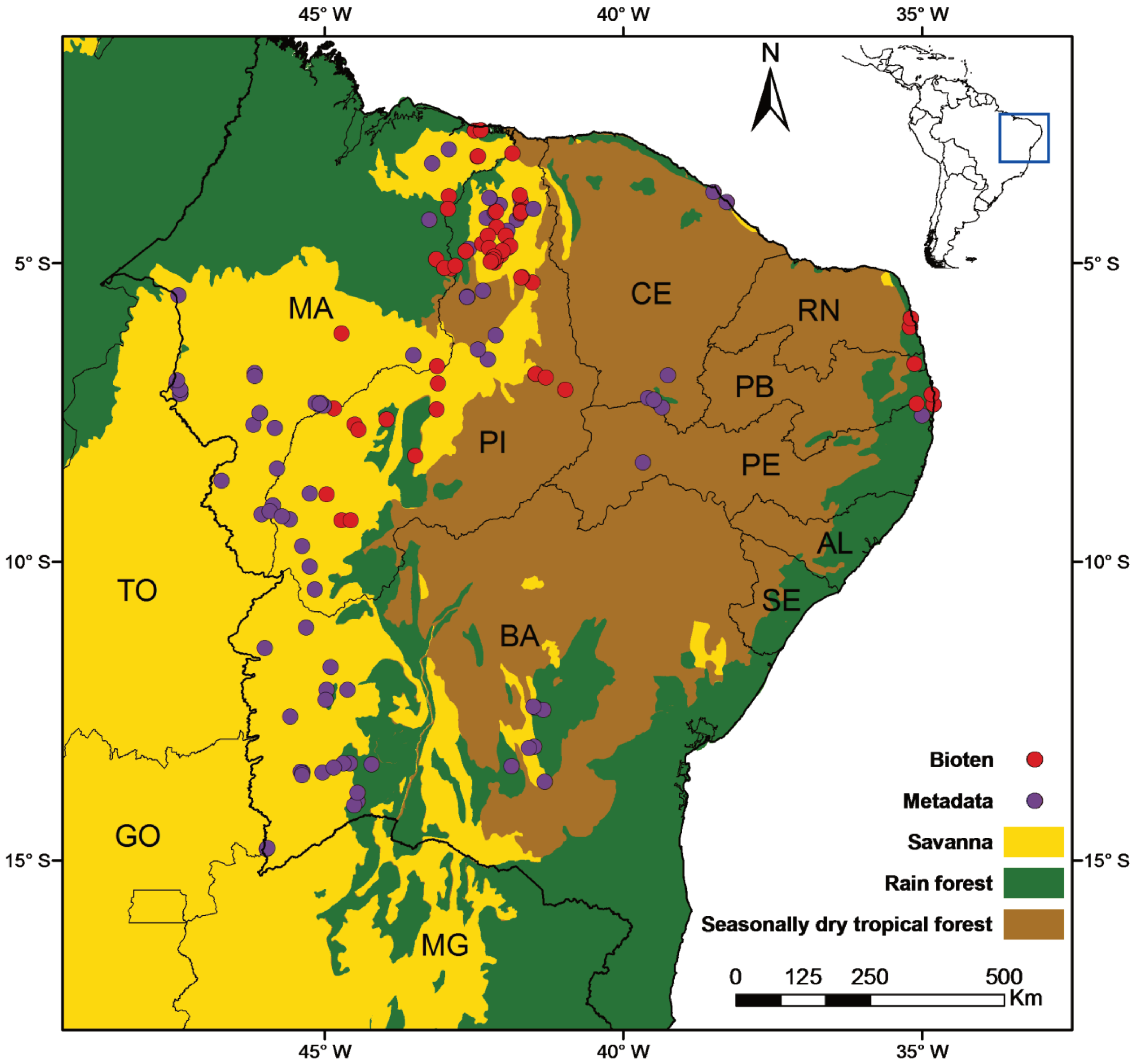

Fig. 2. Map of cerrado northeastern of Brazil showing the surveys gathered from metadata (red circles) and Bioten Program (purple circles). States: MA-Maranhão, PI-Piauí, CE-Ceará, RN-Rio Grande do Norte, PB-Paraíba, PE-Pernambuco, AL-Alagoas, SE-Sergipe, BA-Bahia, MG-Minas Gerais, GO-Goiás, TO-Tocantins.

conditions of the site where it had been surveyed, a species could be classified in more than one growth-form. Then, we filtered out every species that may be classified as liana or herb and kept only truly woody species. We also excluded exotic species of Brazil, and were left with a refined floristic list, upon which we based our analysis.

Binomials with dubious identification (*aff.* or *cf.* species) were kept in our databank because we think that such taxonomic doubts could indicate ongoing speciation processes due to special local environmental conditions and isolation. We also kept incompletely identified taxa, such as those identified only to genus or family, and those totally unknown, because we think that these taxa can give a fair idea of both the magnitude of the flora richness and the degree of taxonomic difficulty in dealing with this flora. In refined analyses we excluded dubious identifications.

We called this databank as FLORACENE, an acronym for FLOra of the CErrados of the NorthEastern Brazilian Region. Most of field surveys from our team presented here are inedited, as an outcome of a project developed as part of the Biodiversity Program of the Northeastern Ecotonal Tropic (Bioten) which represents the end of a 10 year-long project named Northeastern Marginal Cerrados – Biodiversity and Fragmentation of Ecosystems of the Northeastern Marginal Cerrados under the Brazilian Long Term Ecological Research Program (LTER).

Analysis

We followed Turner (1994), Castro et al. (1999) and Ratter et al. (2003) to analyze the tree flora of the northeastern cerrado of Brazil. We computed the lower, intermediary and upper limits of the number of species, genera and families. For the lower limit we considered only the taxa completely identified. For the intermediary limit we considered the dubious binomials and the genera and families that were not completely identified, but we did not consider the unknown taxa. For the upper limit we considered all records in the FLORACENE, and attributed the status of a different new taxon to each unknown or incompletely identified taxon. We proceeded with these calculations in order to estimate the northeastern province richness and to quantify taxonomic deficiencies.

We computed the number of genera and species per family, and the number of species per genera. We calculate the constancy for species, genera and families as the percentage of samples with the taxon presence in relation to the total number of our 160 samples (Cain 1938). Following Turner (1994), we considered a genus or family to be monospecific if they had only one species or genus. For these computations we considered only the confidently identified binomials in order to avoid uncertainty. All computations were performed in R statistical language and environment (R Development Core Team 2011).

Results

Considering only the confidently identified taxa, the lower limits of the flora richness would be 936 species, 376 genera and 84 families. The dubious identifications referred to 115 *cf.* and 31 *aff.* binomials, out of which 32 and 15, respectively, was not already appeared in our databank as confidently identified binomials. Disregarding the 83 *cf.* and 16 *aff.* duplicates and considering incomplete identifications, we arrived at an intermediate limit of 983 species, 383 genera and 84 families. When we considered all unknown or dubious taxa as potentially new families, genera and species, the upper limits had 270 families (89 identified, 181 unknowns), 608 genera (405 identified, 12 dubious and 191 unknowns), and 2,254 species (936 identified, 146 dubious and 1,172 unknown). These results are summarized in Table 1.

Table 1. Lower, intermediary and upper limits of richness in species, genus and family level found in 160 surveys of northeastern cerrado of Brazil.

	Lower Limits	**Intermediary Limits**	**Upper Limits**
Species	936	983	2254 (146 dubious and 1172 unknowns)
Genera	376	383	608 (191 unknowns)
Families	84	84	270 (181 unknowns)

The largest number of genera (70) was shown by Fabaceae, followed by Asteraceae (28), Rubiaceae (20), Malvaceae (15), Euphorbiaceae (13), Apocynaceae (12), Arecaceae (11) and Melastomataceae (11) (Fig. 3). We recorded 32 monogeneric families (38%), 18 families were represented by two genera (21.4%), and six by three genera (7.1%) (Appendix B). The most speciose family was also Fabaceae with 214 species, followed by Myrtaceae (46), Asteraceae (40), Malpighiaceae (39), Rubiaceae (39), and Euphorbiaceae (38) (Fig. 4). We recorded 19 monospecific families (22.6%), 10 families were represented by two species (11.9%), and five by three species (5.9%) (Appendix B). The more constant family was Fabaceae, present in 158 surveys out of 160, which represents 98.75%, followed by Vochysiaceae (90%), Anacardiaceae (88.12%), Apocynaceae (82.5%), Combretaceae (80.62%) and Malpighiaceae (80.62%). Eleven families were recorded in only one site, nine in two sites, and four in three sites (Appendix B).

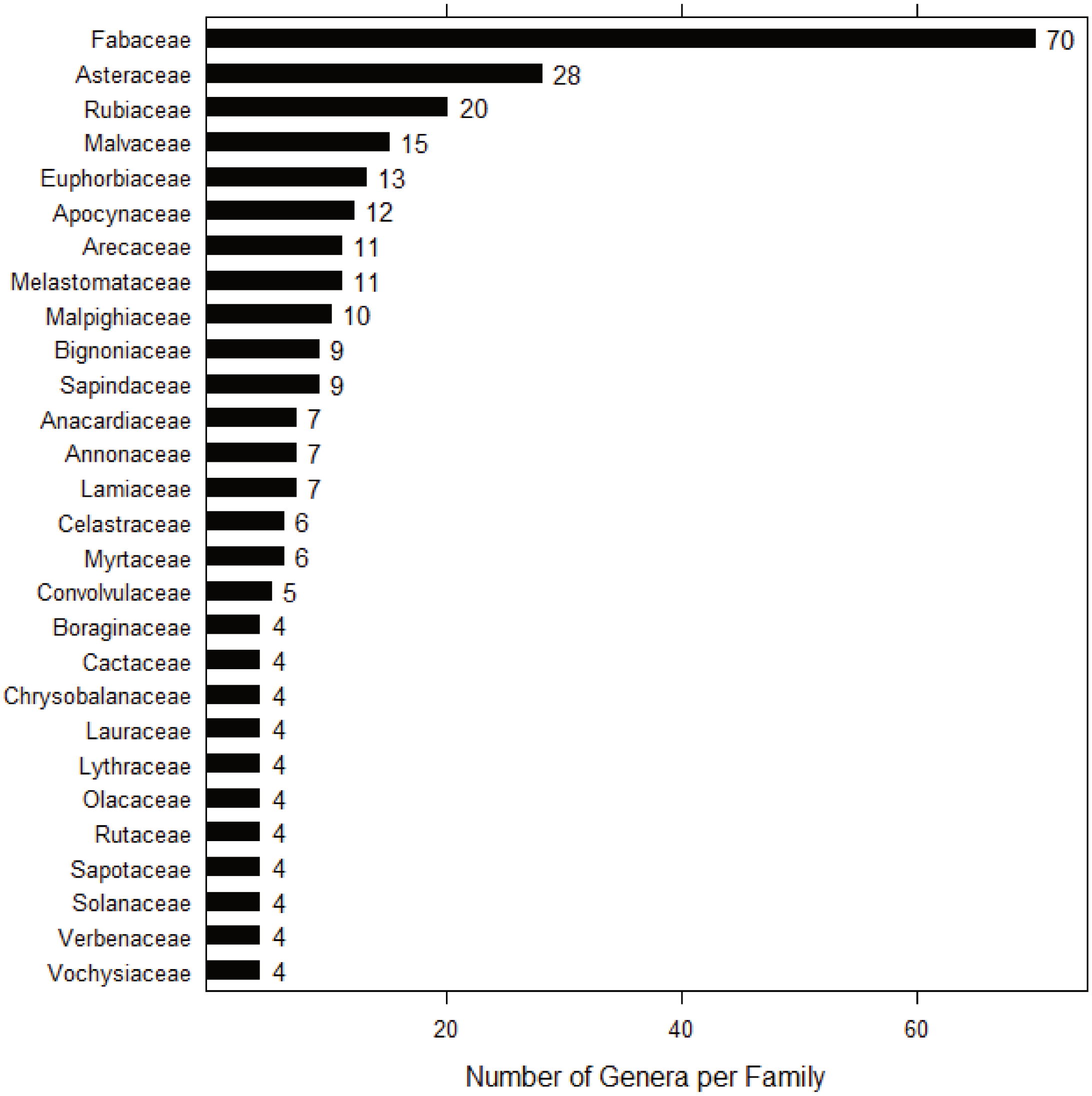

Fig. 3. Genera number per family of woody flora of the northeastern cerrado of Brazil. Families with more than 3 genera are shown.

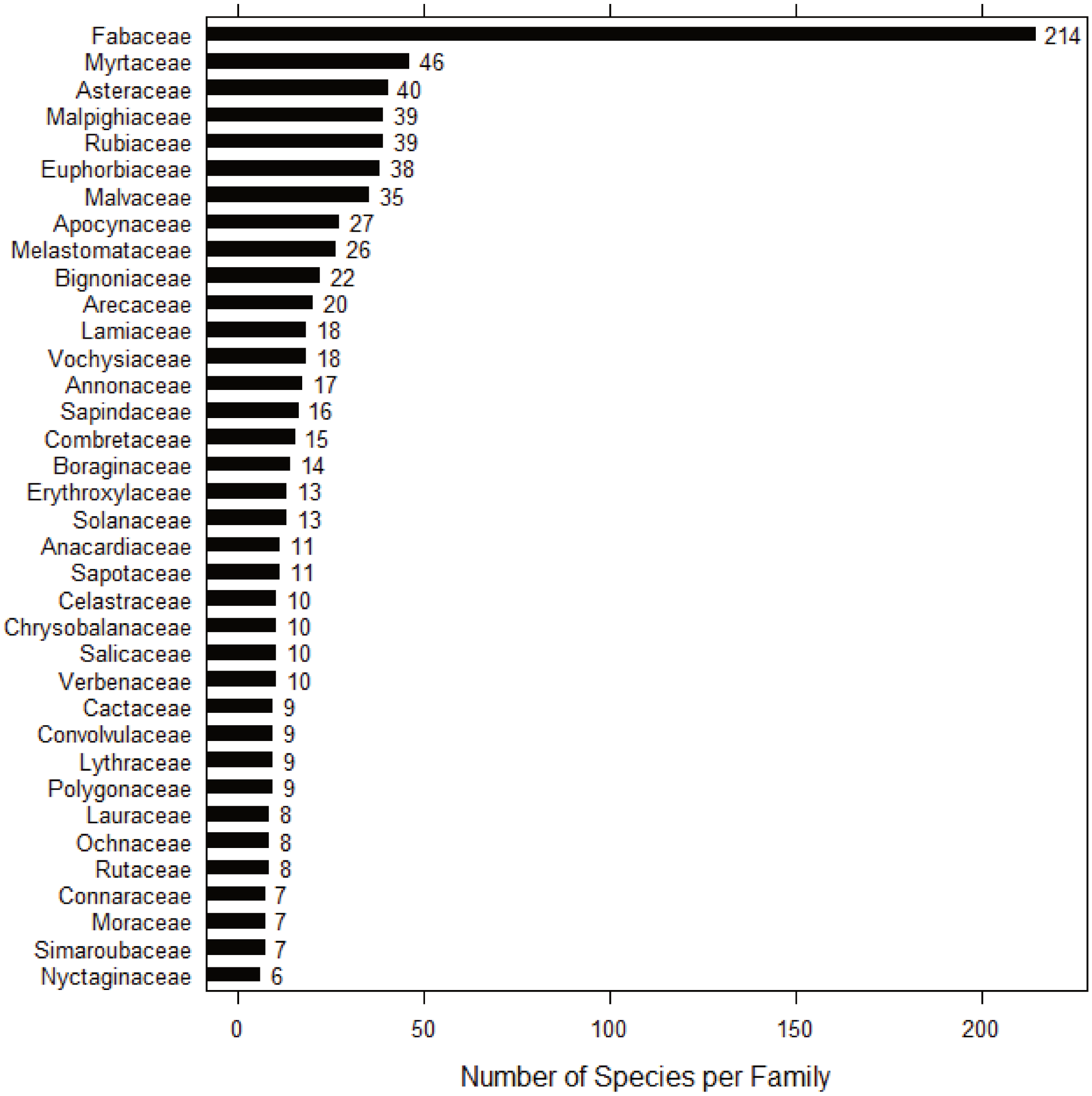

Fig. 4. Species number per family of woody flora of the northeastern cerrado of Brazil. Families with more than 5 species are shown.

The largest number of species occurred in the genus *Byrsonima* (Malpighiaceae) with 21 species, followed by *Senna* (Fabaceae, 20), *Chamaecrista* (Fabaceae, 18), *Myrcia* (Myrtaceae, 18), *Bauhinia* (Fabaceae, 16) and *Mimosa* (Fabaceae, 15) (Fig. 5). We recorded 205 monospecific genera (54.5%), 70 genera were represented by two species (18.6%), and 32 by three species (8.5%) (Appendix C). The more constant genus was *Qualea*, present in 136 surveys out of 160, which represents 85%, followed by *Byrsonima* (124 sites, 77.5%), *Anacardium* (121 sites, 75.6%), *Bowdichia* (117 sites, 73.1%), *Annona* (106 sites, 66.2%) and

Caryocar (106 sites, 66.2%). We recorded 113 genera that were present in only one site, 55 in two sites, and 29 genera in three sites (Appendix C).

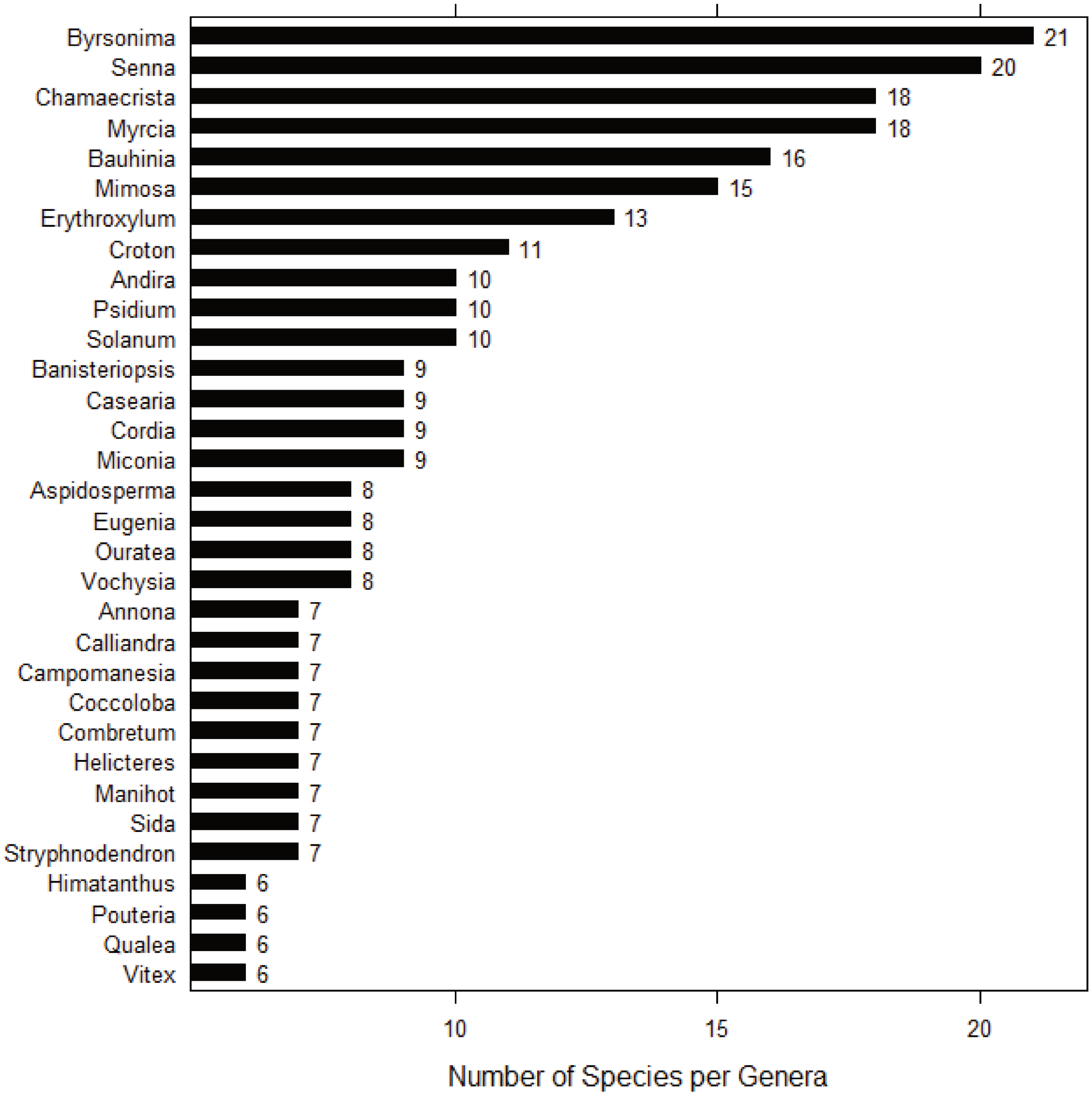

Fig. 5. Species number per genera of woody flora of the northeastern cerrado of Brazil. Genera with more than 5 species are shown.

The more constant species were *Qualea parviflora*, which was present in 129 (80.62%) sites out of the total 160 surveys, followed by *Anacardium occidentale* (119 sites, 74.38%), *Bowdichia virgilioides* (117 sites, 73.12%), *Qualea grandiflora* (115 sites, 71.88%), *Salvertia convallariodora* (98 sites, 61.25%), *Curatella americana* (95 sites, 59.38%), *Vatairea macrocarpa* (94 sites, 58.75%) and *Parkia platycephala* (92 sites, 57.5%) (Fig. 6).

We recorded 443 species present in only one site, 145 in two sites, 58 in three sites, and 38 species in four sites (Appendix D). Thus, 684 species (73.07% out of the total species) were sampled in up to 2.5% (4) of the sites and only 16 species (1.69%) were present in 50% or more of the sites (80 sites).

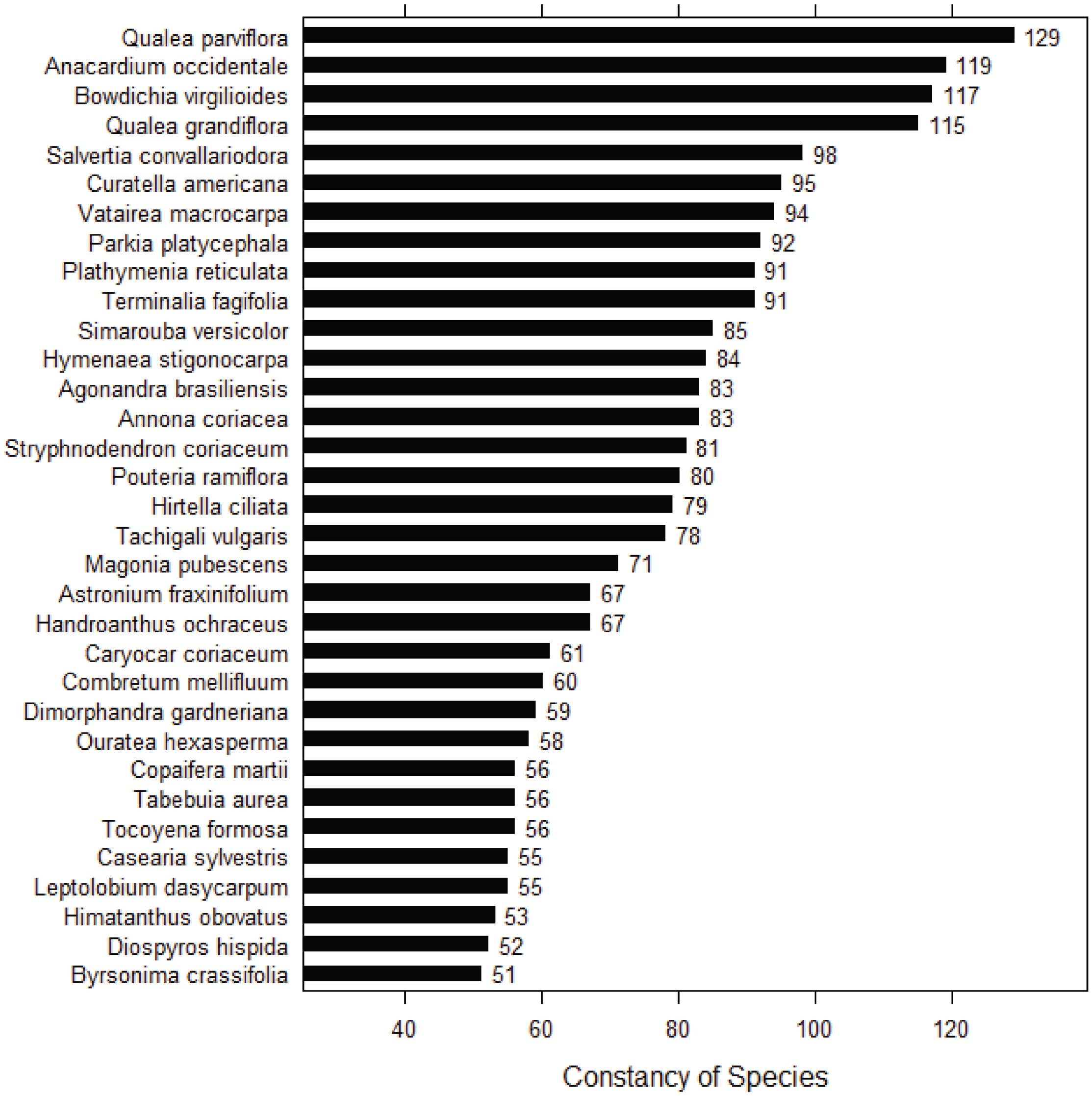

Fig. 6. Constancy of woody flora in the northeastern cerrado of Brazil. Species which occurred in more than 50 sites are shown.

Discussion

Castro et al. (1999) considered the estimations of the upper and lower richness limits to be unreliable, since it is implausible that each of the unknown taxa would be new to the list (upper limits) or that all the unknowns would in fact be taxa that had already been identified (lower limits). The intermediary limits stay close to the lower limits, being increased in 47 species by the dubious binomials, in seven genera and none family. The dubious binomials summed up 146 species, which correspond to ca. 15% of the total number of species completely identified. Different climatic and soils conditions could lead to differentiation of phenotypic traits among cerrado species (Hoffmann et al. 2012, Rossatto 2012), which may occur for species of the cerrado northeastern in relation to the core area. On the other hand, different climatic and soils conditions of the cerrado northeastern could lead to phenotypic differentiation until the speciation in the northeastern populations would be in course. As there are more taxonomists in core cerrado, the diversity of phenotypic traits among core and marginal cerrado species renders difficult the complete identification for cerrado northeastern species.

The number of 936 confidently identified binomials that we recorded in 160 sites of the cerrado northeastern is very close to the tree richness reported so far for the whole cerrado in Brazil. Castro et al. (1999) reported a total of 973 species in 78 sites, whereas Ratter et al. (2003) found 951 species in 376 sites, although, in their recent revision, this number was reduced to 850 species in 367 sites due mainly to synonyms (Ratter et al. 2011). Thus, we found a very rich woody flora in the northeastern province, with many species, genera and families, but great proportions of families with only one genus and/or only one species and monospecific genera. A great proportion of families with only one genus also have appeared in the local community in the cerrado (Batalha and Martins 2007).

Following Sarmiento (1983), we suggest that high proportions of monogeneric families and monospecific genera and families would be an outcome of the alternating vicariant and dispersal events that would have occurred during the climate oscillations of the Quaternary. During the humid-to-dry shifts rainforests occupying large areas of South America would have contracted, leaving behind remnant woody species of different families that would constitute the original lineages leading to speciation in the expanding savanna new environment (Hoffmann and Franco 2003, Simon et al. 2009). Only one to a few genera of each family could thrive in the savanna environment, where they should cope with longer and severer dry seasons, fire recurrence, soil impoverishment, and competition with predominant C_4 grasses, thus evolving *in situ* adaptations, hence, originating new species (see Simon et al. 2009). Conversely, during the dry-to-humid climate shifts, the previously continuous Cerrado would be fragment in isolated patches, thus promoting allopatric speciation. The alternating of these dispersal and vicariance events could be repeated many times following the climatic oscillations, so that the cerrado woody flora would have evolved *in situ* via recent and frequent adaptive shifts to resist fire, rather than via dispersal of lineages already adapted to fire (Simon et al. 2009). The adaptations *in situ* probably also must be occurred due to soil quality and toxicity by aluminum in the cerrado area (Furley and Ratter 1988), but further analysis must be made to confirm this hypothesis.

Very different lineages are thought to have been captured by the expanding savanna new environment (Hoffmann and Franco 2003). However, most of them could only remain as families with only one genus or species, or genera with only one species, thus producing the high proportion of monogeneric families and monospecific families and genera that is currently found in the cerrado woody flora. This probably means that the savanna represented a very harsh environment that only one or a few species evolved *in situ* could withstand. On the other hand, families and genera that could well cope with recurrent drought and fire stresses, and permanent nutrition stress in the savanna environment were able to speciate in many taxa. Sarmiento (1983) stated that the frequent displacements of whole phytogeographic domains along continental distances provided ample opportunities for speciation in isolation in forests and savannas refuges during Quaternary oscillations. This would be the case of high diversity families, such as Fabaceae, Asteraceae, Rubiaceae, Euphorbiaceae, Arecaceae and Myrtaceae, and high diversity genera, such as *Senna, Myrcia, Byrsonima, Mimosa* and *Chamaecrista* in the cerrado northeastern. Thus, comparing these high diversity families among phytogeographic domains would not be enough to provide adequate evolutionary interpretations. For instance, with few exceptions Fabaceae is the most species-rich family everywhere in the world (Pennington et al. 2009); thus, analysis at species and genera levels of taxa occurring in different phytogeographic domains could be more informative for these high diverse families.

The most constant species we found in the cerrado northeastern are not the same found by Ratter et al. (2003) in the core cerrado. For example, in the whole cerrado *Qualea grandiflora* is the most constant species (Ratter et al. 2003), but in the cerrado northeastern we found *Q. parviflora* as the most constant. The second most constant species in the cerrado northeastern, *Anacardium occidentale*, is not even among the 38 most constant species in the whole cerrado. Also, other highly constant species in the cerrado northeastern (*Parkia platycephala, Terminalia fagifolia, Simarouba versicolor*, *Agonandra brasiliensis*, and *Stryphnodendron coriaceum*) are not among the highly constant in the whole cerrado. All these species can be considered the characteristic species of the cerrado northeastern. This result was expected, given that the cerrado northeastern has different environmental conditions from the core cerrado, especially regarding climate and soil. On the other hand, all the 38 most constant species in the whole cerrado (Ratter et al. 2003) occurred in the cerrado northeastern, but their constancy was smaller (Appendix D). In the cerrado northeastern we found 113 species (see Appendix D) out of the 121 widespread ‘oligarch’ species of Bridgewater et al. (2004) for the whole cerrado. Out of the 16 species with constancy ≥ 50% in the cerrado northeastern, only *Stryphnodendron coriaceum* and *P. platycephala* were not included in the widespread “oligarch” species stated by Bridgewater et al. (2004). Following Sarmiento (1983), these oligarch species could be considered part of the few lineages that were able to evolve species that could cope with the different ecological conditions of different cerrado provinces.

Almost 75% of the 936 binomials we recorded in the cerrado northeastern were restricted to less than 4 surveys (2.5% of the surveys). The concept of rarity may be understood as the current status of an extant organism which, by any combination of biological or physical factors, is restricted either in numbers or area to a level that is demonstrably less than the majority of the other organisms of comparable taxonomic entities (Reveal 1981). Therefore, we may infer that most species are rare in the cerrado northeastern since great number of species have restricted distribution.

Our results do not support the hypothesis proposed by Rizzini (1963, 1979) that the woody flora is richer in the core cerrado than in the marginal sites. Ratter et al. (2003) observed similar richness between core and marginal sites in Araguaia and Xingu rivers and São Paulo state. Also, they stated that the marginal sites had a flora of peculiar savanna species, without a significant proportion of accessory species. We were not able to distinguish whether the richness of cerrado northeastern were outcome of incoming accessory species from adjacent phytogeographic domains. To assess whether a marginal site contains accessory species, each species should be classified as "peculiar" or "accessory", and in order to do this it is necessary to gather information of the woody flora of all adjacent phytogeographic domains, in our case the Atlantic Forest, Caatinga, Amazonian Forest and the core cerrado. Future investigation is needed on this issue. Sarmiento (1983) concluded that two groups of genera constitute the characteristic woody elements of the neotropical savannas, either by their exclusive occurrence or by their greater evolutionary radiation: one with species growing in the cerrado and other savanna-like formations, often monospecific genera, such as *Bowdichia virgilioides*, *Curatella americana*, *Magonia pubescens* and *Salvertia convallariodora*; and another group with genera having species in the rainforest and a larger number of species exclusive to the Cerrado, such as *Anarcardium*, *Byrsonima*, *Kielmeyera* and *Stryphnodendron* (Gottsberger and Silberbauer-Gottsberger 2006). Both groups of genera were well represented in the cerrado northeastern.

We showed that the woody flora of the cerrado northeastern is much richer than supposed by many authors. The higher proportion of monospecific families and genera and monogeneric families associated with a greater number of species restricted to up to four sites would advocate the high degree of endemism of this province. The most constant species are characteristic of the cerrado northeastern, since they have a lower constancy in other provinces. Also, the woody floristic structure of the cerrado northeastern seems to reflect the recurrent alternations of dispersal and vicariant biogeographic processes during the climatic oscillations in the Tertiary and Quaternary in South America. Therefore, during the evolutionary history an intense interchange occurred between the Cerrado and the neighbor rainforests and Caatinga. Thus, we propose two broad processes of evolutionary speciation: during the cerrado dispersal events a “savanna capture process” would occur, when the expanding savanna new environment selected lineages left behind by the shrinking forests; whereas during the cerrado vicariant events a “savanna dropping process” would take place, when savanna lineages were dropped in the expanding forests during by the retracting cerrado. The diversity of the most rich ecosystems of the world, namely the Cerrado, the Atlantic and the Amazon forest (Fiaschi and Pirani 2009) would have been influenced by this recurrence of capture and dropping processes. A fair knowledge of a flora is the start point for many other researches in order to understand what factors and processes have rendered the flora of the cerrado northeastern so rich in species and so different from the core cerrado. Considering that the interchange between the cerrado and neighbor vegetation during evolutionary time would be one of the causes of the high diversity of both cerrado and forest formations in South America, conservation policy should guarantee the continuity of the evolutionary processes and consider all natural vegetation formations in a regional context. Thus, the whole cerrado northeastern, including the disjunct areas, must be preserved, however, diversity centers, sites of endemism, and forms and causes of rarity are issues to be investigated in an attempt to underpin the choice of conservation units and the elaboration of policies to ensure that the maximum of biodiversity will persist in the future.

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Appendix A. Surveys of northeastern cerrado of Brazil compiled in this study and their references. States: BA-Bahia, CE-Ceará, MA-Maranhão, PB-Paraíba, PE-Pernambuco, PI-Piauí, RN-Rio Grande do Norte; Alt: altitude; SM: Sampling methods - PCQM: Point-Centered Quarter Method. Area in hectare when pertinent. NS: Total number of species, including dubious species and incomplete identification/Number of species confidently identified. References of surveys are after the table. † number may be different from original work due to synonymization or growth-form categorization; * data available from Ratter et al. (2011).

Code	State	Municipally	Locality	Longitude	Latitude	Alt	SM	Area (ha)	NS†	References
1	BA	Correntina	Chapada do Espigão Mestre do São Francisco	45W 18' 35"	11S 06' 12"	550	Plots	1	64/58	Felfili & Júnior (2001)
2	BA	Formoso do Rio Preto		46W 00' 00"	11S 27' 00"		Plots/ Transect		63/62	Walter & Ribeiro (1996)*
3	BA	Riachão das Neves		44W 54' 00"	11S 46' 00"		Rapid survey		48/48	Ratter et al. (2001)*
4	BA	Barreiras		44W 58' 00"	12S 09' 00"		Rapid survey		56/56	Ratter et al. (2001)*
5	BA	Barreiras		44W 37' 00"	12S 09' 00"		Rapid survey		42/42	Ratter et al. (2001)*
6	BA	São Desidério		44W 59' 00"	12S 19' 00"		Rapid survey		50/50	Ratter et al. (2001)*
7	BA	Lençóis		41W 30' 00"	12S 26' 00"		Rapid survey		41/41	Ratter et al. (2001)*
8	BA	Palmeiras	Chapada Diamantina (Ponto 36), Campos de São João	41W 28' 10"	12S 26' 55"	829	Plots	0.1	12/7	Harley et al. (2005)
9	BA	Lençóis		41W 20' 00"	12S 29' 00"		Rapid survey		41/41	Ratter et al. (2001)*
10	BA	São Desidério	Chapada do Espigão Mestre do São Francisco	45W 34' 48"	12S 35' 46"	695-775	Plots	1	67/66	Felfili & Júnior (2001)

Code	State	Municipally	Locality	Longitude	Latitude	Alt	SM	Area (ha)	NS†	References
11	BA	Mucugê	Chapada Diamantina (Ponto 41)	41W 29' 06"	13S 05' 52"	1150	Plots	0.1	61/43	Harley et al. (2005)
12	BA	Mucugê	Chapada Diamantina (Ponto 68)	41W 34' 39"	13S 07' 12"	1195	Plots	0.1	52/42	Harley et al. (2005)
13	BA	Correntina		44W 41' 00"	13S 23' 00"		Rapid survey		54/54	Ratter et al. (2001)*
14	BA	Correntina	Fazenda Jatobá	44W 41' 00"	13S 23' 00"		-		79/78	Andrade & Machado (1991-1993)*
15	BA	Correntina		44W 35' 00"	13S 23' 00"		Rapid survey		54/54	Ratter et al. (2001)*
16	BA	Santa Maria da Vitória		44W 13' 00"	13S 24' 00"		Rapid survey		28/28	Ratter et al. (2001)*
17	BA	Rio de Contas	Chapada Diamantina (Ponto 07)	41W 52' 15"	13S 25' 39"	1266	Plots	0.1	118/96	Harley et al. (2005)
18	BA	Correntina		44W 51' 00"	13S 27' 00"		Rapid survey		33/33	Ratter et al. (2011)*
19	BA	Rio das Eguas		45W 24' 00"	13S 31' 00"		Rapid survey		52/52	Ratter et al. (2011) *
20	BA	Formosa do Rio Preto	Chapada do Espigão Mestre do São Francisco	45W 22' 25"	13S 31' 46"	586	Plots	1	67/64	Felfili & Júnior (2001)
21	BA	Correntina		45W 02' 00"	13S 32' 00"		Rapid survey		28/28	Ratter et al. (2011)
22	BA	Posto Nova Italia		45W 23' 00"	13S 33' 00"		Rapid survey		42/42	Ratter et al. (2011)
23	BA	Posto Nova Italia		45W 23' 00"	13S 35' 00"		Rapid survey		41/41	Ratter et al. (2011)

Code	State	Municipally	Locality	Longitude	Latitude	Alt	SM	Area (ha)	NS†	References
24	BA	Barra da Estiva	Chapada Diamantina (Ponto 42)	41W 18' 54"	13S 41' 10"	1210	Plots	0.1	50/33	Harley et al. (2005)
25	BA	Coribe		44W 27' 00"	13S 52' 00"		Rapid survey		53/52	Ratter et al. (2001)*
26	BA	Cocos		44W 27' 00"	14S 01' 00"		Rapid survey		54/53	Ratter et al. (2001)*
27	BA	Cocos		44W 30' 00"	14S 05' 00"		Rapid survey		54/53	Ratter et al. (2001)*
28	BA	Jaborandi	Fazenda Trijuncão	45W 57' 00"	14S 48' 00"		Rapid survey		50/49	Ratter et al. (2001)*
29	BA	Cocos	Fazenda Trijuncão	45W 58' 00"	14S 49' 00"		Rapid survey		53/52	Ratter et al. (2001)*
30	PE	Goiana	(Tabuleiros do Nordeste)	35W 00' 00"	7S 33' 00"	13	Transect	-	26/16	Tavares (1964a, 1964b); Haynes (1970)
31	PB	Mamanguape	-	35W 07' 32"	6S 40' 42"	35	PCQM	-	22/18	Bioten Program (2007)
32	PB	João Pessoa	-	34W 50' 03"	7S 11' 15"	47	PCQM	-	44/29	Bioten Program (2007)
33	PB	Pedras de Fogo	-	35W 05' 08"	7S 21' 12"	177	PCQM	-	32/26	Bioten Program (2007)
34	PB	Conde	-	34W 48' 24"	7S 21' 19"	112	PCQM	-	42/29	Bioten Program (2007)
35	RN	Parnamirim	-	35W 11' 29"	5S 55' 02"	53	PCQM	-	26/21	Bioten Program (2007)
36	RN	Nísia Floresta	-	35W 12' 14"	6S 03' 48"	20	PCQM	-	29/22	Bioten Program (2007)
37	CE	Fortaleza	Cambeba	38W 29' 10"	3S 47' 55"	16	Plots;	1	67/59	Moro (2011)
38	CE	Aquiraz	-	38W 16' 00"	3S 58' 00"	35	Plots	0.05	33/24	Granjeiro (1983)

Code	State	Municipally	Locality	Longitude	Latitude	Alt	SM	Area (ha)	NS†	References
39	CE	Aurora, Caririaçu, Farias Brito, Granjeiro, Lavras da Mangabeira and Várzea Alegre	(Semi-árido cearense)	39W 15' 00"	6S 52' 00"	440	Floristic inventory	-	31/28	Figueiredo & Fernandes (1987); Figueiredo (1989)
40	CE	Crato, Nova Olinda and Santana do Cariri	Chapada do Araripe	39W 34' 59"	7S 15' 00"	871	Plots	0.25	36/28	Albuquerque (1987)
41	CE	Chapada do Araripe		39W 29' 00"	7S 17' 00"		Rapid survey		43/43	Ratter et al. (2001)*
42	CE	Barbalha	Floresta Nacional do Araripe (FLONA-Araripe)	39W 20' 58"	7S 24' 25"	900	PCQM	-	42/38	Costa & Araújo (2007)
43	CE	Nova Olinda	Sítio sozinho	39W 40' 02"	8S 19' 44"	445	Plots	0.68	34/20	Sousa et al. (2007)
44	MA	Tutóia	Siriema/Santa Clara	42W 22' 59"	2S 46' 00"	26	Plots	1	39/25	Bioten Program (2007)
45	MA	Paulino Neves	Tingidor/Curva da morte	42W 29' 03"	2S 46' 10"	22	Plots	1	35/24	Bioten Program (2007)
46	MA	Santa Quitéria	-	42W 55' 00"	3S 04' 59"	36	Plots	3	41/40	Imaña-Encinas & De Paula (2003)
47	MA	São Bernardo	Baixa Grande	42W 26' 28"	3S 12' 11"	42	PCQM	0.21	40/27	Bioten Program (2001)
48	MA	Urbano Santos	Fazenda Bonfim	43W 12' 00"	3S 19' 00"	40	PCQM	-	67/36	Silva et al. (2008)
49	MA	Buriti	Baixão do Jatobá	42W 55' 00"	3S 52' 00"	110	PCQM	0.2	51/31	Bioten Program (2003)
50	MA	Duque Bacelar	Povoado Taboquinha	42W 56' 15"	4S 05' 02"	45	PCQM	0.1	60/41	Bioten Program (2003)

Code	State	Municipally	Locality	Longitude	Latitude	Alt	SM	Area (ha)	NS†	References
51	MA	Afonso Cunha	-	43W 15' 00"	4S 16' 00"	35-130	Plots	1	41/27	Ferreira (1997)
52	MA	Caxias	Propriedade Simplicia	43W 07' 59"	4S 55' 48"	120	PCQM	0.2	100/46	Bioten Program (2003)
53	MA	Timon	Propriedade Todos os Santos	42W 59' 54"	5S 04' 26"	185	Floristic inventory	-	85/49	Bioten Program (2002)
54	MA	Timon	Propriedade Caiçara	42W 52' 54"	5S 04' 45"	120-147	PCQM	0.13	58/39	Bioten Program (2003)
55	MA	Imperatriz	Povoado Bananal	47W 26' 35"	5S 31' 32"	95	PCQM	2.6	41/35	Soares (1996)
56	MA	Mirador	Parque Estadual do Mirador	44W 43' 00"	6S 10' 00"	186	Plots	0.6	159/156	Bioten Program (2000)
57	MA	Barão de Grajaú		43W 31' 00"	6S 32' 00"		Rapid survey		38/38	Ratter et al. (2001)*
58	MA	São João dos Patos		43W 31' 00"	6S 32' 00"		Rapid survey		42/42	Ratter et al. (2001)*
59	MA	Barão de Grajaú		43W 07' 15"	6S 43' 06"	130	Plots	1	53/32	Bioten Program (2009)
60	MA	Fortaleza dos Nogueiras		46W 10' 00"	6S 50' 00"		Rapid survey		80/80	Ratter et al. (2001)*
61	MA	Fortaleza dos Nogueiras		46W 10' 00"	6S 53' 00"		Rapid survey		63/63	Ratter et al. (2001)*
62	MA	Pedra Caída		47W 28' 00"	6S 57' 00"		Rapid survey		64/63	Ratter et al. (1996)*
63	MA	Carolina	Usina Elétrica de Estreito	47W 28' 21"	7S 01' 03"	150	Plots	1	52/47	Medeiros et al. (2008)
64	MA	Carolina		47W 25' 00"	7S 07' 00"		Rapid survey		62/61	Ratter et al. (1996)*
65	MA	Carolina		47W 25' 00"	7S 07' 00"		Rapid survey		20/20	Ratter et al. (1996)*
66	MA	Carolina	-	47W 25' 00"	7S 10' 59"	167	Transect	1.8	25/25	Sanaiotti (1996)
67	MA	Carolina	-	47W 25' 00"	7S 10' 59"	167	Transect	2.65	17/17	Sanaiotti (1996)

Code	State	Municipally	Locality	Longitude	Latitude	Alt	SM	Area (ha)	NS†	References
68	MA	Carolina	-	47W 25' 00"	7S 10' 59"	167	Transect	3.8	19/19	Sanaiotti (1996)
69	MA	Carolina	-	47W 25' 00"	7S 10' 59"	167	Transect	4.8	26/25	Sanaiotti (1996)
70	MA	Loreto		45W 09' 00"	7S 20' 00"		Rapid survey		50/50	Ratter et al. (2001)*
71	MA	Loreto	Fazenda Morro	45W 04' 00"	7S 20' 00"		Rapid survey		19/19	Ratter et al. (2001)*
72	MA	Loreto		45W 05' 00"	7S 21' 00"		-		78/77	Eiten (1998)*
73	MA	Loreto		45W 05' 00"	7S 21' 00"		Rapid survey		40/40	Ratter et al. (2001)*
74	MA	Loreto		45W 06' 00"	7S 22' 00"		Rapid survey		53/53	Ratter et al. (2001)*
75	MA	Loreto	Fazenda Morro	45W 01' 00"	7S 23' 00"		Rapid survey		43/43	Ratter et al. (2001)*
76	MA	Balsas	Fazenda Parnaíba	46W 05' 00"	7S 30' 00"		Rapid survey		70/69	Ratter et al. (1996)*
77	MA	Balsas		46W 05' 00"	7S 30' 00"		Rapid survey		45/45	Ratter et al. (1996)*
78	MA	Balsas	Chapada do Gado Bravo	46W 10' 59"	7S 42' 00"	600-700	PCQM	-	72/38	Figueiredo & Andrade (2007)
79	MA	Balsas		45W 50' 00"	7S 45' 00"		Rapid survey		61/60	Ratter et al. (1996)*
80	MA	Tasso Fragoso		45W 48' 00"	8S 26' 00"		Rapid survey		61/61	Ratter et al. (2001)*
81	MA	Balsas		46W 43' 00"	8S 38' 00"		-		56/56	Walter et al. (2000)*
82	MA	Alto Parnaíba		45W 52' 00"	9S 03' 00"		Rapid survey		52/52	Ratter et al. (2001)*
83	MA	Alto Parnaíba		45W 55' 00"	9S 09' 00"		Rapid survey		54/54	Ratter et al. (2001)*
84	MA	Alto Parnaíba		46W 03' 00"	9S 12' 00"		Rapid survey		62/62	Ratter et al. (2001)*

Code	State	Municipally	Locality	Longitude	Latitude	Alt	SM	Area (ha)	NS†	References
85	PI	Buriti dos Lopes	Fazenda Bionativa	41W 51' 00"	3S 09' 00"	80	PCQM	0.7	61/34	Bioten Program (2002)
86	PI	Uruçuí	E.E. de Uruçui Uma (Baixa Grande do Ribeiro)	42W 25' 59"	3S 12' 00"	40-42	PCQM	-	42/26	Bioten Program (2001)
87	PI	São José do Divino	-	41W 43' 59"	3S 51' 06"	108	Plots	1	24/24	Bioten Program (2008)
88	PI	Esperantina	Olho D'água dos Pires	42W 14' 01"	3S 54' 06"	120	Floristic inventory	-	64/62	Torquato (2006)
89	PI	Esperantina	Quilombo Olho D'água dos Pires	42W 14' 18"	3S 54' 10"	120	Floristic inventory	-	111/103	Franco (2005)
90	PI	Piracuruca	Fazenda Alto Bonito	41W 43' 00"	3S 55' 59"	70	Plots	1	23/22	Castro (1994)
91	PI	Batalha	Fazenda Caiçara	42W 04' 00"	4S 01' 00"	80	Plots	1	30/25	Castro (1994)
92	PI	Piracuruca	Povoado Mata Fria	41W 40' 26"	4S 02' 39"	105-160	Plots	0.06	70/46	Bioten Program (2006)
93	PI	Piracuruca, Brasileira	PARNA 7 Cidades	41W 30' 00"	4S 04' 59"	100-450	Plots	1	47/41	Moura (2007)
94	PI	Piracuruca/Brasileira	Parque Nacional de Sete Cidades	41W 30' 00"	4S 04' 59"	100-300	Plots	1	45/45	Lindoso (2008)
95	PI	Piracuruca, Piripiri	PN7C	41W 43' 00"	4S 06' 00"	275	Floristic inventory	-	120/102	Barroso & Guimarães (1980)
96	PI	Piracuruca/Brasileira	PARNA de 7 Cidades-Baixa do Barreiro	41W 42' 29"	4S 07' 14"	205	Plots	0.34	92/66	Bioten Program (2004)
97	PI	Piracuruca/Brasileira	PARNA de 7 Cidades-Baixa do Barreiro	41W 42' 09"	4S 07' 20"	205	Plots;	0.39	107/74	Bioten Program (2004)
98	PI	N.Sra de Nazaré	-	42W 07' 51"	4S 07' 51"	170	Plots	0.1	15/10	Bioten Program (2005)

Code	State	Municipally	Locality	Longitude	Latitude	Alt	SM	Area (ha)	NS†	References
99	PI	Batalha	Fazenda Bom Princípio	42W 09' 00"	4S 07' 59"	80	Plots	1	21/20	Castro (1994)
100	PI	Piracuruca/Brasileira	PARNA de 7 Cidades	41W 43' 00"	4S 07' 59"	231	Plots	1.8	106/52	Bioten Program (2006)
101	PI	Piracuruca, Brasileira	PARNA de 7 Cidades	41W 42' 45"	4S 09' 18"	200	Plots	0.6	88/77	Bioten Program (2003)
102	PI	Barras	Fazenda Lagoa Seca	42W 16' 59"	4S 13' 59"	75	Plots	1	25/23	Castro (1994)
103	PI	Piripiri	Fazenda Carnaubal	41W 46' 59"	4S 16' 00"	160	Plots	1	24/23	Castro (1994)
104	PI	Boa Hora	Caraíba/Buriti do Atola/Finado Raimundo Sereia	42W 07' 00"	4S 22' 59"	119	Plots	1	50/41	Bioten Program (2007)
105	PI	Capitão de Campos	Fazenda Santana	41W 55' 59"	4S 27' 00"	140	Plots	1	34/30	Castro (1994)
106	PI	Cocal de Telha	Gama/Gama II	41W 58' 00"	4S 31' 51"	164	Plots	1	69/49	Bioten Program (2007)
107	PI	Cabeceiras	Cajueiro/Lagoa Santa	42W 16' 00"	4S 31' 59"	137	Plots	1	62/48	Bioten Program (2007)
108	PI	José de Freitas	Faz. Santa Fé	42W 21' 52"	4S 39' 55"	155	PCQM	0.31	42/27	Bioten Program (2004)
109	PI	Jatobá do Piauí	Baixa do Ferro	41W 53' 25"	4S 42' 37"	230	Plots	1	69/51	Bioten Program (2008)
110	PI	Campo Maior	Capão das Cutias	41W 55' 59"	4S 43' 59"	214	Plots	1	68/54	Bioten Program (2008)
111	PI	Campo Maior	Geoambiente4	42W 14' 57"	4S 44' 16"	130	Plots	1	55/44	Bioten Program (2005)
112	PI	José de Freitas	Fazenda Tucum	42W 34' 59"	4S 45' 00"	137	Plots	1	36/30	Castro (1994)
113	PI	Campo Maior	Geoambiente6	42W 01' 00"	4S 46' 59"	141	Plots	1	78/62	Bioten Program (2005)
114	PI	José de Freitas	Eco Rizort Nazareth	42W 38' 17"	4S 47' 37"	140	PCQM	0.1	63/21	Bioten Program (2004)

Code	State	Municipally	Locality	Longitude	Latitude	Alt	SM	Area (ha)	NS†	References
115	PI	Campo Maior	Alto do Comandante	42W 03' 08"	4S 51' 42"	120	PCQM	0.15	66/59	Bioten Program (2003)
116	PI	Campo Maior	Baixão da Cobra	42W 04' 31"	4S 52' 21"	95-120	PCQM	0.14	65/56	Bioten Program (2003)
117	PI	Campo Maior	Geoambiente7	42W 10' 00"	4S 52' 59"	177	Plots	0.7	62/46	Bioten Program (2005)
118	PI	Campo Maior	Geoambiente5	42W 10' 23"	4S 53' 14"	100	Plots	0.7	55/48	Bioten Program (2005)
119	PI	Campo Maior	Geoambiente2	42W 08' 12"	4S 54' 10"	110	Plots	1	66/51	Bioten Program (2005)
120	PI	Campo Maior	Geoambiente1	42W 10' 01"	4S 54' 16"	100	Plots	1	52/42	Bioten Program (2005)
121	PI	Campo Maior	Geoambiente8	42W 10' 59"	4S 55' 59"	187	Plots	0.6	49/37	Bioten Program (2005)
122	PI	Campo Maior	Geoambiente3	42W 12' 03"	4S 56' 47"	120	Plots	0.8	66/45	Bioten Program (2005)
123	PI	Campo Maior	Serra de Santo Antonio	42W 11' 33"	4S 56' 53"	238	Plots	1	35/25	Bioten Program (2008)
124	PI	Campo Maior	Serra de Bugarim	42W 11' 38"	4S 57' 19"	247	Plots	1	51/28	Bioten Program (2008)
125	PI	Campo Maior	Serra de Passa Tempo	42W 13' 00"	4S 58' 00"	253	Plots	1	59/42	Bioten Program (2008)
126	PI	Campo Maior	Serra de Campo Maior-Cruzeiro	42W 09' 00"	4S 58' 59"	170 m	PCQM	-	30/23	Bioten Program (2005)
127	PI	Teresina	Parque Ambiental de Teresina	42W 48' 36"	5S 01' 51"	60	PCQM	-	65/33	Bioten Program (2004)
128	PI	Castelo do Piauí	Percurso da Raposa	41W 41' 47"	5S 13' 36"	200	PCQM	0.25	27/25	Bioten Program (2005)
129	PI	Castelo do Piauí	Propriedade Raposa-ECB	41W 42' 37"	5S 14' 08"	200	PCQM	0.34	48/36	Bioten Program (2003)

Code	State	Municipally	Locality	Longitude	Latitude	Alt	SM	Area (ha)	NS†	References
130	PI	Castelo do Piauí	Grotão da Caraúba	41W 31' 00"	5S 19' 00"	170	Plots	1	71/62	Bioten Program (2005)
131	PI	Beneditinos	Fazenda Descanso	42W 21' 00"	5S 27' 00"	80	Plots	1	37/33	Castro (1994)
132	PI	Monsenhor Gil	Fazenda Toti Negra	42W 37' 00"	5S 33' 00"	115	Plots	1	26/24	Castro (1994)
133	PI	Monsenhor Gil	Fazenda Palmares	42W 37' 02"	5S 33' 45"	100-300	Plots	1	92/68	Ribeiro (2000)
134	PI	Monsenhor Gil	Fazenda Palmares	42W 37' 02"	5S 33' 45"	100-300	Plots	0.5	74/53	Ribeiro (2000)
135	PI	Monsenhor Gil	Fazenda Palmares	42W 37' 02"	5S 33' 45"	100-300	Plots	1	65/50	Ribeiro (2000)
136	PI	Monsenhor Gil	Fazenda Palmares	42W 37' 02"	5S 33' 45"	100-300	Plots	1	52/43	Ribeiro (2000)
137	PI	Monsenhor Gil	Boa Esperança, Bolívia, Cadoz, Canafístula, Fazenda Saquinho, Monte Alegre, São Luís e Varjota	42W 37' 02"	5S 33' 45"	116	Floristic inventory	-	136/113	Santos (2008)
138	PI	Elesbão Veloso	Fazenda Vista Alegre	42W 07' 59"	6S 12' 00"	230	Plots	1	27/24	Castro (1994)
139	PI	Arraial/Regeneração	Chapada Grande Meridional	42W 25' 59"	6S 25' 59"	164-338	Plots	1	49/42	Lindoso (2008)
140	PI	Oeiras	Fazenda Piloto Chapada Grande	42W 16' 00"	6S 36' 00"	430	Plots	0.6	69/59	Castro (1994)
141	PI	São José do Piauí	Morro do Baixio	41W 28' 00"	6S 51' 00"	430-540	PCQM	0.14	78/54	Bioten Program (2003)
142	PI	São José do Piauí	Morro do Baixio	41W 28' 00"	6S 51' 00"	430-540	Plots/PCQM	0.43	59/47	Bioten Program (2003)
143	PI	Bocaina	Alto do Sangradouro/Morro do Curral Velho	41W 17' 58"	6S 54' 34"	260	PCQM	0.08	22/17	Bioten Program (2000)

Code	State	Municipally	Locality	Longitude	Latitude	Alt	SM	Area (ha)	NS†	References
144	PI	Floriano		43W 06' 03"	7S 00' 34"	180	Plots	1	44/30	Bioten Program (2009)
145	PI	Padre Marcos	Serra Velha	40W 58' 00"	7S 07' 00"	420	Plots	0.45	59/44	Bioten Program (1995)
146	PI	Uruçuí	Barra da Volta	44W 50' 56"	7S 25' 25"	300	PCQM	0.52	54/28	Bioten Program (2003)
147	PI	Itaueira		43W 07' 40"	7S 26' 31"	230	Plots	1	58/39	Bioten Program (2009)
148	PI	Bertolínea		43W 57' 39"	7S 36' 45"	325	Plots	1	43/28	Bioten Program (2009)
149	PI	Uruçuí	Condomínio União e Ouro Preto (TC)	44W 29' 43"	7S 41' 24"	411	Plots	1	55/39	Bioten Program (2008)
150	PI	Uruçuí	Barra da Prata, Meirim, Pratinha e Santa Bárbara (DI)	44W 25' 59"	7S 46' 59"	298	Plots	1	62/40	Bioten Program (2008)
151	PI	Jerumenha		43W 29' 12"	8S 13' 09"	380	Plots	1	52/35	Bioten Program (2011)
152	PI	Ribeiro Gonçalves	E.E. de Uruçuí-Una	45W 15' 00"	8S 51' 00"	400	Floristic inventory	-	115/68	Castro (1984)
153	PI	Baixa Grande do Ribeiro	E.E. de Uruçui Una	44W 58' 00"	8S 52' 00"	300	PCQM	0.34	42/27	Bioten Program (2003)
154	PI	Santo Filomena		45W 43' 00"	9S 14' 00"		Rapid survey		44/44	Ratter et al. (2001)*
155	PI	Gilbués		45W 35' 00"	9S 17' 00"		Rapid survey		40/40	Ratter et al. (2001)*
156	PI	Bom Jesus	Serra do Quilombo	44W 34' 01"	9S 17' 51"	350	Plots	1	67/37	Bioten Program (2009)
157	PI	Bom Jesus	Serra do Quilombo	44W 43' 00"	9S 18' 00"	612	PCQM	0.32	27/17	Bioten Program (2002)
158	PI	Gilbués		45W 23' 00"	9S 44' 00"		Rapid survey		56/56	Ratter et al. (2001)*

Code	State	Municipally	Locality	Longitude	Latitude	Alt	SM	Area (ha)	NS†	References
159	PI	Corrente		45W 15' 00"	10S 05' 00"		Rapid survey		36/36	Ratter et al. (2001)*
160	PI	Corrente		45W 10' 00"	10S 28' 00"		Rapid survey		31/31	Ratter et al. (2001)*

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Appendix B. Families recorded in the northeastern cerrado of Brazil. Families arranged alphabetically. Constancy: absolute constancy of families out of 160 surveys.

Family	Number of Genera	Number of species	Constancy	Constancy (%)
Acanthaceae	3	4	4	2.50
Achariaceae	1	1	1	0.62
Amaranthaceae	2	2	3	1.88
Anacardiaceae	7	11	141	88.12
Annonaceae	7	17	120	75.00
Apocynaceae	12	27	132	82.50
Aquifoliaceae	1	1	1	0.62
Araceae	1	1	2	1.25
Araliaceae	1	2	7	4.38
Arecaceae	11	20	50	31.25
Asteraceae	28	40	28	17.50
Bignoniaceae	9	22	123	76.88
Bixaceae	2	3	27	16.88
Boraginaceae	4	14	38	23.75
Burseraceae	2	4	19	11.88
Cactaceae	4	9	31	19.38
Calophyllaceae	1	5	40	25.00
Cannabaceae	1	1	2	1.25
Capparaceae	2	3	3	1.88
Caricaceae	2	2	2	1.25
Caryocaraceae	1	4	106	66.25
Celastraceae	6	10	55	34.38
Chrysobalanaceae	4	10	95	59.38
Cleomaceae	1	1	4	2.50
Clusiaceae	2	4	20	12.50
Combretaceae	3	15	129	80.62
Connaraceae	2	7	57	35.62
Convolvulaceae	5	9	6	3.75
Cucurbitaceae	1	1	1	0.62
Dilleniaceae	2	4	116	72.50
Ebenaceae	1	5	72	45.00
Emmotaceae	1	1	36	22.50

Family	Number of Genera	Number of species	Constancy	Constancy (%)
Erythroxylaceae	1	13	46	28.75
Euphorbiaceae	13	38	58	36.25
Fabaceae	70	214	158	98.75
Humiriaceae	2	3	6	3.75
Hydroleaceae	1	1	1	0.62
Hypericaceae	1	4	18	11.25
Krameriaceae	1	1	22	13.75
Lamiaceae	7	18	57	35.62
Lauraceae	4	8	13	8.12
Lecythidaceae	2	5	17	10.62
Loganiaceae	3	5	39	24.38
Loranthaceae	3	4	2	1.25
Lythraceae	4	9	89	55.62
Malpighiaceae	10	39	129	80.62
Malvaceae	15	35	78	48.75
Melastomataceae	11	26	79	49.38
Meliaceae	2	2	2	1.25
Moraceae	3	7	33	20.62
Myristicaceae	1	2	2	1.25
Myrsinaceae	2	5	5	3.12
Myrtaceae	6	46	120	75.00
Nyctaginaceae	3	6	20	12.50
Ochnaceae	1	8	75	46.88
Olacaceae	4	5	60	37.50
Onagraceae	1	2	2	1.25
Opiliaceae	1	3	85	53.12
Orobanchaceae	1	1	1	0.62
Pedaliaceae	1	1	1	0.62
Picramniaceae	1	1	1	0.62
Plumbaginaceae	1	1	2	1.25
Polygalaceae	2	5	20	12.50
Polygonaceae	2	9	15	9.38
Proteaceae	2	2	13	8.12
Rhamnaceae	2	3	3	1.88

Family	Number of Genera	Number of species	Constancy	Constancy (%)
Rosaceae	1	1	1	0.62
Rubiaceae	20	39	121	75.62
Rutaceae	4	8	13	8.12
Salicaceae	2	10	75	46.88
Santalaceae	1	1	1	0.62
Sapindaceae	9	16	87	54.37
Sapotaceae	4	11	92	57.50
Schoepfiaceae	1	1	1	0.62
Simaroubaceae	2	7	96	60.00
Siparunaceae	1	1	9	5.62
Solanaceae	4	13	21	13.12
Styracaceae	1	2	5	3.12
Symplocaceae	1	1	1	0.62
Trigoniaceae	1	1	2	1.25
Urticaceae	1	2	10	6.25
Velloziaceae	1	2	3	1.88
Verbenaceae	4	10	14	8.75
Vochysiaceae	4	18	144	90.00

Appendix C. Genera recorded in the northeastern cerrado of Brazil. Genera arranged alphabetically by family. Constancy: absolute constancy of genera out of 160 surveys.

Genus	Family	Number of species	Constancy	Constancy (%)
Anisacanthus	Acanthaceae	1	1	0.62
Justicia	Acanthaceae	1	1	0.62
Ruellia	Acanthaceae	2	2	1.25
Lindackeria	Achariaceae	1	1	0.62
Gomphrena	Amaranthaceae	1	3	1.88
Pfaffia	Amaranthaceae	1	2	1.25
Anacardium	Anacardiaceae	2	121	75.62
Apterokarpos	Anacardiaceae	1	2	1.25
Astronium	Anacardiaceae	1	67	41.88
Myracrodruon	Anacardiaceae	1	28	17.50
Spondias	Anacardiaceae	3	3	1.88
Tapirira	Anacardiaceae	2	11	6.88
Thyrsodium	Anacardiaceae	1	6	3.75
Anaxagorea	Annonaceae	1	1	0.62
Annona	Annonaceae	7	106	66.25
Duguetia	Annonaceae	4	24	15.00
Ephedranthus	Annonaceae	1	14	8.75
Oxandra	Annonaceae	1	8	5.00
Rollinia	Annonaceae	1	1	0.62
Xylopia	Annonaceae	2	16	10.00
Allamanda	Apocynaceae	2	7	4.38
Aspidosperma	Apocynaceae	8	80	50.00
Barjonia	Apocynaceae	1	1	0.62
Catharanthus	Apocynaceae	1	1	0.62
Ditassa	Apocynaceae	1	1	0.62
Forsteronia	Apocynaceae	1	1	0.62
Hancornia	Apocynaceae	1	48	30.00
Himatanthus	Apocynaceae	6	88	55.00
Matelea	Apocynaceae	1	1	0.62
Nerium	Apocynaceae	1	2	1.25
Rauvolfia	Apocynaceae	1	1	0.62
Tabernaemontana	Apocynaceae	3	7	4.38

Genus	Family	Number of species	Constancy	Constancy (%)
Ilex	Aquifoliaceae	1	1	0.62
Taccarum	Araceae	1	2	1.25
Schefflera	Araliaceae	2	7	4.38
Acrocomia	Arecaceae	3	5	3.12
Allagoptera	Arecaceae	1	3	1.88
Astrocaryum	Arecaceae	2	22	13.75
Attalea	Arecaceae	3	6	3.75
Cocos	Arecaceae	1	1	0.62
Copernicia	Arecaceae	1	10	6.25
Desmoncus	Arecaceae	1	1	0.62
Elaeis	Arecaceae	1	1	0.62
Mauritia	Arecaceae	1	2	1.25
Mauritiella	Arecaceae	1	1	0.62
Syagrus	Arecaceae	5	18	11.25
Acritopappus	Asteraceae	1	2	1.25
Aspilia	Asteraceae	1	1	0.62
Baccharis	Asteraceae	1	1	0.62
Bidens	Asteraceae	1	2	1.25
Centratherum	Asteraceae	1	2	1.25
Chromolaena	Asteraceae	2	3	1.88
Clibadium	Asteraceae	1	1	0.62
Elephantopus	Asteraceae	1	1	0.62
Eremanthus	Asteraceae	5	6	3.75
Eupatorium	Asteraceae	2	2	1.25
Gochnatia	Asteraceae	1	2	1.25
Lepidaploa	Asteraceae	4	6	3.75
Lessingianthus	Asteraceae	1	1	0.62
Lychnophora	Asteraceae	2	2	1.25
Melampodium	Asteraceae	1	2	1.25
Mikania	Asteraceae	1	1	0.62
Piptocarpha	Asteraceae	1	6	3.75
Pithecoseris	Asteraceae	1	1	0.62
Platypodanthera	Asteraceae	1	2	1.25
Porophyllum	Asteraceae	1	1	0.62

Genus	Family	Number of species	Constancy	Constancy (%)
Pseudobrickellia	Asteraceae	1	1	0.62
Rolandra	Asteraceae	1	1	0.62
Stilpnopappus	Asteraceae	2	2	1.25
Symphyopappus	Asteraceae	1	1	0.62
Tilesia	Asteraceae	1	1	0.62
Trichogonia	Asteraceae	1	1	0.62
Trixis	Asteraceae	1	1	0.62
Vernonanthura	Asteraceae	2	11	6.88
Adenocalymma	Bignoniaceae	1	1	0.62
Anemopaegma	Bignoniaceae	3	4	2.50
Cybistax	Bignoniaceae	1	37	23.12
Fridericia	Bignoniaceae	2	15	9.38
Godmania	Bignoniaceae	1	2	1.25
Handroanthus	Bignoniaceae	4	98	61.25
Jacaranda	Bignoniaceae	5	29	18.12
Tabebuia	Bignoniaceae	3	57	35.62
Zeyheria	Bignoniaceae	2	27	16.88
Bixa	Bixaceae	1	2	1.25
Cochlospermum	Bixaceae	2	27	16.88
Cordia	Boraginaceae	9	34	21.25
Heliotropium	Boraginaceae	1	2	1.25
Tournefortia	Boraginaceae	1	1	0.62
Varronia	Boraginaceae	3	8	5.00
Commiphora	Burseraceae	1	4	2.50
Protium	Burseraceae	3	16	10.00
Arrojadoa	Cactaceae	1	1	0.62
Cereus	Cactaceae	2	29	18.12
Nopalea	Cactaceae	1	1	0.62
Pilosocereus	Cactaceae	5	7	4.38
Kielmeyera	Calophyllaceae	5	40	25.00
Trema	Cannabaceae	1	2	1.25
Capparis	Capparaceae	2	2	1.25
Crateva	Capparaceae	1	2	1.25
Carica	Caricaceae	1	1	0.62

Genus	Family	Number of species	Constancy	Constancy (%)
Jacaratia	Caricaceae	1	1	0.62
Caryocar	Caryocaraceae	4	106	66.25
Celastrus	Celastraceae	1	7	4.38
Cheiloclinium	Celastraceae	1	1	0.62
Maytenus	Celastraceae	3	9	5.62
Plenckia	Celastraceae	1	7	4.38
Salacia	Celastraceae	3	33	20.62
Tontelea	Celastraceae	1	1	0.62
Couepia	Chrysobalanaceae	1	21	13.12
Exellodendron	Chrysobalanaceae	2	7	4.38
Hirtella	Chrysobalanaceae	5	83	51.88
Licania	Chrysobalanaceae	2	5	3.12
Cleome	Cleomaceae	1	4	2.50
Clusia	Clusiaceae	3	4	2.50
Platonia	Clusiaceae	1	17	10.62
Buchenavia	Combretaceae	3	26	16.25
Combretum	Combretaceae	7	88	55.00
Terminalia	Combretaceae	4	99	61.88
Connarus	Connaraceae	3	53	33.12
Rourea	Connaraceae	3	22	13.75
Evolvulus	Convolvulaceae	4	4	2.50
Ipomoea	Convolvulaceae	1	1	0.62
Jacquemontia	Convolvulaceae	1	1	0.62
Merremia	Convolvulaceae	1	2	1.25
Operculina	Convolvulaceae	2	2	1.25
Cayaponia	Cucurbitaceae	1	1	0.62
Curatella	Dilleniaceae	1	95	59.38
Davilla	Dilleniaceae	3	39	24.38
Diospyros	Ebenaceae	5	72	45.00
Emmotum	Emmotaceae	1	36	22.50
Erythroxylum	Erythroxylaceae	13	46	28.75
Alchornea	Euphorbiaceae	1	1	0.62
Chaetocarpus	Euphorbiaceae	1	1	0.62
Cnidoscolus	Euphorbiaceae	3	4	2.50

Genus	Family	Number of species	Constancy	Constancy (%)
Croton	Euphorbiaceae	11	20	12.50
Jatropha	Euphorbiaceae	4	3	1.88
Mabea	Euphorbiaceae	3	7	4.38
Manihot	Euphorbiaceae	7	9	5.62
Maprounea	Euphorbiaceae	2	19	11.88
Microstachys	Euphorbiaceae	2	3	1.88
Pera	Euphorbiaceae	1	5	3.12
Pogonophora	Euphorbiaceae	1	1	0.62
Sapium	Euphorbiaceae	1	3	1.88
Sebastiania	Euphorbiaceae	1	1	0.62
Abarema	Fabaceae	2	5	3.12
Aeschynomene	Fabaceae	2	2	1.25
Albizia	Fabaceae	2	2	1.25
Amburana	Fabaceae	1	9	5.62
Anadenanthera	Fabaceae	1	14	8.75
Andira	Fabaceae	10	71	44.38
Apuleia	Fabaceae	1	2	1.25
Ateleia	Fabaceae	1	1	0.62
Bauhinia	Fabaceae	16	49	30.63
Bionia	Fabaceae	1	2	1.25
Bocoa	Fabaceae	1	1	0.62
Bowdichia	Fabaceae	1	117	73.12
Caesalpinia	Fabaceae	2	2	1.25
Calliandra	Fabaceae	7	12	7.50
Camptosema	Fabaceae	1	1	0.62
Cassia	Fabaceae	1	1	0.62
Cenostigma	Fabaceae	1	6	3.75
Chamaecrista	Fabaceae	18	24	15.00
Chloroleucon	Fabaceae	4	6	3.75
Copaifera	Fabaceae	4	81	50.62
Cratylia	Fabaceae	2	3	1.88
Crotalaria	Fabaceae	2	2	1.25
Dalbergia	Fabaceae	2	46	28.75
Delonix	Fabaceae	1	1	0.62

Genus	Family	Number of species	Constancy	Constancy (%)
Desmodium	Fabaceae	1	1	0.62
Dialium	Fabaceae	1	1	0.62
Dimorphandra	Fabaceae	2	105	65.62
Dipteryx	Fabaceae	2	8	5.00
Diptychandra	Fabaceae	1	3	1.88
Enterolobium	Fabaceae	4	35	21.88
Erythrina	Fabaceae	1	1	0.62
Harpalyce	Fabaceae	1	5	3.12
Holocalyx	Fabaceae	1	1	0.62
Hymenaea	Fabaceae	5	103	64.38
Indigofera	Fabaceae	2	2	1.25
Inga	Fabaceae	4	8	5.00
Leptolobium	Fabaceae	2	55	34.38
Libidibia	Fabaceae	1	16	10.00
Lonchocarpus	Fabaceae	1	8	5.00
Luetzelburgia	Fabaceae	1	33	20.62
Machaerium	Fabaceae	4	62	38.75
Martiodendron	Fabaceae	1	24	15.00
Mimosa	Fabaceae	15	41	25.62
Moldenhawera	Fabaceae	1	1	0.62
Parkia	Fabaceae	1	92	57.50
Peltogyne	Fabaceae	1	8	5.00
Periandra	Fabaceae	1	3	1.88
Phanera	Fabaceae	3	3	1.88
Piptadenia	Fabaceae	2	6	3.75
Pityrocarpa	Fabaceae	1	23	14.37
Plathymenia	Fabaceae	1	91	56.88
Platypodium	Fabaceae	1	3	1.88
Poeppigia	Fabaceae	1	2	1.25
Poincianella	Fabaceae	2	10	6.25
Pterocarpus	Fabaceae	2	6	3.75
Pterodon	Fabaceae	3	46	28.75
Samanea	Fabaceae	1	2	1.25
Senegalia	Fabaceae	4	3	1.88

Genus	Family	Number of species	Constancy	Constancy (%)
Senna	Fabaceae	20	39	24.38
Stryphnodendron	Fabaceae	7	105	65.62
Stylosanthes	Fabaceae	3	4	2.50
Swartzia	Fabaceae	3	10	6.25
Tachigali	Fabaceae	5	93	58.13
Tamarindus	Fabaceae	1	2	1.25
Taralea	Fabaceae	1	1	0.62
Trischidium	Fabaceae	1	2	1.25
Vachellia	Fabaceae	1	1	0.62
Vatairea	Fabaceae	1	94	58.75
Vigna	Fabaceae	1	1	0.62
Zollernia	Fabaceae	1	3	1.88
Humiria	Humiriaceae	1	1	0.62
Sacoglottis	Humiriaceae	2	5	3.12
Hydrolea	Hydroleaceae	1	1	0.62
Vismia	Hypericaceae	4	18	11.25
Krameria	Krameriaceae	1	22	13.75
Aegiphila	Lamiaceae	3	21	13.12
Amasonia	Lamiaceae	1	7	4.38
Eriope	Lamiaceae	4	2	1.25
Hypenia	Lamiaceae	2	3	1.88
Hyptis	Lamiaceae	1	2	1.25
Leonotis	Lamiaceae	1	1	0.62
Vitex	Lamiaceae	6	32	20.00
Mezilaurus	Lauraceae	1	1	0.62
Nectandra	Lauraceae	1	1	0.62
Ocotea	Lauraceae	5	10	6.25
Persea	Lauraceae	1	1	0.62
Eschweilera	Lecythidaceae	2	12	7.50
Lecythis	Lecythidaceae	3	7	4.38
Antonia	Loganiaceae	1	17	10.62
Spigelia	Loganiaceae	1	1	0.62
Strychnos	Loganiaceae	3	24	15.00
Phthirusa	Loranthaceae	1	1	0.62

Genus	Family	Number of species	Constancy	Constancy (%)
Psittacanthus	Loranthaceae	1	2	1.25
Struthanthus	Loranthaceae	2	2	1.25
Cuphea	Lythraceae	4	4	2.50
Diplusodon	Lythraceae	1	1	0.62
Lafoensia	Lythraceae	2	85	53.12
Punica	Lythraceae	1	1	0.62
Banisteriopsis	Malpighiaceae	9	13	8.12
Barnebya	Malpighiaceae	1	2	1.25
Bunchosia	Malpighiaceae	1	1	0.62
Byrsonima	Malpighiaceae	21	124	77.50
Camarea	Malpighiaceae	1	1	0.62
Diplopterys	Malpighiaceae	1	1	0.62
Heteropterys	Malpighiaceae	2	11	6.88
Malpighia	Malpighiaceae	1	1	0.62
Stigmaphyllon	Malpighiaceae	1	3	1.88
Tetrapterys	Malpighiaceae	1	1	0.62
Abelmoschus	Malvaceae	1	1	0.62
Apeiba	Malvaceae	1	3	1.88
Ayenia	Malvaceae	1	2	1.25
Ceiba	Malvaceae	1	1	0.62
Eriotheca	Malvaceae	3	21	13.12
Gossypium	Malvaceae	1	1	0.62
Guazuma	Malvaceae	1	12	7.50
Helicteres	Malvaceae	7	24	15.00
Hibiscus	Malvaceae	1	1	0.62
Luehea	Malvaceae	4	36	22.50
Peltaea	Malvaceae	1	1	0.62
Pseudobombax	Malvaceae	2	7	4.38
Sida	Malvaceae	7	6	3.75
Sterculia	Malvaceae	2	9	5.62
Waltheria	Malvaceae	2	3	1.88
Cambessedesia	Melastomataceae	2	1	0.62
Clidemia	Melastomataceae	1	1	0.62
Leandra	Melastomataceae	1	1	0.62

Genus	Family	Number of species	Constancy	Constancy (%)
Macairea	Melastomataceae	1	1	0.62
Marcetia	Melastomataceae	2	2	1.25
Miconia	Melastomataceae	9	26	16.25
Microlicia	Melastomataceae	1	1	0.62
Mouriri	Melastomataceae	5	68	42.50
Pterolepis	Melastomataceae	1	1	0.62
Rhynchanthera	Melastomataceae	2	1	0.62
Tibouchina	Melastomataceae	1	1	0.62
Cabralea	Meliaceae	1	1	0.62
Trichilia	Meliaceae	1	1	0.62
Brosimum	Moraceae	3	28	17.50
Ficus	Moraceae	3	6	3.75
Maclura	Moraceae	1	1	0.62
Virola	Myristicaceae	2	2	1.25
Cybianthus	Myrsinaceae	1	3	1.88
Myrsine	Myrsinaceae	4	4	2.50
Campomanesia	Myrtaceae	7	18	11.25
Eugenia	Myrtaceae	8	54	33.75
Myrcia	Myrtaceae	18	61	38.12
Myrciaria	Myrtaceae	2	2	1.25
Psidium	Myrtaceae	10	84	52.50
Syzygium	Myrtaceae	1	2	1.25
Bougainvillea	Nyctaginaceae	1	1	0.62
Guapira	Nyctaginaceae	4	8	5.00
Neea	Nyctaginaceae	1	13	8.12
Ouratea	Ochnaceae	8	75	46.88
Cathedra	Olacaceae	1	3	1.88
Chaunochiton	Olacaceae	1	1	0.62
Heisteria	Olacaceae	2	24	15.00
Ximenia	Olacaceae	1	34	21.25
Ludwigia	Onagraceae	2	2	1.25
Agonandra	Opiliaceae	2	85	53.12
Esterhazya	Orobanchaceae	1	1	0.62
Sesamum	Pedaliaceae	1	1	0.62

Genus	Family	Number of species	Constancy	Constancy (%)
Picramnia	Picramniaceae	1	1	0.62
Plumbago	Plumbaginaceae	1	2	1.25
Bredemeyera	Polygalaceae	3	18	11.25
Polygala	Polygalaceae	2	2	1.25
Coccoloba	Polygonaceae	7	12	7.50
Triplaris	Polygonaceae	2	3	1.88
Euplassa	Proteaceae	1	3	1.88
Roupala	Proteaceae	1	11	6.88
Rhamnidium	Rhamnaceae	1	1	0.62
Ziziphus	Rhamnaceae	2	2	1.25
Prunus	Rosaceae	1	1	0.62
Alibertia	Rubiaceae	3	29	18.12
Chiococca	Rubiaceae	1	2	1.25
Chomelia	Rubiaceae	2	18	11.25
Cordiera	Rubiaceae	5	22	13.75
Coussarea	Rubiaceae	1	3	1.88
Coutarea	Rubiaceae	1	3	1.88
Declieuxia	Rubiaceae	1	1	0.62
Diodella	Rubiaceae	1	2	1.25
Faramea	Rubiaceae	2	3	1.88
Ferdinandusa	Rubiaceae	2	12	7.50
Genipa	Rubiaceae	1	5	3.12
Guettarda	Rubiaceae	4	39	24.38
Mitracarpus	Rubiaceae	1	1	0.62
Palicourea	Rubiaceae	2	12	7.50
Psychotria	Rubiaceae	3	3	1.88
Psyllocarpus	Rubiaceae	1	1	0.62
Randia	Rubiaceae	1	5	3.12
Rudgea	Rubiaceae	1	1	0.62
Salzmannia	Rubiaceae	1	1	0.62
Tocoyena	Rubiaceae	4	81	50.62
Dictyoloma	Rutaceae	1	1	0.62
Esenbeckia	Rutaceae	1	1	0.62
Spiranthera	Rutaceae	1	2	1.25

Genus	Family	Number of species	Constancy	Constancy (%)
Zanthoxylum	Rutaceae	5	11	6.88
Casearia	Salicaceae	9	72	45.00
Xylosma	Salicaceae	1	4	2.50
Phoradendron	Santalaceae	1	1	0.62
Allophylus	Sapindaceae	3	7	4.38
Cupania	Sapindaceae	4	7	4.38
Dilodendron	Sapindaceae	1	1	0.62
Dodonaea	Sapindaceae	1	1	0.62
Magonia	Sapindaceae	1	71	44.38
Matayba	Sapindaceae	2	6	3.75
Sapindus	Sapindaceae	1	1	0.62
Talisia	Sapindaceae	1	3	1.88
Toulicia	Sapindaceae	2	9	5.62
Chrysophyllum	Sapotaceae	2	5	3.12
Manilkara	Sapotaceae	2	3	1.88
Micropholis	Sapotaceae	1	1	0.62
Pouteria	Sapotaceae	6	87	54.37
Schoepfia	Schoepfiaceae	1	1	0.62
Simaba	Simaroubaceae	5	15	9.38
Simarouba	Simaroubaceae	2	87	54.37
Siparuna	Siparunaceae	1	9	5.62
Cestrum	Solanaceae	1	1	0.62
Physalis	Solanaceae	1	1	0.62
Schwenckia	Solanaceae	1	2	1.25
Solanum	Solanaceae	10	19	11.88
Styrax	Styracaceae	2	5	3.12
Symplocos	Symplocaceae	1	1	0.62
Trigonia	Trigoniaceae	1	2	1.25
Cecropia	Urticaceae	2	10	6.25
Vellozia	Velloziaceae	2	3	1.88
Aloysia	Verbenaceae	1	1	0.62
Lantana	Verbenaceae	2	2	1.25
Lippia	Verbenaceae	5	10	6.25
Stachytarpheta	Verbenaceae	2	2	1.25

Genus	Family	Number of species	Constancy	Constancy (%)
Callisthene	Vochysiaceae	3	33	20.62
Qualea	Vochysiaceae	6	136	85.00
Salvertia	Vochysiaceae	1	98	61.25
Vochysia	Vochysiaceae	8	51	31.87

Appendix D. The 936 species completely identified recorded in the northeastern cerrado of Brazil. Species arranged alphabetically by family. Constancy: absolute constancy of species out of 160 surveys. Const. (%): constancy percentage of species of 160 surveys. Ref.1: major species constancy in percentage for the whole Cerrado recorded in Ratter et al. (2003); Ref.2: major species constancy in percentage for the northeastern province cerrado recorded in Bridgewater et al. (2004); "*" indicate the species considered as widespread 'oligarch' species by Bridgewater et al. (2004) for whole Cerrado.

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Anisacanthus trilobus Lindau	Acanthaceae	1	0.62		
Justicia pectoralis Jacq.	Acanthaceae	1	0.62		
Ruellia incompta (Ness) Lindau	Acanthaceae	1	0.62		
Ruellia ochroleuca Mart. ex Ness.	Acanthaceae	1	0.62		
Lindackeria latifolia Benth.	Achariaceae	1	0.62		
Gomphrena agrestis Mart.	Amaranthaceae	3	1.88		
Pfaffia acutifolia (Moq.) O. Stützer	Amaranthaceae	2	1.25		
Anacardium humile A. St.-Hil.	Anacardiaceae	3	1.88		
Anacardium occidentale L.	Anacardiaceae	119	74.38		70*
Apterokarpos gardneri (Engl.) Rizzini	Anacardiaceae	2	1.25		
Astronium fraxinifolium Schott ex Spreng.	Anacardiaceae	67	41.88	55	45*
Myracrodruon urundeuva Allemão	Anacardiaceae	28	17.50		16*
Spondias mombin L.	Anacardiaceae	2	1.25		
Spondias purpurea L.	Anacardiaceae	1	0.62		
Spondias tuberosa Arruda	Anacardiaceae	1	0.62		
Tapirira guianensis Aubl.	Anacardiaceae	10	6.25		*
Tapirira obtusa (Benth.) J.D. Mitch.	Anacardiaceae	1	0.62		
Thyrsodium spruceanum Benth.	Anacardiaceae	6	3.75		
Anaxagorea dolichocarpa Sprague & Sandwith	Annonaceae	1	0.62		
Annona coriacea Mart.	Annonaceae	83	51.88	54	43*
Annona crassiflora Mart.	Annonaceae	26	16.25		48*
Annona dioica A. St.-Hil.	Annonaceae	1	0.62		
Annona leptopetala (R.E. Fr.) H. Rainer	Annonaceae	5	3.12		
Annona pickelli (Diels) H.Rainer	Annonaceae	1	0.62		
Annona squamosa L.	Annonaceae	1	0.62		
Annona tomentosa R.E. Fr.	Annonaceae	5	3.12		
Duguetia echinophora R. E. Fries	Annonaceae	1	0.62		
Duguetia furfuracea (A. St.-Hil.) Saff.	Annonaceae	21	13.12		18*
Duguetia lanceolata A. St. -Hil.	Annonaceae	1	0.62		
Duguetia marcgraviana Mart.	Annonaceae	1	0.62		
Ephedranthus pisocarpus R.E. Fr.	Annonaceae	14	8.75		
Oxandra sessiliflora R.E. Fr.	Annonaceae	8	5.00		
Rollinia sylvatica (A. St.-Hil.) Martius	Annonaceae	1	0.62		

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Xylopia aromatica (Lam.) Mart.	Annonaceae	15	9.38	55	34*
Xylopia sericea A.St.-Hil.	Annonaceae	4	2.50		
Allamanda blanchetti DC.	Apocynaceae	6	3.75		
Allamanda polyantha Müll. Arg.	Apocynaceae	1	0.62		
Aspidosperma australe Müll.Arg.	Apocynaceae	1	0.62		
Aspidosperma cuspa (Kunth) S.T. Blake	Apocynaceae	11	6.88		
Aspidosperma discolor A. DC.	Apocynaceae	6	3.75		
Aspidosperma macrocarpon Mart.	Apocynaceae	29	18.12		42*
Aspidosperma multiflorum A. DC.	Apocynaceae	27	16.88		
Aspidosperma pyrifolium Mart.	Apocynaceae	14	8.75		
Aspidosperma subincanum Mart. ex A. DC.	Apocynaceae	20	12.50		*
Aspidosperma tomentosum Mart.	Apocynaceae	20	12.50	51	31*
Barjonia erecta (Vell.) K. Schum.	Apocynaceae	1	0.62		
Catharanthus roseus (L.) G. Don	Apocynaceae	1	0.62		
Ditassa acerosa Mart.	Apocynaceae	1	0.62		
Forsteronia pubescens A. DC.	Apocynaceae	1	0.62		
Hancornia speciosa Gomes	Apocynaceae	48	30.00	53	49*
Himatanthus articulatus (Vahl) Woodson	Apocynaceae	17	10.62		
Himatanthus bracteatus (A. DC.) Woodson	Apocynaceae	1	0.62		
Himatanthus drasticus (Mart.) Plumel	Apocynaceae	15	9.38		
Himatanthus obovatus (Muell. Arg.) Woodson	Apocynaceae	53	33.12	59	78*
Himatanthus phagedaenicus (Mart.) Woodson	Apocynaceae	3	1.88		
Himatanthus sucuuba (Spruce ex Müll. Arg.) Woodson	Apocynaceae	2	1.25		
Matelea maritima (Jacq.) Woodson	Apocynaceae	1	0.62		
Nerium oleander L.	Apocynaceae	2	1.25		
Rauvolfia ligustrina Willd. ex Roem. & Schult.	Apocynaceae	1	0.62		
Tabernaemontana catharinensis A.DC.	Apocynaceae	2	1.25		
Tabernaemontana hystrix Steud	Apocynaceae	5	3.12		
Tabernaemontana solanifolia A.DC.	Apocynaceae	1	0.62		
Ilex velutina Mart.	Aquifoliaceae	1	0.62		
Taccarum peregrinum (Schott) Engl.	Araceae	2	1.25		
Schefflera morototoni (Aubl.) Maguire	Araliaceae	1	0.62		15
Schefflera vinosa (Cham. & Schltdl.) Frodin & Fiaschi	Araliaceae	6	3.75		
Acrocomia aculeata (Jacq.) Lodd. ex Mart.	Arecaceae	3	1.88		
Acrocomia hassleri (Barb. Rodr.) W.J. Hahn	Arecaceae	1	0.62		
Acrocomia intumescens Drude	Arecaceae	1	0.62		
Allagoptera campestris (Mart.) Kuntze	Arecaceae	3	1.88		
Astrocaryum campestre Mart.	Arecaceae	1	0.62		
Astrocaryum vulgare Mart.	Arecaceae	21	13.12		
Attalea barreirensis Glassman	Arecaceae	1	0.62		
Attalea funifera Mart.	Arecaceae	1	0.62		

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Attalea speciosa Mart.	Arecaceae	5	3.12		
Cocos nucifera L.	Arecaceae	1	0.62		
Copernicia prunifera (Mill.) H. E. Moore	Arecaceae	10	6.25		
Desmoncus phoenicocarpus Barb. Rodr.	Arecaceae	1	0.62		
Elaeis guineensis W.J.Jacq.	Arecaceae	1	0.62		
Mauritia flexuosa L. f.	Arecaceae	2	1.25		
Mauritiella armata (Mart.) Burret	Arecaceae	1	0.62		
Syagrus botryophora (Mart.) Mart.	Arecaceae	1	0.62		
Syagrus cocoides Mart.	Arecaceae	3	1.88		
Syagrus comosa (Mart.) Mart.	Arecaceae	13	8.12		31*
Syagrus flexuosa (Mart.) Becc.	Arecaceae	2	1.25		*
Syagrus werdermannii Burret	Arecaceae	1	0.62		
Acritopappus confertus (Gardner) R.M. King & H. Rob.	Asteraceae	2	1.25		
Aspilia riedelii Baker	Asteraceae	1	0.62		
Baccharis aphylla (Vell.) DC.	Asteraceae	1	0.62		
Bidens riparia Kunth	Asteraceae	2	1.25		
Centratherum punctatum Cass.	Asteraceae	2	1.25		
Chromolaena horminoides DC.	Asteraceae	2	1.25		
Chromolaena maximilianii (Schad. ex DC.) R. M. Kieg. & H. Rob.	Asteraceae	1	0.62		
Clibadium rotundifolium A. DC.	Asteraceae	1	0.62		
Elephantopus piauiensis R. Barros & Semir	Asteraceae	1	0.62		
Eremanthus glomerulatus Less.	Asteraceae	2	1.25		
Eremanthus goyazensis (Gardner) Sch. Bip.	Asteraceae	1	0.62		
Eremanthus graciellae MacLeish & H. Schumacher	Asteraceae	1	0.62		
Eremanthus incanus (Less.) Less.	Asteraceae	1	0.62		
Eremanthus pohlii (Baker) MacLeish	Asteraceae	1	0.62		
Eupatorium clematideum Griseb.	Asteraceae	1	0.62		
Eupatorium odoratum L.	Asteraceae	1	0.62		
Gochnatia blanchetiana (DC.) Cabrera	Asteraceae	2	1.25		
Lepidaploa cotoneaster (Willd. ex Spreng.) H. Rob.	Asteraceae	1	0.62		
Lepidaploa nitens (Gardner) H. Rob.	Asteraceae	2	1.25		
Lepidaploa remotiflora (Rich.) H. Rob.	Asteraceae	2	1.25		
Lepidaploa rufogrisea (A. St.-Hil.) H. Rob.	Asteraceae	1	0.62		
Lessingianthus rosmarinifolius (Less.) H. Rob.	Asteraceae	1	0.62		
Lychnophora bahiensis Mattf.	Asteraceae	1	0.62		
Lychnophora salicifolia Mart.	Asteraceae	2	1.25		
Melampodium divaricatum (Rich.) DC.	Asteraceae	2	1.25		
Mikania luetzelburgii Mattf.	Asteraceae	1	0.62		
Piptocarpha rotundifolia (Less.) Baker	Asteraceae	6	3.75		16*
Pithecoseris pacourinoides Mart.	Asteraceae	1	0.62		
Platypodanthera melissifolia (DC.) R.M. King & H. Rob.	Asteraceae	2	1.25		

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Porophyllum obscurum (Spreng.) DC.	Asteraceae	1	0.62		
Pseudobrickellia brasiliensis (Spreng.) R.M.King & H.Rob.	Asteraceae	1	0.62		
Rolandra fruticosa (L.) Kuntze	Asteraceae	1	0.62		
Stilpnopappus pratensis Mart. ex DC.	Asteraceae	2	1.25		
Stilpnopappus trichospiroides Mart. ex DC.	Asteraceae	1	0.62		
Symphyopappus compressus (Gardner) B.L. Rob.	Asteraceae	1	0.62		
Tilesia baccata (L.) Pruski	Asteraceae	1	0.62		
Trichogonia campestris Gardner	Asteraceae	1	0.62		
Trixis vauthieri DC.	Asteraceae	1	0.62		
Vernonanthura brasiliana (L.) H. Rob.	Asteraceae	4	2.50		
Vernonanthura ferruginea (Less.) H. Rob.	Asteraceae	7	4.38		16*
Adenocalymma pedunculatum (Vell.) L. Lohmann	Bignoniaceae	1	0.62		
Anemopaegma album Mart. ex DC.	Bignoniaceae	2	1.25		
Anemopaegma scabriusculum Mart. ex DC.	Bignoniaceae	1	0.62		
Anemopaegma velutinum Mart. ex DC.	Bignoniaceae	2	1.25		
Cybistax antisyphilitica (Mart.) Mart.	Bignoniaceae	37	23.12		27*
Fridericia dispar (Bureau ex K.Schum.) L.G.Lohmann	Bignoniaceae	4	2.50		
Fridericia platyphylla (Cham.) L.G.Lohmann	Bignoniaceae	13	8.12		
Godmania dardanoi (J.C.Gomes) A.H.Gentry	Bignoniaceae	2	1.25		
Handroanthus albus (Cham.) Mattos	Bignoniaceae	1	0.62		
Handroanthus impetiginosus (Mart. ex DC.) Mattos	Bignoniaceae	22	13.75		
Handroanthus ochraceus (Cham.) Mattos	Bignoniaceae	67	41.88	66	64*
Handroanthus serratifolius (Vahl) S.O.Grose	Bignoniaceae	44	27.50		
Jacaranda brasiliana (Lam.) Pers.	Bignoniaceae	20	12.50		
Jacaranda irwinii A.H.Gentry	Bignoniaceae	1	0.62		
Jacaranda jasminoides (Thunb.) Sandwith	Bignoniaceae	5	3.12		
Jacaranda praetermissa Sandwith	Bignoniaceae	2	1.25		
Jacaranda ulei Bureau & K. Schum	Bignoniaceae	1	0.62		
Tabebuia aurea (Manso) Benth. & Hook. f. ex S. Moore	Bignoniaceae	56	35.00	67	64*
Tabebuia pilosa A.Gentry	Bignoniaceae	1	0.62		
Tabebuia roseoalba (Ridl.) Sw.	Bignoniaceae	1	0.62		
Zeyheria montana Mart.	Bignoniaceae	26	16.25		33*
Zeyheria tuberculosa (Vell.) Bureau ex Verl.	Bignoniaceae	2	1.25		
Bixa orellana L.	Bixaceae	2	1.25		
Cochlospermum regium (Schrank) Pilger	Bixaceae	11	6.88		
Cochlospermum vitifolium (Willd.) Sprenge	Bixaceae	16	10.00		
Cordia alliodora (Ruiz Lopez & Pavon) Oken	Boraginaceae	1	0.62		
Cordia bicolor A. DC.	Boraginaceae	1	0.62		
Cordia glabrata (Mart.) A. DC.	Boraginaceae	2	1.25		
Cordia rufescens A.DC.	Boraginaceae	23	14.37		
Cordia scabrifolia A. DC.	Boraginaceae	1	0.62		

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Cordia sellowiana Cham.	Boraginaceae	1	0.62		
Cordia superba Cham.	Boraginaceae	4	2.50		
Cordia toqueve Aubl.	Boraginaceae	1	0.62		
Cordia trichotoma (Vell.) Arráb. ex Steud.	Boraginaceae	5	3.12		
Heliotropium lanceolatum Ruiz & Pav.	Boraginaceae	2	1.25		
Tournefortia rubicunda Salzm. ex DC.	Boraginaceae	1	0.62		
Varronia curassavica Jacq.	Boraginaceae	5	3.12		
Varronia guazumaefolia Desv.	Boraginaceae	1	0.62		
Varronia polycephala Lam.	Boraginaceae	2	1.25		
Commiphora leptophloeos (Mart.) J.B. Gillett	Burseraceae	4	2.50		
Protium bahianum Daly	Burseraceae	1	0.62		
Protium heptaphyllum (Aublet) Marchand	Burseraceae	10	6.25		*
Protium ovatum Engl.	Burseraceae	6	3.75		*
Arrojadoa rhodantha (Gürke) Britton & Rose	Cactaceae	1	0.62		
Cereus albicaulis (Britton & Rose) Luetzelb.	Cactaceae	2	1.25		
Cereus jamacaru DC.	Cactaceae	29	18.12		
Nopalea cochenillifera (L.) Salm-Dyck	Cactaceae	1	0.62		
Pilosocereus flavipulvinatus (Buining & Brederoo) F. Ritter	Cactaceae	1	0.62		
Pilosocereus gounellei (F.A.C. Weber) Byles e Rowley	Cactaceae	5	3.12		
Pilosocereus pachycladus Ritter	Cactaceae	1	0.62		
Pilosocereus piauhyensis (Gürke) Byles & G.D. Rowley	Cactaceae	1	0.62		
Pilosocereus tuberculatus (Werdem.) Byles & Rowley	Cactaceae	1	0.62		
Kielmeyera coriacea Mart. & Zucc.	Calophyllaceae	35	21.88	70	63*
Kielmeyera lathrophyton Saddi	Calophyllaceae	18	11.25		33
Kielmeyera neriifolia Cambess.	Calophyllaceae	1	0.62		
Kielmeyera speciosa A. St.-Hil.	Calophyllaceae	1	0.62		*
Kielmeyera variabilis Mart. & Zucc.	Calophyllaceae	2	1.25		
Trema micrantha (L.) Blume	Cannabaceae	2	1.25		
Capparis flexuosa (L.) L.	Capparaceae	1	0.62		
Capparis hastata Jacq.	Capparaceae	1	0.62		
Crateva tapia L.	Capparaceae	2	1.25		
Carica papaya L.	Caricaceae	1	0.62		
Jacaratia spinosa (Aubl.) A. DC.	Caricaceae	1	0.62		
Caryocar brasiliense Cambess.	Caryocaraceae	16	10.00	61	30*
Caryocar coriaceum Wittm.	Caryocaraceae	61	38.12		
Caryocar cuneatum Wittm.	Caryocaraceae	29	18.12		54*
Caryocar villosum (Aubl.) Pers.	Caryocaraceae	1	0.62		
Celastrus maytenus Willd.	Celastraceae	7	4.38		
Cheiloclinium cognatum (Miers) A. C. Sm.	Celastraceae	1	0.62		
Maytenus distichophylla Mart.	Celastraceae	6	3.75		

Species	Family	Constancy	Const. (%)	Refl	Ref.2
Maytenus obtusifolia Mart.	Celastraceae	2	1.25		
Maytenus rigida Mart.	Celastraceae	2	1.25		
Plenckia populnea Reissek	Celastraceae	7	4.38		*
Salacia amygdalina Peyr.	Celastraceae	1	0.62		
Salacia crassifolia (Mart. ex Schult.) G. Don	Celastraceae	19	11.88		36*
Salacia elliptica (Mart. ex Schult.) G.Don.	Celastraceae	13	8.12		
Tontelea micrantha (Mart. ex Schult.) A.C. Sm.	Celastraceae	1	0.62		
Couepia grandiflora (Mart. & Zucc.) Benth. Ex Hook.f.	Chrysobalanaceae	21	13.12		30*
Exellodendron cordatum (Hook. f.) Prance	Chrysobalanaceae	3	1.88		
Exellodendron gardneri (Hook. f.) Prance	Chrysobalanaceae	4	2.50		
Hirtella ciliata Mart. & Zucc.	Chrysobalanaceae	79	49.38		52*
Hirtella glandulosa Spreng.	Chrysobalanaceae	6	3.75		
Hirtella gracilipes (Hook. f.) Prance	Chrysobalanaceae	5	3.12		
Hirtella hebeclada Moric. ex DC.	Chrysobalanaceae	1	0.62		
Hirtella racemosa Lam.	Chrysobalanaceae	5	3.12		
Licania octandra (Hoffmanns. ex Schult.) Kuntze	Chrysobalanaceae	3	1.88		
Licania rigida Benth.	Chrysobalanaceae	2	1.25		
Cleome spinosa Jacq.	Cleomaceae	4	2.50		
Clusia dardanoi G. Mariz & Maguire	Clusiaceae	1	0.62		
Clusia panapanari (Aubl.) Choisy	Clusiaceae	1	0.62		
Clusia sellowiana Schltdl.	Clusiaceae	2	1.25		
Platonia insignis Mart.	Clusiaceae	17	10.62		
Buchenavia grandis Ducke	Combretaceae	3	1.88		
Buchenavia tetraphylla (Aubl.) R. Howard	Combretaceae	17	10.62		
Buchenavia tomentosa Eichler	Combretaceae	6	3.75		13
Combretum duarteanum Cambess.	Combretaceae	29	18.12		
Combretum ellipticum Sim.	Combretaceae	1	0.62		
Combretum fruticosum (Loefl.) Stuntz	Combretaceae	1	0.62		
Combretum glaucocarpum Mart.	Combretaceae	13	8.12		
Combretum lanceolatum Pohl ex Eichler	Combretaceae	4	2.50		
Combretum leprosum Mart.	Combretaceae	44	27.50		
Combretum mellifluum Eichler	Combretaceae	60	37.50		36
Combretum mellifluum var. *mellifluum* Eichler	Combretaceae	1	0.62		
Terminalia actinophylla Mart.	Combretaceae	11	6.88		
Terminalia argentea Mart.	Combretaceae	2	1.25		*
Terminalia fagifolia Mart.	Combretaceae	91	56.88		57*
Terminalia glabrescens Mart.	Combretaceae	5	3.12		
Connarus favosus Planch.	Connaraceae	1	0.62		
Connarus regnellii Schellenb.	Connaraceae	1	0.62		
Connarus suberosus Planch.	Connaraceae	50	31.25	73	78*
Connarus suberosus var. *fulvus* (Planchon) Forero	Connaraceae	6	3.75		
Rourea doniana Baker.	Connaraceae	1	0.62		

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Rourea gardneriana Planh.	Connaraceae	1	0.62		
Rourea induta Planh.	Connaraceae	21	13.12		37*
Evolvulus elegans Moric.	Convolvulaceae	1	0.62		
Evolvulus glomeratus Nees & C. Mart.	Convolvulaceae	2	1.25		
Evolvulus latifolius Ker Gawl.	Convolvulaceae	1	0.62		
Evolvulus pterocaulon Moric.	Convolvulaceae	2	1.25		
Ipomoea carnea Jacq.	Convolvulaceae	1	0.62		
Jacquemontia agrestis (Mart. ex Choisy) Meisn.	Convolvulaceae	1	0.62		
Merremia digitata (Spreng.) Hallier f.	Convolvulaceae	2	1.25		
Operculina alata Urb.	Convolvulaceae	1	0.62		
Operculina macrocarpa (Linn) Urb.	Convolvulaceae	1	0.62		
Cayaponia tayuya (Vell.) Cogn.	Cucurbitaceae	1	0.62		
Curatella americana L.	Dilleniaceae	95	59.38	62	51*
Davilla cearensis Huber	Dilleniaceae	2	1.25		
Davilla elliptica A. St.-Hil.	Dilleniaceae	35	21.88	58	61*
Davilla macrocarpa Eichler	Dilleniaceae	3	1.88		
Diospyros brasiliensis Mart. ex Miq.	Ebenaceae	1	0.62		
Diospyros coccolobaefolia Mart. ex Miq.	Ebenaceae	7	4.38		
Diospyros hispida A. DC.	Ebenaceae	52	32.50	57	70*
Diospyros inconstans Jacq.	Ebenaceae	2	1.25		
Diospyros sericea A. DC.	Ebenaceae	15	9.38		
Emmotum nitens (Benth.) Miers	Emmotaceae	36	22.50		49*
Erythroxylum arrojadoi O.E.Schuz	Erythroxylaceae	7	4.38		
Erythroxylum barbatum O.E.Schuz	Erythroxylaceae	5	3.12		
Erythroxylum betulaceum Mart.	Erythroxylaceae	4	2.50		
Erythroxylum bezerrae Plowmann	Erythroxylaceae	3	1.88		
Erythroxylum buxus Peyr.	Erythroxylaceae	1	0.62		
Erythroxylum campestre A. St.-Hil.	Erythroxylaceae	1	0.62		
Erythroxylum daphnites Mart.	Erythroxylaceae	1	0.62		
Erythroxylum deciduum St. Hil.	Erythroxylaceae	14	8.75		19
Erythroxylum laetevirens O.E.Schulz	Erythroxylaceae	5	3.12		
Erythroxylum suberosum A. St.-Hil.	Erythroxylaceae	6	3.75	62	39*
Erythroxylum subracemosum Turcz	Erythroxylaceae	15	9.38		
Erythroxylum tortuosum Mart.	Erythroxylaceae	1	0.62		*
Erythroxylum vacciniifolium Mart.	Erythroxylaceae	2	1.25		
Alchornea triplinervia (Spreng.) Müll. Arg.	Euphorbiaceae	1	0.62		
Chaetocarpus myrsinites Baill.	Euphorbiaceae	1	0.62		
Cnidoscolus cnicodendron Griseb.	Euphorbiaceae	1	0.62		
Cnidoscolus urens (L.) Arthur	Euphorbiaceae	2	1.25		
Cnidoscolus vitifolius (Mill.) Pohl	Euphorbiaceae	1	0.62		
Croton argyrophylloides Müll. Arg.	Euphorbiaceae	1	0.62		
Croton betaceus Baill.	Euphorbiaceae	3	1.88		

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Croton betulaster Müll. Arg.	Euphorbiaceae	1	0.62		
Croton blanchetianus Baill.	Euphorbiaceae	1	0.62		
Croton campestris A. St.-Hil.	Euphorbiaceae	12	7.50		
Croton celtidifolius Baill.	Euphorbiaceae	1	0.62		
Croton essequiboensis Klotzsch	Euphorbiaceae	1	0.62		
Croton heliotropiifolius Kunth	Euphorbiaceae	1	0.62		
Croton lundianus (Didr.) Müll. Arg.	Euphorbiaceae	2	1.25		
Croton pedicellatus Kunth	Euphorbiaceae	2	1.25		
Croton sonderianus Müll. Arg.	Euphorbiaceae	3	1.88		
Jatropha curcas L.	Euphorbiaceae	1	0.62		
Jatropha gossypiifolia L.	Euphorbiaceae	2	1.25		
Jatropha mollissima (Pohl) Baill.	Euphorbiaceae	1	0.62		
Jatropha mutabilis (Pohl) Baill.	Euphorbiaceae	1	0.62		
Mabea fistulifera Mart.	Euphorbiaceae	5	3.12		
Mabea nitida Spruce ex Benth.	Euphorbiaceae	1	0.62		
Mabea pohliana (Benth.) Müll. Arg.	Euphorbiaceae	1	0.62		
Manihot anomala Pohl	Euphorbiaceae	1	0.62		
Manihot caerulescens Pohl	Euphorbiaceae	2	1.25		
Manihot carthaginensis subsp. *glaziovii* (Müll.Arg.) Allem	Euphorbiaceae	1	0.62		
Manihot esculenta Crantz.	Euphorbiaceae	1	0.62		
Manihot maracasensis Ule	Euphorbiaceae	3	1.88		
Manihot pruinosa Pohl	Euphorbiaceae	1	0.62		
Manihot tripartita (Spreng.) Müll. Arg.	Euphorbiaceae	1	0.62		
Maprounea brasiliensis A. St.-Hil.	Euphorbiaceae	1	0.62		
Maprounea guianensis Aubl.	Euphorbiaceae	18	11.25		30*
Microstachys corniculata (Vahl) Griseb.	Euphorbiaceae	2	1.25		
Microstachys serrulata (Mart.) Müll.Arg.	Euphorbiaceae	1	0.62		
Pera glabrata (Schott.) Poepp. ex Baill.	Euphorbiaceae	5	3.12		
Pogonophora schombugkiana Miers ex Benth.	Euphorbiaceae	1	0.62		
Sapium glandulosum (L.) Morong	Euphorbiaceae	3	1.88		
Sebastiania brevifolia (Müll. Arg.) Müll. Arg.	Euphorbiaceae	1	0.62		
Abarema cochleata (Willd.) Barneby & J.W. Grimes	Fabaceae	2	1.25		
Abarema cochliacarpos (Gomes) Barneby & J. W. Grimes	Fabaceae	4	2.50		
Aeschynomene paniculata Willd. ex Vogel	Fabaceae	1	0.62		
Aeschynomene sensitiva Sw.	Fabaceae	1	0.62		
Albizia niopoides (Spruce ex Benth.) Burkart	Fabaceae	1	0.62		
Albizia polycephala (Benth.) Killip	Fabaceae	1	0.62		
Amburana cearensis (Alemão) A. C. Sm.	Fabaceae	9	5.62		
Anadenanthera colubrina (Vell.) Brenan	Fabaceae	5	3.12		
Anadenanthera colubrina var. *cebil* (Griseb.) Altschul	Fabaceae	10	6.25		*
Andira anthelmia (Vell.) J.F. Macbr.	Fabaceae	3	1.88		

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Andira cordata Arroyo ex R.T. Penn. & H.C. Lima	Fabaceae	16	10.00		18
Andira cujabensis Benth.	Fabaceae	9	5.62		16*
Andira fraxinifolia Benth.	Fabaceae	5	3.12		
Andira humilis Mart. ex Benth.	Fabaceae	4	2.50		
Andira legalis (Vell.) Toledo	Fabaceae	1	0.62		
Andira nitida Mart. ex Benth.	Fabaceae	3	1.88		
Andira paniculata Benth.	Fabaceae	4	2.50		
Andira surinamensis (Bondt) Splitg. ex Amshoff	Fabaceae	6	3.75		
Andira vermifuga Mart. ex Benth.	Fabaceae	39	24.38		67*
Apuleia leiocarpa (Vogel) J. F. Macbr.	Fabaceae	2	1.25		
Ateleia glazioveana Baillon	Fabaceae	1	0.62		
Bauhinia aculeata L.	Fabaceae	1	0.62		
Bauhinia acuruana Moric.	Fabaceae	1	0.62		
Bauhinia brevipes Vogel	Fabaceae	2	1.25		
Bauhinia burchellii Benth.	Fabaceae	1	0.62		
Bauhinia cheilantha (Bong.) Steud.	Fabaceae	2	1.25		
Bauhinia cupulata Benth.	Fabaceae	1	0.62		
Bauhinia cuyabensis (Bong.) Steudel	Fabaceae	2	1.25		
Bauhinia dubia G. Don	Fabaceae	21	13.12		
Bauhinia forficata Link	Fabaceae	2	1.25		
Bauhinia longifolia (Bong.) Steud.	Fabaceae	1	0.62		
Bauhinia pentandra (Bong.) Vogel ex Steud.	Fabaceae	1	0.62		
Bauhinia pulchella Benth.	Fabaceae	26	16.25		
Bauhinia rufa (Bong.) Steud.	Fabaceae	2	1.25		*
Bauhinia subclavata Benth.	Fabaceae	1	0.62		
Bauhinia tenella Benth.	Fabaceae	1	0.62		
Bauhinia ungulata L.	Fabaceae	21	13.12		
Bionia coriacea (Nees & Mart.) Benth.	Fabaceae	2	1.25		
Bocoa ratteri H.E. Ireland	Fabaceae	1	0.62		
Bowdichia virgilioides Kunth.	Fabaceae	117	73.12	77	78*
Caesalpinia echinata Lam.	Fabaceae	1	0.62		
Caesalpinia pulcherrima (L.) Sw.	Fabaceae	1	0.62		
Calliandra abbreviata Benth.	Fabaceae	1	0.62		
Calliandra bahiana Renvoize	Fabaceae	2	1.25		
Calliandra fernandesii Barneby	Fabaceae	6	3.75		
Calliandra longipinna Benth.	Fabaceae	1	0.62		
Calliandra parviflora Benth.	Fabaceae	1	0.62		
Calliandra sessilis Benth.	Fabaceae	3	1.88		
Calliandra umbellifera Benth.	Fabaceae	1	0.62		
Camptosema pedicellatum var. *longibothrys* Benth.	Fabaceae	1	0.62		
Camptosema pedicellatum var. *pedicellatum* Benth.	Fabaceae	1	0.62		
Cassia grandis L. F.	Fabaceae	1	0.62		

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Cenostigma macrophyllum Tul.	Fabaceae	6	3.75		
Chamaecrista apoucouita (Aubl.) H.S. Irwin & Barneby	Fabaceae	1	0.62		
Chamaecrista bahiae (H. S. Irwin) H. S. Irwin & Barneby	Fabaceae	1	0.62		
Chamaecrista claussenii (Benth.) H.S. Irwin & Barneby	Fabaceae	1	0.62		
Chamaecrista desvauxii (Collad.) Killip	Fabaceae	1	0.62		
Chamaecrista desvauxii var. *malacophylla* (Vogel) H.Irwin & Barneby	Fabaceae	1	0.62		
Chamaecrista eitenorum (H.S. Irwin & Barneby) H.S. Irwin & Barneby	Fabaceae	4	2.50		
Chamaecrista ensiformis (Vell. Conc.) H. Irwin & Barneby	Fabaceae	5	3.12		
Chamaecrista fagonioides (Vogel) H.Irwin & Barneby	Fabaceae	1	0.62		
Chamaecrista flexuosa (L.) Greene	Fabaceae	4	2.50		
Chamaecrista hispidula (Vahl.0 H. S. i rwin & Barn.	Fabaceae	1	0.62		
Chamaecrista juruenensis (Hoehne) H. Irwin & Barneby	Fabaceae	1	0.62		
Chamaecrista langsdorffii (Kunth ex Vogel) Britton ex Pittier	Fabaceae	1	0.62		
Chamaecrista nictitans (L.) Moench	Fabaceae	2	1.25		
Chamaecrista orbiculata (Benth.) H.S. Irwin & Barneby	Fabaceae	2	1.25		
Chamaecrista ramosa (Vogel) H.S. Irwin & Barneby	Fabaceae	1	0.62		
Chamaecrista repens var. *multijuga* (Benth.) H.S. Irwin & Barneby	Fabaceae	1	0.62		
Chamaecrista rotundata (Vogel) H. Irwin & Barneby	Fabaceae	1	0.62		
Chamaecrista viscosa (Kunth) H.S. Irwin & Barneby	Fabaceae	1	0.62		
Chamaecrista zygophylloides (Taubert) H. Irwin & Barneby	Fabaceae	1	0.62		
Chloroleucon acacioides (Ducke) Barneby & J.W. Grimes	Fabaceae	3	1.88		
Chloroleucon dumosum (Benth.) G.P.Lewis	Fabaceae	1	0.62		
Chloroleucon foliolosum (Benth.) G.P.Lewis	Fabaceae	1	0.62		
Chloroleucon mangense (Jacq.) Britton & Rosé	Fabaceae	1	0.62		
Copaifera elliptica Mart.	Fabaceae	1	0.62		
Copaifera langsdorffii Desf.	Fabaceae	23	14.37		25*
Copaifera luetzelburgii Harms	Fabaceae	4	2.50		
Copaifera martii Mart.	Fabaceae	56	35.00		36
Cratylia argentea (Desv.) Kuntze	Fabaceae	2	1.25		
Cratylia mollis Mart. ex Benth.	Fabaceae	1	0.62		
Crotalaria holosericea Nees & Mart.	Fabaceae	1	0.62		
Crotalaria stipularia Desv.	Fabaceae	1	0.62		
Dalbergia cearensis Ducke	Fabaceae	1	0.62		
Dalbergia miscolobium Benth.	Fabaceae	45	28.12		37*

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Delonix regia (Bojer ex Hook.) Raf.	Fabaceae	1	0.62		
Desmodium triflorum (L.) DC.	Fabaceae	1	0.62		
Dialium guianense (Aubl.) Sandwith	Fabaceae	1	0.62		
Dimorphandra gardneriana Tul.	Fabaceae	59	36.88		
Dimorphandra mollis Benth	Fabaceae	50	31.25	74	81*
Dipteryx alata Vogel	Fabaceae	6	3.75		*
Dipteryx lacunifera Ducke	Fabaceae	3	1.88		
Diptychandra aurantiaca subsp. *epunctata* (Tul.) H.C.Lima et al.	Fabaceae	1	0.62		
Diptychandra aurantiaca Tul.	Fabaceae	2	1.25		
Enterolobium contortisiliquum (Vell.) Morong	Fabaceae	5	3.12		
Enterolobium ellipticum Benth.	Fabaceae	1	0.62		
Enterolobium gummiferum (Mart.) Mcbr.	Fabaceae	28	17.50		43*
Enterolobium schomburgkii (Benth.) Benth	Fabaceae	1	0.62		
Erythrina velutina Willd.	Fabaceae	1	0.62		
Harpalyce brasiliana Benth.	Fabaceae	5	3.12		
Holocalyx balansae Micheli	Fabaceae	1	0.62		
Hymenaea courbaril var. *longifolia*(Benth.) Y.T. Lee & Andrade-Lima	Fabaceae	5	3.12		
Hymenaea courbaril var. *stilbocarpa* (Hayne) Y.T. Lee & Langenh.	Fabaceae	7	4.38		
*Hymenaea courbaril*L.	Fabaceae	18	11.25		
Hymenaea eriogyne Benth.	Fabaceae	1	0.62		
Hymenaea maranhensis Lee & Langenh.	Fabaceae	4	2.50		
Hymenaea stigonocarpa Mart. ex Hayne	Fabaceae	84	52.50	73	82*
Hymenaea stigonocarpa var. *pubescens* Benth.	Fabaceae	3	1.88		
Hymenaea velutina Ducke	Fabaceae	6	3.75		
Indigofera blanchetiana Benth.	Fabaceae	1	0.62		
Indigofera hirsuta L.	Fabaceae	1	0.62		
Inga capitata Desv.	Fabaceae	4	2.50		
Inga laurina (Sw.) Willd.	Fabaceae	3	1.88		
Inga scabriuscula Benth.	Fabaceae	1	0.62		
Inga vera Willd.	Fabaceae	1	0.62		
Leptolobium dasycarpum Vogel	Fabaceae	55	34.38	62	58*
Leptolobium elegans Vogel	Fabaceae	1	0.62		
Libidibia ferrea (Mart. ex Tul.) L.P.Queiroz	Fabaceae	16	10.00		
Lonchocarpus araripensis Benth.	Fabaceae	8	5.00		
Luetzelburgia auriculata (Allemão) Ducke	Fabaceae	33	20.62		
Machaerium aculeatum Raddi	Fabaceae	1	0.62		
Machaerium acutifolium var. *acutifolium* Vogel	Fabaceae	1	0.62		
Machaerium acutifolium Vogel	Fabaceae	47	29.38	58	36*
Machaerium opacum Vogel	Fabaceae	16	10.00		27*
Machaerium scleroxylon Tul.	Fabaceae	2	1.25		
Martiodendron mediterraneum (Mart. ex Benth.) R.	Fabaceae	24	15.00		

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Koeppen					
Mimosa acutistipula (Mart.) Benth.	Fabaceae	6	3.75		
Mimosa arenosa (Willd.) Poir.	Fabaceae	1	0.62		
Mimosa caesalpiniifolia Benth.	Fabaceae	16	10.00		
Mimosa camporum Benth.	Fabaceae	1	0.62		
Mimosa exalbescens Barneby	Fabaceae	3	1.88		
Mimosa gemmulata Barneby	Fabaceae	1	0.62		
Mimosa honesta Mart.	Fabaceae	1	0.62		
Mimosa lasiophylla Benth.	Fabaceae	1	0.62		
Mimosa ophthalmocentra Mart. ex Benth.	Fabaceae	1	0.62		
Mimosa polycarpa Kunth.	Fabaceae	1	0.62		
Mimosa polydidyma Barneby	Fabaceae	1	0.62		
Mimosa sericantha Benth.	Fabaceae	2	1.25		
Mimosa somnians Humb. & Bonpl. ex Willd.	Fabaceae	2	1.25		
Mimosa tenuiflora (Willd.) Poir.	Fabaceae	6	3.75		
Mimosa verrucosa Benth.	Fabaceae	14	8.75		
Moldenhawera acuminata Afr. Fernandes & P. Bezerra	Fabaceae	1	0.62		
Parkia platycephala Benth.	Fabaceae	92	57.50		42
Peltogyne confertiflora (Mart. ex Hayne) Benth.	Fabaceae	8	5.00		
Periandra mediterranea (Vell.) Taub.	Fabaceae	3	1.88		
Phanera flexuosa (Moric.) L.P.Queiroz	Fabaceae	1	0.62		
Phanera glabra (Jacq.) Vaz	Fabaceae	2	1.25		
Phanera trichosepala L.P. Queiroz	Fabaceae	1	0.62		
Piptadenia stipulacea (Benth.) Ducke	Fabaceae	5	3.12		
Piptadenia viridiflora (Kunth.) Benth.	Fabaceae	1	0.62		
Pityrocarpa moniliformis (Benth.) Luckow & R. W. Jobson	Fabaceae	23	14.37		
Plathymenia reticulata Benth.	Fabaceae	91	56.88	53	64*
Platypodium elegans Vogel	Fabaceae	3	1.88		*
Poeppigia procera Presl.	Fabaceae	2	1.25		
Poincianella bracteosa (Tul.) L.P.Queiroz	Fabaceae	8	5.00		
Poincianella pyramidalis (Tul.) L.P.Queiroz	Fabaceae	2	1.25		
Pterocarpus rohrii Vahl	Fabaceae	2	1.25		
Pterocarpus villosus (Mart. ex Benth.) Benth.	Fabaceae	4	2.50		
Pterodon abruptus (Moric.) Benth.	Fabaceae	1	0.62		
Pterodon emarginatus Vogel	Fabaceae	39	24.38		57*
Pterodon pubescens (Benth.) Benth.	Fabaceae	9	5.62		*
Samanea tubulosa (Benth.) Barneby & J.W. Grimes	Fabaceae	2	1.25		
Senegalia piauhiensis (Benth.) Seigler & Ebinger	Fabaceae	1	0.62		
Senegalia polyphylla (DC.) Britton & Rose	Fabaceae	1	0.62		
Senegalia riparia (Kunth) Britton & Rose	Fabaceae	1	0.62		
Senegalia tenuifolia (L.) Britton & Rose	Fabaceae	1	0.62		

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Senna acuruensis (Benth.) Irwin & Barneby	Fabaceae	16	10.00		
Senna alata (L.) Roxb.	Fabaceae	3	1.88		
Senna barnebyana Lass.	Fabaceae	1	0.62		
Senna cana var. *hypoleuca* H. S. Irwin & Barneby	Fabaceae	1	0.62		
Senna cearensis A.Fern.	Fabaceae	2	1.25		
Senna gardneri (Benth.) H.S.Irwin & Barneby	Fabaceae	1	0.62		
Senna latifolia (G. Meyer) H. S. Irwin & Barneby	Fabaceae	1	0.62		
Senna lechriosperma H.S. Irwin & Barneby	Fabaceae	2	1.25		
Senna macranthera (DC. ex Collad.) H.S. Irwin & Barneby	Fabaceae	4	2.50		
Senna macranthera var. *pudibunda* (Benth.) H.S.Irwin & Barneby	Fabaceae	2	1.25		
Senna obtusifolia (L.) H.S.Irwin & Barneby.	Fabaceae	2	1.25		
Senna occidentalis (L.) Link	Fabaceae	2	1.25		
Senna pendula (Humb. & Bonpl. ex Willd.) H.S. Irwin & Barneby	Fabaceae	1	0.62		
Senna rizzinii H.S. Irwin & Barneby	Fabaceae	1	0.62		
Senna rostrata (Mart.) H. S. Irwin & Barneby	Fabaceae	1	0.62		
Senna rugosa (G. Don.) H. S. Irwin & Barneby	Fabaceae	5	3.12		
Senna siamea (Lamarck) H.S.Irwin & Barneby.	Fabaceae	2	1.25		
Senna silvestris (Vell. Conc.) H. S. Irwin & Barneby	Fabaceae	2	1.25		
Senna spectabilis (DC.) H. S. Irwin & Barneby	Fabaceae	1	0.62		
Senna spectabilis var. *excelsa* (Schrader) H. S. Irwin & Barneby	Fabaceae	2	1.25		
Senna trachypus (Mart. ex Benth.) H.S. Irwin & Barneby	Fabaceae	6	3.75		
Senna velutina (Vogel) H.S. Irwin & Barneby	Fabaceae	2	1.25		
Stryphnodendron adstringens (Mart.) Coville	Fabaceae	5	3.12		*
Stryphnodendron coriaceum Benth.	Fabaceae	81	50.62		22
Stryphnodendron guianense (Aubl.) Benth.	Fabaceae	2	1.25		
Stryphnodendron obovatum Benth.	Fabaceae	27	16.88		52*
Stryphnodendron polyphyllum Mart.	Fabaceae	3	1.88		
Stryphnodendron pulcherrimum (Willd) Hocher	Fabaceae	3	1.88		
Stryphnodendron rotundifolium Mart.	Fabaceae	3	1.88		
Stylosanthes capitata Vogel	Fabaceae	2	1.25		
Stylosanthes gracilis Kunth	Fabaceae	1	0.62		
Stylosanthes guianensis (Aubl.) Sw.	Fabaceae	1	0.62		
Swartzia apetala Raddi	Fabaceae	1	0.62		
Swartzia flaemingii Raddi	Fabaceae	4	2.50		
Swartzia psilonema Harms	Fabaceae	5	3.12		
Tachigali aurea Tul.	Fabaceae	31	19.38	55	43*
Tachigali goeldiana (Huber) L.G.Silva & H.C.Lima	Fabaceae	1	0.62		
Tachigali hypoleuca (Benth.) Zarucchi & Herend.	Fabaceae	1	0.62		
Tachigali subvelutina (Benth.) Oliveira-Filho	Fabaceae	1	0.62		
Tachigali vulgaris L.G.Silva & H.C.Lima	Fabaceae	78	48.75		75*

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Tamarindus indica L.	Fabaceae	2	1.25		
Taralea oppositifolia Aubl.	Fabaceae	1	0.62		
Trischidium molle (Benth.) H.E. Ireland	Fabaceae	2	1.25		
Vachellia farnesiana (L.) Wight & Arn.	Fabaceae	1	0.62		
Vatairea macrocarpa (Benth.) Ducke	Fabaceae	94	58.75	59	69*
Vigna firmula (Benth.) Marechal, Mascherpa & Stainier	Fabaceae	1	0.62		
Zollernia ilicifolia (Brongn.) Vogel	Fabaceae	3	1.88		
Humiria balsamifera Aublet	Humiriaceae	1	0.62		
Sacoglottis guianensis Benth.	Humiriaceae	1	0.62		
Sacoglottis mattogrossensis Malme	Humiriaceae	4	2.50		
Hydrolea spinosa L.	Hydroleaceae	1	0.62		
Vismia cayennensis (Jacq.) Pers.	Hypericaceae	1	0.62		
Vismia confertiflora Spruce ex Reichardt	Hypericaceae	1	0.62		
Vismia guianensis (Aubl.) Pers.	Hypericaceae	15	9.38		
Vismia magnoliifolia Cham. & Schldl.	Hypericaceae	1	0.62		
Krameria tomentosa A. St.-Hil.	Krameriaceae	22	13.75		
Aegiphila hastingsiana Moldenke	Lamiaceae	5	3.12		
Aegiphila pernambucensis Moldenke	Lamiaceae	1	0.62		
Aegiphila verticillata Vell.	Lamiaceae	15	9.38		21
Amasonia campestris (Aubl.) Moldenke	Lamiaceae	7	4.38		
Eriope hypenioides Mart. ex Benth.	Lamiaceae	1	0.62		
Eriope latifolia (Mart. ex Benth.) Harley	Lamiaceae	1	0.62		
Eriope macrostachya Mart. ex Benth.	Lamiaceae	1	0.62		
Eriope polyphylla Mart. ex Benth.	Lamiaceae	1	0.62		
Hypenia salzmannii (Benth.) Harley	Lamiaceae	1	0.62		
Hypenia vitifolia (Pohl ex Benth.) Harley	Lamiaceae	2	1.25		
Hyptis crinita Benth.	Lamiaceae	2	1.25		
Leonotis nepetifolia (L.) R. Br.	Lamiaceae	1	0.62		
Vitex cymosa Bertero ex Spreng.	Lamiaceae	18	11.25		
Vitex flavens Kunth	Lamiaceae	7	4.38		
Vitex panshaniana Mold.	Lamiaceae	1	0.62		
Vitex polygama Cham.	Lamiaceae	4	2.50		
Vitex rufescens A. Juss.	Lamiaceae	1	0.62		
Vitex trifolia L.	Lamiaceae	1	0.62		
Mezilaurus itauba (Meisn.) Taub. ex Mez	Lauraceae	1	0.62		
Nectandra cuspidata Nees	Lauraceae	1	0.62		
Ocotea brachybotrya (Meisn.)Mez	Lauraceae	6	3.75		
Ocotea duckei Vatt.	Lauraceae	1	0.62		
Ocotea nitida (Meisn.) Mez	Lauraceae	1	0.62		
Ocotea pallida (Meiss.) Mez.	Lauraceae	1	0.62		
Ocotea percoriacea (Meisn.) Kosterm.	Lauraceae	1	0.62		
Persea americana Mill.	Lauraceae	1	0.62		

Species	Family	Constancy	Const. (%)	Refl	Ref.2
Eschweilera nana (O. Berg) Miers	Lecythidaceae	10	6.25		22
Eschweilera ovata (Cambess.) Miers	Lecythidaceae	2	1.25		
Lecythis idatimon Aubl.	Lecythidaceae	1	0.62		
Lecythis lurida (Miers.) Mori	Lecythidaceae	2	1.25		
Lecythis pisonis Cambess.	Lecythidaceae	5	3.12		
Antonia ovata Pohl	Loganiaceae	17	10.62		
Spigelia pulchella Mart.	Loganiaceae	1	0.62		
Strychnos mitscherlichii var. *amapensis* Krukoff & Barneby	Loganiaceae	1	0.62		
Strychnos parvifolia Spruce ex Benth.	Loganiaceae	2	1.25		
Strychnos pseudoquina A. St. Hil.	Loganiaceae	21	13.12		28*
Phthirusa stelis (L.) Kuijt	Loranthaceae	1	0.62		
Psittacanthus robustus (Mart.) Mart.	Loranthaceae	2	1.25		
Struthanthus marginatus (Desr.) Blume	Loranthaceae	1	0.62		
Struthanthus oerstedii (Oliv.) Standl.	Loranthaceae	1	0.62		
Cuphea antisyphilitica Humb., Bonpl. & Kunth	Lythraceae	1	0.62		
Cuphea campestris Koehne	Lythraceae	1	0.62		
Cuphea ericoides Cham. & Schltdl.	Lythraceae	1	0.62		
Cuphea laricoides Koehne	Lythraceae	1	0.62		
Diplusodon parvifolius DC.	Lythraceae	1	0.62		
Lafoensia pacari A. St. Hil.	Lythraceae	40	25.00	74	66*
Lafoensia vandelliana Cham. & Schltdl.	Lythraceae	2	1.25		
Lafoensia vandelliana subsp. *replicata* (Pohl) Lourteig	Lythraceae	43	26.88		
Punica granatum L.	Lythraceae	1	0.62		
Banisteriopsis angustifolia (A. Juss.) B. Gates	Malpighiaceae	2	1.25		
Banisteriopsis campestris (A. Juss.) Little	Malpighiaceae	1	0.62		
Banisteriopsis gardneriana (A. Juss.) W.R. Anderson & B. Gates	Malpighiaceae	1	0.62		
Banisteriopsis harleyi B. Gates	Malpighiaceae	1	0.62		
Banisteriopsis latifolia (A. Juss.) B. Gates	Malpighiaceae	1	0.62		
Banisteriopsis lutea (Griseb.) Cuatrec.	Malpighiaceae	2	1.25		
Banisteriopsis malifolia (Nees & Mart.) B. Gates	Malpighiaceae	3	1.88		
Banisteriopsis nummifera (A. Juss.) B. Gates	Malpighiaceae	3	1.88		
Banisteriopsis stellaris (Griseb.) B. Gates	Malpighiaceae	5	3.12		
Barnebya harleyi W. R. Anderson & B. Gates	Malpighiaceae	2	1.25		
Bunchosia armeniaca (Cav.) DC.	Malpighiaceae	1	0.62		
Byrsonima basiloba A. Juss.	Malpighiaceae	1	0.62		
Byrsonima blanchetiana Miq.	Malpighiaceae	6	3.75		
Byrsonima chrysophylla Kunth	Malpighiaceae	1	0.62		
Byrsonima coccolobifolia Kunth	Malpighiaceae	16	10.00	65	27*
Byrsonima coriacea (Sw.) DC.	Malpighiaceae	1	0.62		
Byrsonima correifolia A. Juss.	Malpighiaceae	31	19.38		
Byrsonima crassifolia (L.) Kunth	Malpighiaceae	51	31.87		15

Species	Family	Constancy	Const. (%)	Refl	Ref.2
Byrsonima cydoniifolia A. Juss.	Malpighiaceae	3	1.88		
Byrsonima dealbata Griseb.	Malpighiaceae	2	1.25		
Byrsonima gardnerana A. Juss.	Malpighiaceae	3	1.88		
Byrsonima intermedia A. Juss.	Malpighiaceae	4	2.50		*
Byrsonima laevis Nied.	Malpighiaceae	1	0.62		
Byrsonima lancifolia A. Juss.	Malpighiaceae	3	1.88		
Byrsonima oblongifolia A. Juss.	Malpighiaceae	2	1.25		
Byrsonima pachyphylla A. Juss.	Malpighiaceae	36	22.50	60	67*
Byrsonima rotunda Griseb.	Malpighiaceae	1	0.62		
Byrsonima sericea A. DC.	Malpighiaceae	19	11.88		
Byrsonima spicata (Cav.) DC.	Malpighiaceae	1	0.62		
Byrsonima umbellata Mart. ex A.Juss.	Malpighiaceae	1	0.62		
Byrsonima vacciniifolia A. Juss.	Malpighiaceae	1	0.62		
Byrsonima verbascifolia (L.) DC.	Malpighiaceae	9	5.62	50	22*
Camarea affinis A. St.-Hil.	Malpighiaceae	1	0.62		
Diplopterys pubipetala (A. Juss.) W.R. Anderson & C.Cav. Davis	Malpighiaceae	1	0.62		
Heteropterys anoptera Adr. Juss.	Malpighiaceae	3	1.88		
Heteropterys byrsonimifolia A. Juss.	Malpighiaceae	8	5.00		16*
Malpighia glabra L.	Malpighiaceae	1	0.62		
Stigmaphyllon paralias Adr. Juss.	Malpighiaceae	3	1.88		
Tetrapterys styloptera A. Juss.	Malpighiaceae	1	0.62		
Abelmoschus esculentus (L.) Moench	Malvaceae	1	0.62		
Apeiba tibourbou Aubl.	Malvaceae	3	1.88		
Ayenia angustifolia A. St.-Hil. & Naudin	Malvaceae	2	1.25		
Ceiba pentandra (L.) Gaertn.	Malvaceae	1	0.62		
Eriotheca gracilipes (K. Schum.) A. Robyns	Malvaceae	20	12.50	50	33*
Eriotheca macrophylla (K.Schum.) A.Robyns	Malvaceae	1	0.62		
Eriotheca pubescens (Mart. & Zucc.) Schott & Endl.	Malvaceae	1	0.62		*
Gossypium mustelinum Miers ex Watt	Malvaceae	1	0.62		
Guazuma ulmifolia Lam.	Malvaceae	12	7.50		*
Helicteres aspera A. St.-Hil. & Naudin	Malvaceae	1	0.62		
Helicteres baruensis Jacq.	Malvaceae	3	1.88		
Helicteres brevispira A. St.-Hil.	Malvaceae	1	0.62		
Helicteres heptandra L. B. Sm.	Malvaceae	16	10.00		
Helicteres macropetala A. St.-Hil.	Malvaceae	1	0.62		
Helicteres muscosa Mart.	Malvaceae	2	1.25		
Helicteres sacarolha A. St.-Hil., A. Juss. & Cambess.	Malvaceae	2	1.25		
Hibiscus furcellatus Lam.	Malvaceae	1	0.62		
Luehea alternifolia (Mill.) Mabb.	Malvaceae	13	8.12		
Luehea divaricata Mart.	Malvaceae	6	3.75		
Luehea grandiflora Mart.	Malvaceae	1	0.62		

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Luehea paniculata Mart.	Malvaceae	16	10.00		18*
Peltaea trinervis (C. Presl) Krapov. & Cristóbal	Malvaceae	1	0.62		
Pseudobombax longiflorum (Mart. & Zucc.) A. Robyns	Malvaceae	5	3.12		*
Pseudobombax marginatum (A. St.-Hil., Juss. & Cambess.) A. Robyns	Malvaceae	2	1.25		
Sida acuta Burm.F.	Malvaceae	1	0.62		
Sida angustissima A.St.-Hil.	Malvaceae	1	0.62		
Sida cordifolia L.	Malvaceae	1	0.62		
Sida glomerata Cav.	Malvaceae	2	1.25		
Sida rhombifolia L.	Malvaceae	1	0.62		
Sida ulei Ulbr.	Malvaceae	1	0.62		
Sida viarum A. St.-Hil	Malvaceae	1	0.62		
Sterculia apetala (Jacq.) H.Karst.	Malvaceae	1	0.62		
Sterculia striata A. St.-Hil. & Naudin	Malvaceae	8	5.00		
Waltheria ferruginea A.St.-Hill.	Malvaceae	1	0.62		
Waltheria indica L.	Malvaceae	2	1.25		
Cambessedesia membranacea Gardner	Melastomataceae	1	0.62		
Cambessedesia purpurata DC.	Melastomataceae	1	0.62		
Clidemia capitata Benth.	Melastomataceae	1	0.62		
Leandra blanchetiana Cogn.	Melastomataceae	1	0.62		
Macairea radula (Bonpl.) DC.	Melastomataceae	1	0.62		
Marcetia lanuginosa Wurdack	Melastomataceae	1	0.62		
Marcetia taxifolia (A. St.-Hil.) DC.	Melastomataceae	1	0.62		
Miconia albicans (Swartz) Triana	Melastomataceae	20	12.50		28*
Miconia ferruginata DC.	Melastomataceae	5	3.12		*
Miconia leucocarpa DC.	Melastomataceae	1	0.62		
Miconia ligustroides (DC.) Naudin	Melastomataceae	1	0.62		
Miconia macrothyrsa Benth.	Melastomataceae	3	1.88		
Miconia pepericarpa Mart. ex DC.	Melastomataceae	1	0.62		
Miconia rubiginosa (Bonpl.) DC.	Melastomataceae	1	0.62		
Miconia stenostachya DC.	Melastomataceae	1	0.62		
Miconia theaezans (Bonpl.) Cogn.	Melastomataceae	2	1.25		
Microlicia sincorensis Mart.	Melastomataceae	1	0.62		
Mouriri acutiflora Naudin	Melastomataceae	1	0.62		
Mouriri cearensis Huber	Melastomataceae	1	0.62		
Mouriri elliptica Mart.	Melastomataceae	37	23.12		45*
Mouriri guianensis Aublet	Melastomataceae	7	4.38		
Mouriri pusa Gardner	Melastomataceae	44	27.50		45*
Pterolepis glomerata (Rottb.) Miq.	Melastomataceae	1	0.62		
Rhynchanthera cordata DC.	Melastomataceae	1	0.62		
Rhynchanthera grandiflora (Aubl.) DC.	Melastomataceae	1	0.62		
Tibouchina candolleana Cogn.	Melastomataceae	1	0.62		

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Cabralea canjerana (Vell.) Mart.	Meliaceae	1	0.62		
Trichilia elegans A. Juss.	Meliaceae	1	0.62		
Brosimum gaudichaudii Trécul	Moraceae	27	16.88	60	42*
Brosimum guianense (Aubl.) Huber	Moraceae	1	0.62		
Brosimum lactescens (S. Moore) C.C. Berg	Moraceae	1	0.62		
Ficus calyptroceras (Miq.) Miq.	Moraceae	1	0.62		
Ficus gomelleira Kunth & Bouche ex Kunth	Moraceae	3	1.88		
Ficus guianensis Desv. ex Ham.	Moraceae	2	1.25		
Maclura tinctoria (L.) Don. exSteud.	Moraceae	1	0.62		
Virola sessilis (A. DC.) Warb.	Myristicaceae	1	0.62		
Virola surinamensis (Rol. ex Rottb.) Warb.	Myristicaceae	1	0.62		
Cybianthus detergens Mart.	Myrsinaceae	3	1.88		
Myrsine guianensis (Aubl.) Kuntze	Myrsinaceae	3	1.88		*
Myrsine monticola Mart.	Myrsinaceae	1	0.62		
Myrsine umbellata Mart.	Myrsinaceae	1	0.62		
Myrsine venosa A. DC.	Myrsinaceae	1	0.62		
Campomanesia aromatica (Aubl.) Griseb.	Myrtaceae	9	5.62		
Campomanesia dichotoma (O. Berg) Mattos	Myrtaceae	1	0.62		
Campomanesia lineatifolia Ruiz Lopez & Pavon	Myrtaceae	1	0.62		
Campomanesia pubescens (DC.) O.Berg	Myrtaceae	4	2.50		
Campomanesia sessiliflora (O. Berg) Mattos	Myrtaceae	1	0.62		
Campomanesia velutina (Cambess.) O. Berg.	Myrtaceae	3	1.88		
Campomanesia xanthocarpa O. Berg	Myrtaceae	1	0.62		
Eugenia aurata O. Berg.	Myrtaceae	1	0.62		
Eugenia biflora (L.) DC.	Myrtaceae	1	0.62		
Eugenia dysenterica A. DC.	Myrtaceae	36	22.50		49*
Eugenia flavescens A. DC.	Myrtaceae	5	3.12		
Eugenia punicifolia (Kunth.) DC.	Myrtaceae	11	6.88		
Eugenia stictopetala A. DC.	Myrtaceae	5	3.12		
Eugenia uniflora L.	Myrtaceae	3	1.88		
Eugenia warmingiana Kiaersk.	Myrtaceae	1	0.62		
Myrcia albotomentosa DC	Myrtaceae	1	0.62		
Myrcia bella Cambess.	Myrtaceae	1	0.62		
Myrcia bergiana O.Berg.	Myrtaceae	3	1.88		
Myrcia blanchetiana (O.Berg) Mattos	Myrtaceae	1	0.62		
Myrcia decorticans DC.	Myrtaceae	1	0.62		
Myrcia fenzliana O.Berg.	Myrtaceae	4	2.50		
Myrcia guianensis (Aubl.) DC.	Myrtaceae	12	7.50		
Myrcia laruotteana Cambess.	Myrtaceae	1	0.62		
Myrcia multiflora (Lam.) DC.	Myrtaceae	5	3.12		
Myrcia mutabiliis (O. Berg) N. Silveira	Myrtaceae	1	0.62		
Myrcia ochroides O. Berg	Myrtaceae	2	1.25		

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Myrcia polyantha DC.	Myrtaceae	1	0.62		
Myrcia rotundifolia (O. Berg) Kiaersk.	Myrtaceae	2	1.25		
Myrcia rufipes A. DC.	Myrtaceae	1	0.62		
Myrcia selloi (Spreng.) N.Silveira	Myrtaceae	1	0.62		
Myrcia splendens (Sw.) DC.	Myrtaceae	42	26.25		16
Myrcia tomentosa (Aubl.) DC.	Myrtaceae	8	5.00		
Myrcia venulosa DC.	Myrtaceae	1	0.62		
Myrciaria cuspidata O.Berg.	Myrtaceae	1	0.62		
Myrciaria tenella (DC.) O. Berg	Myrtaceae	1	0.62		
Psidium acutangulum Mart. ex DC.	Myrtaceae	2	1.25		
Psidium australe var. *suffruticosum* (O.Berg) Landrum	Myrtaceae	1	0.62		
Psidium grandifolium Mart. ex DC.	Myrtaceae	1	0.62		
Psidium guajava L.	Myrtaceae	2	1.25		
Psidium guineense Sw.	Myrtaceae	7	4.38		
Psidium laruotteanum Cambess.	Myrtaceae	7	4.38		
Psidium myrsinites A. DC.	Myrtaceae	37	23.12		
Psidium myrtoides O. Berg	Myrtaceae	35	21.88		51*
Psidium nutans O. Berg	Myrtaceae	1	0.62		
Psidium salutare var. *pohlianum* (O.Berg) Landrum	Myrtaceae	2	1.25		
Syzygium cumini (L.) Skeels	Myrtaceae	2	1.25		
Bougainvillea glabra Choisy	Nyctaginaceae	1	0.62		
Guapira graciliflora (Schmidt) Lundell	Nyctaginaceae	4	2.50		
Guapira laxa (Netto) Furlan	Nyctaginaceae	2	1.25		
Guapira nitida (Schmidt) Lundell	Nyctaginaceae	1	0.62		
Guapira pernambucensis (Casar.) Lundell	Nyctaginaceae	1	0.62		
Neea theifera Oerst.	Nyctaginaceae	13	8.12		22*
Ouratea castanaefolia (DC.) Engl.	Ochnaceae	4	2.50		
Ouratea cearensis (Tiegh.) Sastre	Ochnaceae	3	1.88		
Ouratea cuspidata Tiegh.	Ochnaceae	2	1.25		
Ouratea fieldingiana Engl.	Ochnaceae	2	1.25		
Ouratea hexasperma (A. St.-Hil.) Baill.	Ochnaceae	58	36.25	53	58*
Ouratea parvifolia (A.St.-Hil.) Engl.	Ochnaceae	2	1.25		
Ouratea semiserrata (Mart. & Nees) Engl.	Ochnaceae	1	0.62		
Ouratea spectabilis (Mart. Ex Engl.) Engl.	Ochnaceae	9	5.62		*
Cathedra rubricaulis Miers	Olacaceae	3	1.88		
Chaunochiton kappleri (Sagot ex Engl.) Ducke	Olacaceae	1	0.62		
Heisteria citrifolia Engl.	Olacaceae	1	0.62		
Heisteria ovata Benth.	Olacaceae	23	14.37		22
Ximenia americana L.	Olacaceae	34	21.25		
Ludwigia hyssopifolia (G. Don) Exell	Onagraceae	1	0.62		
Ludwigia octovalvis (Jacq.) P.H. Raven	Onagraceae	2	1.25		
Agonandra brasiliensis Miers ex Benth. & Hook. f.	Opiliaceae	83	51.88		37*

Species	Family	Constancy	Const. (%)	Refl	Ref.2
Agonandra brasiliensis subsp. *brasiliensis* Miers ex Benth. & Hook. f.	Opiliaceae	2	1.25		
Agonandra silvatica Ducke	Opiliaceae	1	0.62		
Esterhazya splendida J.C. Mikan	Orobanchaceae	1	0.62		
Sesamum indicum L.	Pedaliaceae	1	0.62		
Picramnia sellowii Planch.	Picramniaceae	1	0.62		
Plumbago scandens L.	Plumbaginaceae	2	1.25		
Bredemeyera brevifolia (Benth.) A.W. Benn.	Polygalaceae	2	1.25		
Bredemeyera floribunda Willd.	Polygalaceae	16	10.00		
Bredemeyera laurifolia (A. St.-Hil.) Klotzsch ex A.W. Benn.	Polygalaceae	1	0.62		
Polygala harleyi var. *intermedia* Marques	Polygalaceae	1	0.62		
Polygala multiceps Mart. ex A.W. Benn.	Polygalaceae	1	0.62		
Coccoloba alnifolia Casar	Polygonaceae	1	0.62		
Coccoloba brasiliensis Nees & Mart.	Polygonaceae	1	0.62		
Coccoloba cordifolia Meisn.	Polygonaceae	1	0.62		
Coccoloba latifolia Wedd.	Polygonaceae	2	1.25		
Coccoloba mollis Casar	Polygonaceae	7	4.38		
Coccoloba persicaria Wedd.	Polygonaceae	1	0.62		
Coccoloba ramosissima Wedd.	Polygonaceae	2	1.25		
Triplaris americana L.	Polygonaceae	2	1.25		
Triplaris weigeltiana (Rchb.) Kuntze	Polygonaceae	1	0.62		
Euplassa inaequalis (Pohl) Engl.	Proteaceae	3	1.88		
Roupala montana Aubl.	Proteaceae	11	6.88	62	22*
Rhamnidium elaeocarpum Reissek	Rhamnaceae	1	0.62		*
Ziziphus cotinifolia Reissek	Rhamnaceae	1	0.62		
Ziziphus joazeiro Mart.	Rhamnaceae	1	0.62		
Prunus myrtifolia (L.) Urb.	Rosaceae	1	0.62		
Alibertia edulis (Rich.) A. Rich. ex DC.	Rubiaceae	23	14.37		*
Alibertia myrciifolia (K. Schum.) C.H. Perss. & Delprete	Rubiaceae	6	3.75		
Alibertia rotunda (Cham.) K.Schum.	Rubiaceae	2	1.25		
Chiococca alba (L.) Hitchc.	Rubiaceae	2	1.25		
Chomelia obtusa Cham. & Schldl.	Rubiaceae	17	10.62		
Chomelia parviflora Müll. Arg.	Rubiaceae	1	0.62		
Cordiera concolor (Cham.) Kuntze	Rubiaceae	4	2.50		
Cordiera elliptica (Cham.) Kuntze	Rubiaceae	7	4.38		18
Cordiera obtusa (K. Schum.) Kuntze	Rubiaceae	8	5.00		13
Cordiera rigida (K. Schum.) Kuntze	Rubiaceae	1	0.62		
Cordiera sessilis (Vell.) Kuntze	Rubiaceae	4	2.50		
Coussarea hydrangaefolia (Benth.) Benth. & Hook. f. ex Müll. Arg.	Rubiaceae	3	1.88		
Coutarea hexandra (Jacq.) K. Schum	Rubiaceae	3	1.88		
Declieuxia aspalathoides Müll. Arg.	Rubiaceae	1	0.62		

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Diodella apiculata (Willd. ex Roem. & Schult.) Delprete	Rubiaceae	2	1.25		
Faramea crassifolia Benth.	Rubiaceae	1	0.62		
Faramea nitida Benth.	Rubiaceae	2	1.25		
Ferdinandusa elliptica (Pohl) Pohl	Rubiaceae	12	7.50		22
Ferdinandusa speciosa Pohl	Rubiaceae	1	0.62		
Genipa americana L.	Rubiaceae	5	3.12		
Guettarda angelica Mart. ex Muell. Arg.	Rubiaceae	4	2.50		
Guettarda platypoda A .DC.	Rubiaceae	6	3.75		
Guettarda pohliana Müll. Arg.	Rubiaceae	1	0.62		
Guettarda viburnoides Cham. & Schltdl	Rubiaceae	29	18.12		*
Mitracarpus salzmannianus DC.	Rubiaceae	1	0.62		
Palicourea marcgravii A. St.-Hil.	Rubiaceae	1	0.62		
Palicourea rigida Kunth	Rubiaceae	12	7.50		21*
Psychotria bahiensis DC.	Rubiaceae	1	0.62		
Psychotria colorata (Willd. ex Schult.) Müll.Arg.	Rubiaceae	1	0.62		
Psychotria hoffmannseggiana (Willd. ex Schult.) Müll.Arg.	Rubiaceae	2	1.25		
Psyllocarpus asparagoides Mart. & Zucc.	Rubiaceae	1	0.62		
Randia armata (Sw.) DC.	Rubiaceae	5	3.12		
Rudgea jacobinensis Müll. Arg.	Rubiaceae	1	0.62		
Salzmannia nitida DC.	Rubiaceae	1	0.62		
Tocoyena bullata (Vell.) Mart.	Rubiaceae	1	0.62		
Tocoyena formosa (Cham. & Schldl.) Schum.	Rubiaceae	56	35.00	58	58*
Tocoyena formosa subsp. *tomentosa* Gardner ex A.L.Prado	Rubiaceae	12	7.50		
Tocoyena hispidula Standl.	Rubiaceae	8	5.00		
Tocoyena sellowiana (Cham. & Schldl.) Schum.	Rubiaceae	10	6.25		
Dictyoloma vandellianum A.H.L. Juss.	Rutaceae	1	0.62		
Esenbeckia grandiflora Mart.	Rutaceae	1	0.62		
Spiranthera odoratissima A. St.-Hil.	Rutaceae	2	1.25		
Zanthoxylum gardneri Engl.	Rutaceae	1	0.62		
Zanthoxylum rhoifolium Lam.	Rutaceae	6	3.75		*
Zanthoxylum riedelianum Engl.	Rutaceae	1	0.62		
Zanthoxylum stelligerum Turcz.	Rutaceae	3	1.88		
Zanthoxylum syncarpum Tul.	Rutaceae	1	0.62		
Casearia arborea (Rich.) Urban	Salicaceae	3	1.88		
Casearia commersoniana Cambess.	Salicaceae	1	0.62		
Casearia gossypiosperma Briq.	Salicaceae	1	0.62		
Casearia grandiflora Cambess.	Salicaceae	15	9.38		
Casearia guianensis (Aublet) Urban	Salicaceae	1	0.62		
Casearia javitensis Kunth	Salicaceae	4	2.50		
Casearia mollis Kunth	Salicaceae	1	0.62		
Casearia sylvestris Swartz	Salicaceae	55	34.38	64	64*

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Casearia ulmifolia Vahl ex Vent.	Salicaceae	6	3.75		
Xylosma ciliatifolia (Clos) Eichler	Salicaceae	4	2.50		
Phoradendron interruptum (DC.) B.D.Jacks.	Santalaceae	1	0.62		
Allophylus edulis (A. St.-Hil., A. Juss. & Cambess.) Hieron. ex Niederl.	Sapindaceae	2	1.25		
Allophylus quercifolius Radlk.	Sapindaceae	1	0.62		
Allophylus semidentatus (Miq.) Radlk.	Sapindaceae	4	2.50		
Cupania impressinervia Acev.-Rodr.	Sapindaceae	2	1.25		
Cupania oblongifolia Mart.	Sapindaceae	1	0.62		
Cupania paniculata Cambess.	Sapindaceae	3	1.88		
Cupania rugosa Radlk.	Sapindaceae	1	0.62		
Dilodendron bipinnatum Radlk.	Sapindaceae	1	0.62		*
Dodonaea viscosa Jacq.	Sapindaceae	1	0.62		
Magonia pubescens A. St.-Hil.	Sapindaceae	71	44.38		39*
Matayba guianensis Aubl.	Sapindaceae	4	2.50		
Matayba heterophylla (Mart.) Radlk.	Sapindaceae	2	1.25		
Sapindus saponaria L.	Sapindaceae	1	0.62		
Talisia esculenta (A. S. Hil.) Radlk.	Sapindaceae	3	1.88		
Toulicia crassifolia Radlk.	Sapindaceae	9	5.62		
Toulicia tomentosa Radlk.	Sapindaceae	1	0.62		
Chrysophyllum arenarium Allemão	Sapotaceae	5	3.12		
Chrysophyllum rufum Mart.	Sapotaceae	1	0.62		
Manilkara salzmannii (A. DC.) H.J. Lam	Sapotaceae	2	1.25		
Manilkara triflora (Allemão) Monach.	Sapotaceae	1	0.62		
Micropholis gardneriana (A. DC.) Pierre	Sapotaceae	1	0.62		
Pouteria gardneriana (A.DC.) Radlk.	Sapotaceae	2	1.25		
Pouteria grandiflora (A. DC.) Baehni	Sapotaceae	1	0.62		
Pouteria peduncularis (Mart. & Eichler ex Miq.) Baehni	Sapotaceae	4	2.50		
Pouteria ramiflora (Mart.) Radlk.	Sapotaceae	80	50.00	65	87*
Pouteria reticulata (Engl.) Eyma	Sapotaceae	2	1.25		
Pouteria torta (Mart.) Radlk.	Sapotaceae	24	15.00		31*
Schoepfia brasiliensis A. DC.	Schoepfiaceae	1	0.62		
Simaba blanchetii Turcz.	Simaroubaceae	1	0.62		
Simaba ferruginea A. St.-Hil.	Simaroubaceae	7	4.38		
Simaba floribunda A. St.-Hil.	Simaroubaceae	2	1.25		
Simaba maiana Casar.	Simaroubaceae	5	3.12		
Simaba warmingiana Engl.	Simaroubaceae	1	0.62		
Simarouba amara Aublet	Simaroubaceae	4	2.50		
Simarouba versicolor A. St.-Hil.	Simaroubaceae	85	53.12		60*
Siparuna guianensis Aubl.	Siparunaceae	9	5.62		19*
Cestrum obovatum Sendtn.	Solanaceae	1	0.62		
Physalis heterophylla Nees.	Solanaceae	1	0.62		

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Schwenckia americana Rooyen ex L.	Solanaceae	2	1.25		
Solanum asperum Rich.	Solanaceae	2	1.25		
Solanum cordifolium Dunal	Solanaceae	1	0.62		
Solanum crinitum Lam.	Solanaceae	5	3.12		
Solanum lycocarpum A. St.-Hil.	Solanaceae	6	3.75		
Solanum palinacanthum Dunal	Solanaceae	1	0.62		
Solanum paludosum Moric.	Solanaceae	1	0.62		
Solanum paniculatum L.	Solanaceae	3	1.88		
Solanum rhytidoandrum Sendtn.	Solanaceae	2	1.25		
Solanum stenandrum Sendtn.	Solanaceae	1	0.62		
Solanum stramonifolium var. *stramonifolium* Jacq.	Solanaceae	1	0.62		
Styrax camporum Pohl	Styracaceae	2	1.25		
Styrax ferrugineus Nees & Mart.	Styracaceae	3	1.88		*
Symplocos oblongifolia Casar.	Symplocaceae	1	0.62		
Trigonia nivea Cambess.	Trigoniaceae	2	1.25		
Cecropia glaziovi Snethl.	Urticaceae	1	0.62		
Cecropia pachystachya Trec.	Urticaceae	9	5.62		
Vellozia squamata Pohl	Velloziaceae	2	1.25		*
Vellozia tubiflora (A. Rich.) Kunth	Velloziaceae	1	0.62		
Aloysia virgata (Ruiz & Pav.) Juss.	Verbenaceae	1	0.62		
Lantana camara L.	Verbenaceae	1	0.62		
Lantana canescens Kunth	Verbenaceae	1	0.62		
Lippia alba (Mill.) N.E.Br.	Verbenaceae	1	0.62		
Lippia origanoides Kunth	Verbenaceae	3	1.88		
Lippia rigida Schauer	Verbenaceae	1	0.62		
Lippia salviifolia Cham.	Verbenaceae	4	2.50		
Lippia subracemosa Mansf.	Verbenaceae	1	0.62		
Stachytarpheta angustifolia (Mill.) Vahl.	Verbenaceae	1	0.62		
Stachytarpheta lychnitis Mart.	Verbenaceae	1	0.62		
Callisthene fasciculata Mart.	Vochysiaceae	30	18.75		18*
Callisthene microphylla Warm.	Vochysiaceae	2	1.25		
Callisthene minor Mart.	Vochysiaceae	1	0.62		
Qualea cordata (Mart.) Spreng.	Vochysiaceae	2	1.25		
Qualea dichotoma (Mart.) Warm.	Vochysiaceae	2	1.25		
Qualea grandiflora Mart.	Vochysiaceae	115	71.88	85	84*
Qualea multiflora Mart.	Vochysiaceae	4	2.50	51	*
Qualea parviflora Mart.	Vochysiaceae	129	80.62	78	87*
Qualea selloi Warm.	Vochysiaceae	1	0.62		
Salvertia convallariodora A. St.-Hil.	Vochysiaceae	98	61.25	56	67*
Vochysia divergens Pohl	Vochysiaceae	1	0.62		
Vochysia elliptica Mart.	Vochysiaceae	2	1.25		
Vochysia gardneri Warm.	Vochysiaceae	27	16.88		40*

Species	Family	Constancy	Const. (%)	Ref1	Ref.2
Vochysia haenkeana Mart.	Vochysiaceae	5	3.12		*
Vochysia pyramidalis Mart.	Vochysiaceae	1	0.62		
Vochysia rufa Mart.	Vochysiaceae	12	7.50		18*
Vochysia thyrsoidea Pohl	Vochysiaceae	5	3.12		
Vochysia tucanorum Mart.	Vochysiaceae	11	6.88		

CAPÍTULO 2

Areas of endemism on regional scale reflect influences of adjacent phytogeographic domains. A case study on woody flora of the northeastern cerrado of Brazil. †

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Abstract

Area of endemism (AOE) is a particular area that contains species restricted to it and yet it can be hierarchical in organization, thus a large AOE may contain smaller areas of endemism. Brazilian Cerrado is the third largest hotspots of the world but with almost none information about specific AOE, although it is well know that northeastern (NE) cerrado has a woody flora different from core cerrado. We searched for local AOE within the NE cerrado, which, in its turn, is a regional AOE of the large endemic Cerrado. We investigated whether AOE would reflect the influences of adjacent phytogeographic domains. We recorded 6,962 individuals of 936 woody species gathered from 160 surveys and distributed in 48 grid-cells of 1° latitude-longitude. For each grid-cell we compute indices for species richness and endemism which were tested by spatial autocorrelation analysis (SAC). Additionally we performed a parsimony analysis of endemism (PAE) to discover relationships among areas of endemism. Species richness indices were not spatially autocorrelated in contrast to endemism indices. Thus, there are hotspots for endemism but not for richness. The PAE indicated seven AOE. Considering indices of endemism and PAE, we indicated five areas of endemism in the NE cerrado: the coastal cerrados; Araripe plateau; Diamantina plateau; the northern Piauí; and the southwestern NE cerrado. Out of total species, 611 species were restricted to only one AOE whereas 170 species were widespread. Each AOE had different floristic influences from adjacent phytogeographic domains corroborating our hypothesis. The AOE indicated deserve special attention from conservation policies.

Keywords: biogeographic history, Brazilian savanna, corrected-weight endemism (CWE), parsimony analysis of endemism (PAE), range-corrected endemism (RCE), spatial autocorrelation analysis (SAC).

Resumo

Área de endemismo (ADE) é uma área particular que contém espécies restritas a ela e que pode ter uma organização hierárquica, assim, uma grande ADE pode conter pequenas áreas de endemismo. O Cerrado brasileiro é o terceiro maior *hotspots* do mundo, embora com quase nenhuma informação sobre ADE específicas. Entretanto é sabido que o cerrado nordestino (NE) do Brasil tem uma flora lenhosa diferente da encontrada no cerrado nuclear. Buscou-se ADE locais dentro do cerrado nordestino, que, por sua vez, é um ADE regional do grande Cerrado endêmico. Perguntou-se ADEs iriam refletir as influências dos domínios fitogeográficos adjacentes. A partir de 160 levantamentos florísticos, foram registradas 6.962 indivíduos de 936 espécies lenhosas que foram distribuídas em 48 células de 1 º de latitude-longitude. Para cada célula foi calculado os índices de riqueza de espécies e de endemismo que foram testados pela análise de autocorrelação espacial (ACE). Além disso, realizamos uma análise de parcimônia de endemismo (APE) para descobrir as relações entre as áreas de endemismo. O índice de riqueza de espécies não foi espacialmente autocorrelacionado ao contrário do índice de endemismo. Assim, existem *hotspots* de endemismo, mas não para a riqueza. O APE indicou sete ADE. Considerando o índice de endemismo e APE, indicou-se cinco áreas de endemismo no cerrado nordestino: os cerrados litorâneos; Chapada do Araripe; Chapada Diamantina; o norte do Piauí, e o sudoeste do cerrado nordestino. Do total, 611 espécies foram restritas a apenas uma ADE enquanto que 170 espécies tiveram ampla distribuição. Cada ADE teve diferentes influências florísticas de domínios fitogeográficos adjacentes corroborando nossa hipótese inicial. As ADE indicadas merecem atenção especial das políticas públicas para sua conservação.

Palavras-chave: história biogeográfica, savana brasileira, peso de endemismo corrigido (PER), análise de parcimônia de endemismo (APE), amplitude de endemismo corrigido (AER), análise de autocorrelação espacial (ACE).

1. Introduction

Endemic species and species richness are by far the most addressed variables concerning conservation priorities (Brooks et al. 2006; Burlakova et al. 2011; Kier & Barthlott 2001; Kier et al. 2009; Loyola et al. 2007; Myers et al. 2000). In the simplest definition, species richness is the amount of species in a surface area, and endemic species are the ones restricted to a particular area (Anderson 1994). Endemism and species richness are frequently congruent in global or continental scales (Lamoreux et al. 2006; Pearson & Carroll 1999; Williams & Gaston 1994), thus, often strongly correlated (Crisp et al. 2001).

However, regarding a species or other taxon as endemic without specifying an area is meaningless (Anderson 1994). An area of non-random distributional congruence of different taxa, or simply a substantial overlap in ranges of two or more species is an area of endemism (Morrone 1994). In other words, it is a particular area that contains species restricted to that area (Anderson 1994), meaning that species in the area share a unique history and therefore have similar biogeographic relationships (Linder 2001a), and being considered the basic units of analysis in evolutionary biogeography (Morrone 2008). Besides, areas of endemism (AOE) can be hierarchical in organization, thus a large area of endemism may contain smaller areas of endemism (Crother & Murray 2011).

Areas of endemism are often claimed to be a result of speciation process on vicariance events, especially due expansion and retraction of habitats during Tertiary and Quaternary climatic oscillations (Haffer 1969; Nogueira et al. 2011), however, dispersal speciation has also its contribution (Zink et al. 2000). The vicariance speciation theory states that the speciation was generated through the fragmentation of widespread ancestors by vicariant (isolating) events (Nelson & Platnick 1981).The dispersal speciation theory assumes that species ancestors dispersed from a primitive range across pre-existing barriers, became isolated, and evolved into new species (Udvardy 1969). Although the dispersal is more difficult to falsify than vicariance (Zink et al. 2000), both are equally accept by biogeographers to explain the history of an area of endemism (Ronquist 1997; Zink et al. 2000).

For instance, in Brazilian phytogeographic domains, for different taxa of animals and plants, there are at least eight areas of endemism in Amazon (Ridgely & Tudor 1989), whereas in the Atlantic forest three major areas of endemism are recognized (Cabanne et al. 2007; Carnaval et al. 2009; Carnaval & Moritz 2008; Pellegrino et al. 2005; Silva et al. 2004; Thomé et al. 2010). In both cases, the authors argued that these areas of endemism could be an outcome of vicariance and dispersal events during Tertiary and Quaternary climatic oscillations. Many other authors have also considered the Brazilian Cerrado as a phytogeographic domain with a high level of endemicity of animals and plants (e.g. Klink & Machado 2005; Oliveira & Marquis 2002; Pennington et al. 2006; Ratter et al. 2006; Silva & Bates 2002), however, information of specific areas of endemism in the Cerrado must be improved. Myers et al. (2000) indicated the Brazilian Cerrado as one of the five biodiversity hotspots stated for South America with 4400 endemic plants and 117 endemic vertebrates and experiencing exceptional loss of habitat, thus should be focus of conservation actions.

The Cerrado occupies the second largest area among the Brazilian biomes with an original extent of ca. 2 million km² (Klink & Machado 2005). The vegetation have different physiognomies varying from pure grassland (campo limpo), through savanna (campo sujo, campo cerrado, cerrado *sensu stricto* in order of growing woody biomass), to pure forest (Cerradão; Coutinho 1978, 1990). Named “cerrado” or “cerrados”, with lowercase, refers to complex of vegetation types (Batalha 2011; Castro et al. 1999). Hereafter we used “Cerrado” as a phytogeographic domain, instead a biome, to refers to the whole flora in the subcontinental geographic space (see Batalha 2011; Coutinho 2006; Fiaschi & Pirani 2009).

The Cerrado can be divided into six floristic provinces with different floras and a significant number of exclusive plant species (Ratter et al. 2003). This pattern, confirmed in many papers (Castro 1994a, b; Ratter et al. 1996; Ratter et al. 2001; Ratter et al. 2003; Ratter & Dargie 1992), is congruent with the definition of AOE, and thus to conserve all the plant diversity of the cerrado conservation areas should be established in each floristic province to ensure that biodiversity would adequately be protected (Bridgewater et al. 2004).

The northeastern Brazilian cerrado (hereafter NE cerrado), for instance, is known for its great plant diversity and a great number of rare species (This thesis, chapter 1). The NE cerrado is bordered by the seasonal tropical dry forests (Caatinga) at east, Amazonian rainforest at west, Atlantic rainforest at southeast, and cerrado core at southwest. Also, the NE cerrado has some disjunct enclaves in Caatinga and Atlantic forest (Fig. 1). The NE cerrado is claimed to be unique in the phytogeographic domain because its woody flora is very different from cerrado core (Heringer et al. 1977; Rizzini 1976; This thesis, chapter 1). This differentiation has been attributed both to current climate and soil characteristics as well as to biogeographic processes during the Quaternary (Castro et al. 1998; 1999; Ratter et al. 2003; This thesis, chapter 1). Therefore, the floristic of NE cerrado seems to reflect the recurrent alternations of dispersal and vicariant biogeographic processes during the climatic oscillations in the Tertiary and Quaternary periods and thus an intense interchange might have occurred between the cerrado and the neighbor rainforests and Caatinga (This thesis, chapter 1). This thesis (chapter 1) hypothesized a “savanna capture process”, which describes an evolutionary speciation process during the climatic oscillations in the Quaternary, when the expanding savanna environment would have selected some lineages from the contracting forests. This process could explain the differentiation of the NE cerrado from the core cerrado as well as the high number of monospecific genera and families and monogeneric families (genera and families with one species and families with one genus, respectively) in the NE cerrado (This thesis, chapter 1). Also, marginal and disjunct areas of the Cerrado, as the NE cerrado, would have some proportion of "accessory" species, which come from the neighbor formations (Eiten 1972; Fernandes & Bezerra 1990; Rizzini 1963), than core cerrado, which has the highest proportion of "peculiar" species, which are exclusive to the Cerrado (Rizzini 1963). If the process above occurred, then local areas of endemism of the NE cerrado should contain a high proportion of accessory species from adjacent phytogeographic domain.

Our aim was to investigate whether areas of endemism would reflect the influences of adjacent phytogeographic domains. To attain this goal, we searched for local AOE within the NE cerrado, which, in its turn, is a regional AOE of the large Cerrado endemic woody flora, thus, investigating the cerrado woody flora at its minimum level of hierarchy of areas of endemism. If local AOE can be recognized within the regional AOE NE cerrado and if these areas reflect the influences of the adjacent phytogeographic domains, then assumptions on biogeographic history could be proposed and used as driving forces for public policies for conservation strategies.

2. **Material and Methods**

2.1. Source data

We used the FLORACENE, a databank of the woody flora of the NE Brazilian cerrado described in (This thesis, chapter 1). This databank is a result of a 10 year-long project under the Brazilian Long Term Ecological Research Program (LTER). The primary matrix contains 160 surveys across the NE cerrado, out of which 64 were field surveys from our team (Biodiversity Program of the Ecotonal Northeastern Tropic - Bioten) and 96 were gathered as metadata. Were recorded 6,962 individuals of 936 woody species in 376 genera and 84 families.

2.2. Geographic units

Patterns of richness and endemism are scale-dependent (Crisp et al. 2001; Morrone & Escalante 2002) and are sought for by using geographic units as latitude-longitude grid-cells (e.g. Crisp et al. 2001; Morrone 1994; Morrone & Escalante 2002; Ramírez-Barahona et al. 2011; Szumik & Goloboff 2004). Grid-cell size of 1º latitude x 1º longitude tends to reduce the effects of sampling artifacts such as mapping errors and unsampled grids in sparsely inhabited areas, known as the roadmap effect (Crisp et al. 2001). As the NE cerrado is not homogeneous, sampling grid-cells smaller than 1º x 1º would produce many sparse empty grids. On the other hand, larger grid-cells would pose problems to analyzing endemism and would represent a too coarse resolution on the scale of Northeastern Brazil. Hence, we plotted the species occurrence into a 1º x 1º grid-cell base map. We considered only the grid-cells that contained floristic surveys, resulting 48 grid-cells across the NE cerrado (Fig. 1). The cell dimensions were about 110 km from north to south and 107-111 km from east to west, depending on the latitude, and as this variation was very small (less than 4%), we did not perform the equal-area grid solution (McAllister et al. 1994).

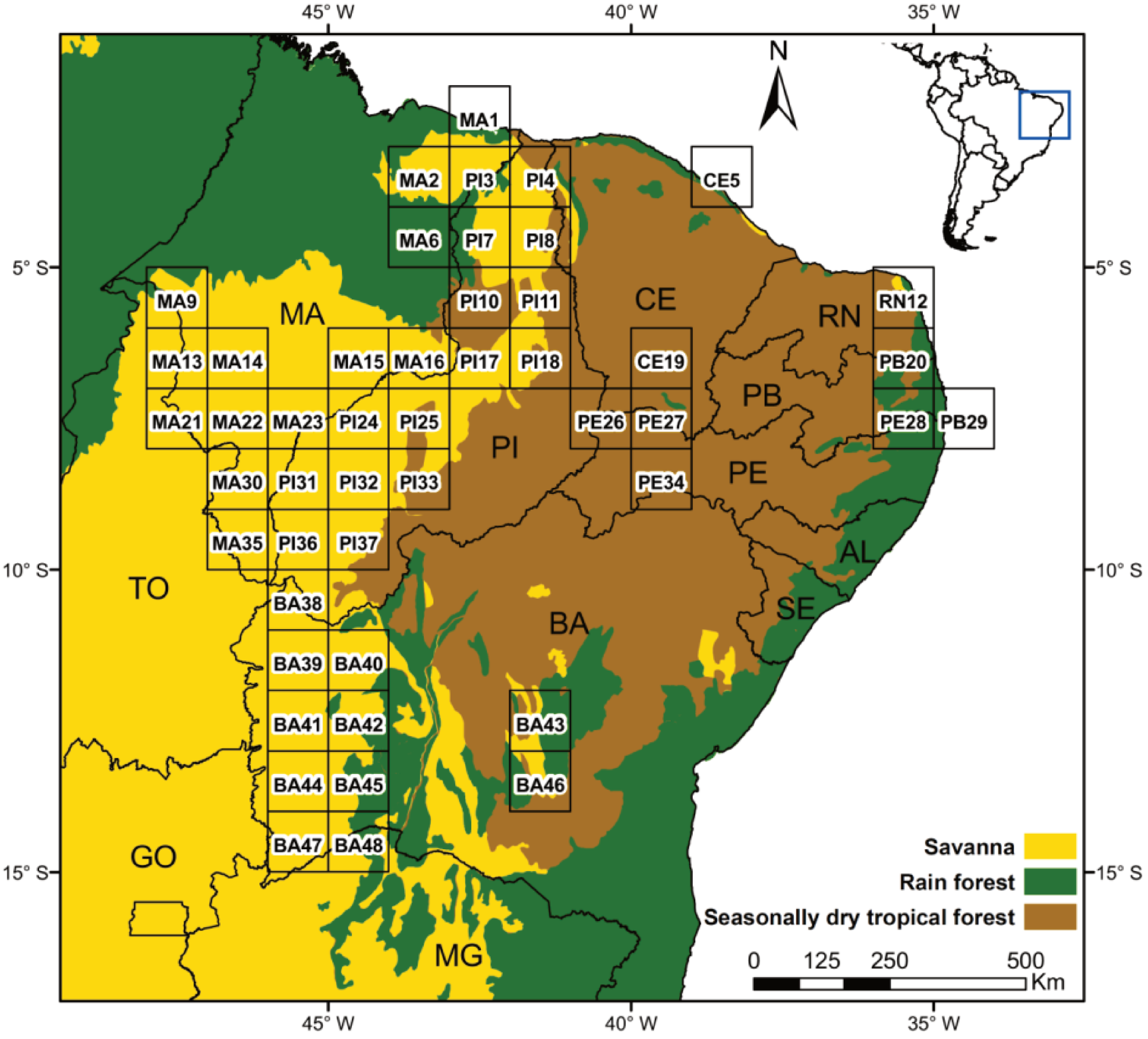

Fig. 1. Map of Northeastern Cerrado Province in Brazil showing the labels of grid-cells. States: MA-Maranhão, PI-Piauí, CE-Ceará, RN-Rio Grande do Norte, PB-Paraíba, PE-Pernambuco, AL-Alagoas, SE-Sergipe, BA-Bahia, MG-Minas Gerais, GO-Goiás, TO-Tocantins. Map based on Olson et al. (2001).

2.3. Species richness

Species richness (*R*) is measured simply as the total count of species within each grid-cell (Crisp et al. 2001). However, as the land area within grid-cells is not uniform, then a corrected richness (*CR*) index was calculated by: *R*/log A, were log A is the logarithm of the land area (km^2) within each grid-cell (Ramírez-Barahona et al. 2011). The area of each grid-cells was clipped in the coastline and the administrative limits of the Northeastern Region of Brazil, and then the area was calculated for each grid-cell. We used the Arc-GIS 10.0 (ESRI 2010) for this procedure. The computations of R and CR were performed in the R statistical language and environment (R Development Core Team 2011) and plotted in maps using the Arc-GIS 10.0 (ESRI 2010). We performed a Spearman´s rank correlation coefficient test among the R and CR in order to assess whether corrected richness was effective to consider the area.

2.4. Endemism indices

The simplest measure of endemism could be the counting of the range-restricted species per cell, but this is strongly correlated to species richness (Crisp et al. 2001). To solve this problem, Crisp et al. (2001) proposed to weight each species by the inverse of its range (numbers of grid-cells with the species). Thus, a single-cell endemic species has the maximum weight of 1, a species occurring in two cells has a weight of 0.5, and a species occurring in 100 cells has a weight of 0.01. To obtain an endemism score for a cell, these weights are summed for all species occurring in the cell (Σs - weighted endemism). Then, the Σs are divided by the total count of species in each cell, deriving the corrected-weight endemism (*CWE*; Crisp et al. 2001; see Linder 2001b). This index corrects for the species richness effect by measuring the proportion of endemics in a grid-cell (Crisp et al. 2001). We performed a Spearman´s rank correlation coefficient test among the CWE and R in order to assess the degree of the richness correction in the endemism index.

However, two or more species present in the same number of grids do not necessarily have the same occurrence range-size, we downweighted each species presence by the decimal logarithm of the sum of the land area (log ΣA) it occupies (Ramírez-Barahona et al. 2011). The area for each grid-cell was calculated as for corrected richness. Then, we calculated the sum of the species downweighted by area for each grid-cell and divided by the corresponding species richness. This index was termed range-corrected endemism (*RCE*; Ramírez-Barahona et al. 2011). All computations were performed in the R statistical language and environment (R Development Core Team 2011) and plotted in maps using the Arc-GIS 10.0 (ESRI 2010). We performed a Spearman´s rank correlation coefficient test among these endemism indices and richness in order to assess the degree of dissociation of endemism from richness.

2.5. Spatial pattern

Since the richness and endemism were examined by mapping the four indices described above, we tested for geographical clustering of the grid-cells using spatial autocorrelation analysis (SAC). Positive spatial autocorrelation means that a pair of grid-cells at certain distance are more similar than expected by chance, whereas the negative spatial autocorrelation a pair of grid-cells are less similar (Legendre 1993). This tests whether the geographical pattern of richness and endemism is essentially random, or whether there are centers or "hotspots" (Crisp et al. 2001).

We assessed the spatial autocorrelation of richness and endemism indices with Moran´s I coefficient (Moran 1950), which tests the null hypothesis of spatial independency. Moran's I coefficient varies between -1 and +1, indicating negative or positive autocorrelation in the data (Legendre & Legendre 1998) and is given by:

$$I = \left(\frac{n}{S}\right)\left[\frac{\sum_i \sum_j w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{\sum_i (y_i - \bar{y})^2}\right]$$

where n is the number of grid-cells, y_i and y_j are values of the variable at pairs of respective grid-cells; $\bar{y}$ is the average of the variable, and w_{ij} is an element of matrix W. In this matrix, w_{ij}=1 if the pair $_i$ and $_j$ of grid-cells is within a given distance class interval (indicating grid-cells that are connected in this class). S indicates the number of entries (connections) in the W matrix (Diniz-Filho et al. 2003). We performed the analyses for each index in the R statistical language and environment (R Development Core Team 2011) with the package "ncf" (Bjørnstad 2009) setting the correlogram with 200 kilometers distance classes, to include minimal pairs of grids, and a two-sided permutation test with 1000 resampling and $\alpha = 0.05$. A Bonferroni corrected level was used for assess the globally significance of a correlogram if at least one correlation coefficient is lower than α divided by the number of distance classes (Legendre & Fortin 1989).

2.6. Parsimony analysis of endemism

Parsimony Analysis of Endemism (PAE) is a parsimonious algorithm that analyses raw distribution matrices and classify areas based on the shared presence of taxa resulting in an area cladogram (Rosen 1988). Derived forms of this analysis were proposed later. For example, whereas Rosen (1988) considered localities, Morrone (1994) applied the method using grid-cells, and Cracraft (1991) ran the analysis with a previously delimited area. In a way that is analogous to cladistics, PAE treats areas as 'taxa', and taxa as 'characters' (Nihei 2006), and is considered a panbiogeographic technique allowing for identifying primary biogeographic homology (Morrone 2001, 2004) that can underpin inferences on the history of areas and biotas (Grehan 2001), which represents a conjecture on a common biogeographic history (Morrone 2005). In fact, the use of PAE to infer area homologies and relationships is still in debate (Brooks & van Veller 2003; Nihei 2006; Santos 2005), nevertheless, PAE is the first step in the attempt to discover historic relationships among areas of endemism, which should be tested by cladistics biogeography (Carvalho 2011) since one of the strongest criticisms towards PAE is the absence of phylogenetic information (Nihei 2006), which could create false relationships among areas (Sigrist & Carvalho 2008).

Following Morrone (1994), we performed the PAE using grid-cells of 1º x 1º latitude-longitude. Smaller quadrats would decrease the number of steps in the area cladogram whereas larger quadrats would tend to increase the number of synapomorphies (taxa that are found in more than one area; Morrone & Escalante 2002; Nihei 2006). Since species occurring in only one grid are not informative in PAE (Katinas et al. 2004), we excluded them from this analysis and built a refined matrix with 48 grid-cells and 432 species in 211 genera and 64 families. To root the cladogram we considered a hypothetical area in which all species would be absent.

We performed the PAE with the software Winclada (Nixon 2002) with interface with Nona software (Goloboff 1999). We set the maximum number of trees to 1000, of replications to 100, and of starting trees per replication to 1000. We accepted a final cladogram with strict consensus produced by the collapsing of unsupported nodes in all trees. We accepted an area of endemism to be indicated by two or more endemic species synapomorphies in a cluster of grids as suggested by Morrone (1994). We assessed the final cladogram with the retention index, which is better than the consistency index (Siebert 1992). The retention index (RI) expresses the actual level of homoplasy as a function of the maximum possible homoplasy (Siebert 1992) and can be thought of as the proportion of similarities that can be interpreted as synapomorphies in a cladogram (Farris 1989), whereas the consistency index (CI) measures the amount of homoplasies in the data (Siebert 1992). The areas of endemism were plotted in maps using the Arc-GIS 10.0 (ESRI 2010).

2.7. Endemic species

We defined areas of endemism according the interpretation of indices of endemism and the results of PAE. After this, we investigated which species occurs at one area of endemism, and which species occurs at two or more areas of endemism. In order to investigate whether each AOE contain different proportion of accessory species from adjacent phytogeographic domains we compared the species restricted to each AOE with lists of species that the record indicates that only occurs in Caatinga or Amazonian or Atlantic forest or Cerrado. These records were obtained from the Species List of Flora of Brazil (Forzza et al. 2010 avaliable online at http://floradobrasil.jbrj.gov.br/2010) selecting all angiosperms that occurs at each phytogeographic domains above.

The species of NE cerrado that were recorded only in Cerrado phytogeographic domain were categorized as “peculiar” species and considered true “endemic species”. Species of NE cerrado that were recorded in only in Caatinga or Amazonian or Atlantic forest phytogeographic domains were categorized as “accessory” species and considered these domains as the origin of the species, thus, being the first register for Cerrado domain. Species that occurs at only one AOE we considered as “restricted species”, and species which occurs at more than one AOE we considered as “widespread species”.

3. Results

Species richness indices of woody species in NE cerrado were high in the south border of Maranhão/Piauí states and in the south-central Bahia (Chapada Diamantina) and were highest in the northern portion of Piauí state (Fig. 2). Intermediate values of species richness were found on the western Bahia and southern Maranhão, whereas the lowest indices were observed in disjunct areas, such as the coast cerrados of Rio Grande do Norte and Paraíba, and central Ceará, Pernambuco and Piauí (Fig. 2). There was no differences on pure species richness (Fig. 2a) and corrected richness (Fig. 2b) since the correlation was extremely high (rs=0.996). The corrected-weight endemism (Fig. 3a) and the range-corrected endemism (Fig. 3b) indices indicated grids-cells with high endemism level concentrated mostly in disjunct cerrado areas, such as the coastal cerrados of Ceará, Rio Grande do Norte and Paraíba; hinterland areas of Ceará and Pernambuco states; and central Bahia; besides the northern Piauí state. There was no difference among both endemism metrics (rs=0.983). The RCE shows little less correlation with richness than CWE (rs= 0.299 and rs=0.305, respectively),

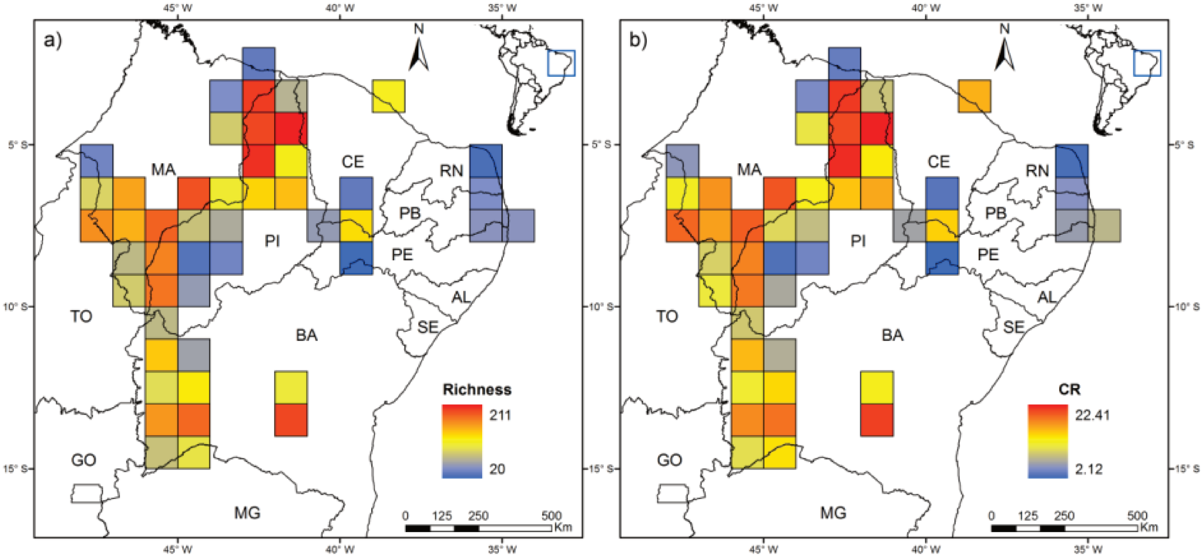

Fig. 2. Map of the species richness (a) and the corrected richness (b) for each grid-cell. Values per grid-cell are available in supporting information (Appendix A).

however, both significantly ($p<0.05$). The values for each grid-cell of both richness and endemism indices are listed in Appendix A.

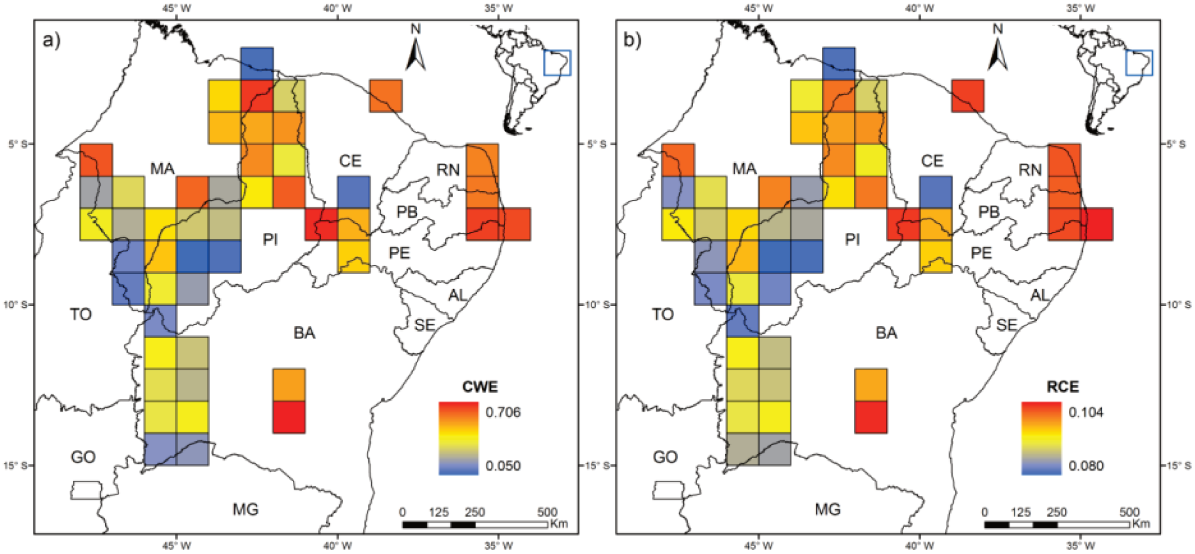

Fig. 3. Map of the (a) corrected-weight endemism (*CWE*; Crisp et al. 2001) and (b) range-corrected endemism (*RCE*; Ramírez-Barahona et al. 2011) for each grid-cell. Values per grid-cell are available in supporting information (Appendix A).

Species richness and corrected richness was not spatially structure at Bonferroni corrected level ($p> 0.00625$), but both richness indices had one significant positive spatial autocorrelation at first distance class (Fig. 4). The CWE and RCE were globally significant autocorrelated ($p<0.00625$), however, the RCE had more significant correlations. Whereas CWE was positively spatial autocorrelated at first distance class and negative at the seven, the RCE was positively autocorrelated at the first two distance classes and negative at the three last (Fig. 4).

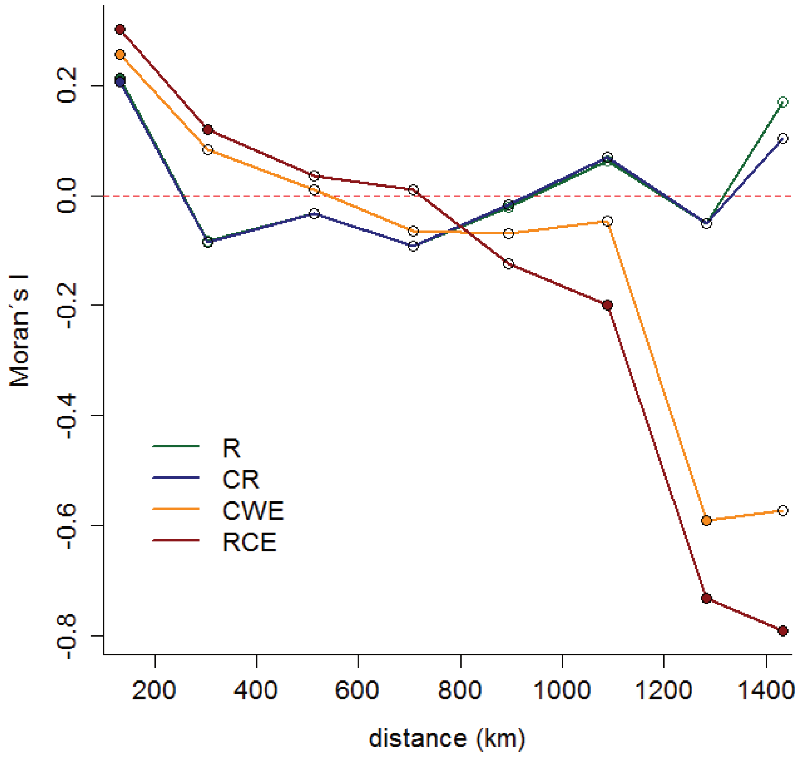

Fig. 4. Correlogram based on Moran´s I coefficient spatial autocorrelation for richness (R), corrected richness (CR), corrected-weight endemism (CWE) and range-corrected endemism (RCE). Significant autocorrelation distance classes at α = 5% are represented by solid circles.

A strict consensus cladogram from parsimony analysis of endemism resulted from the 26 most parsimonious trees (CI=0.21; RI=0,28). This cladogram (Fig. 5) indicated seven areas of endemism (AOE), which were supported by two or more endemic species by definition (synapamorphies). When these areas of endemism were mapped, three minor AOE (A, B and C) were grouped together with the area of endemism F (Fig. 6).

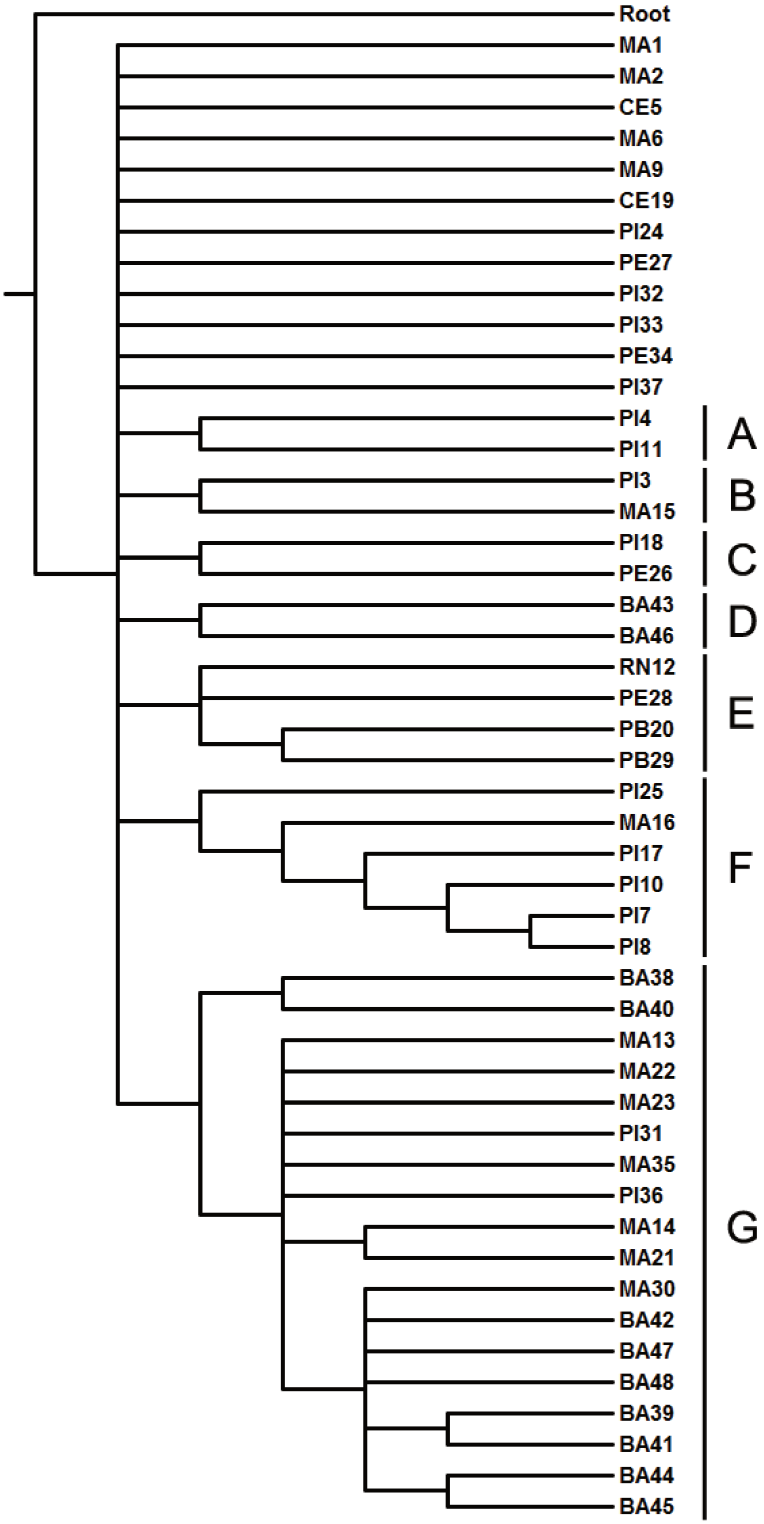

Fig. 5. Cladogram resulting from Parsimony Endemism Analysis using grid-cells of 1° x 1° latitude-longitude for the woody species of the northeastern cerrado of Brazil.

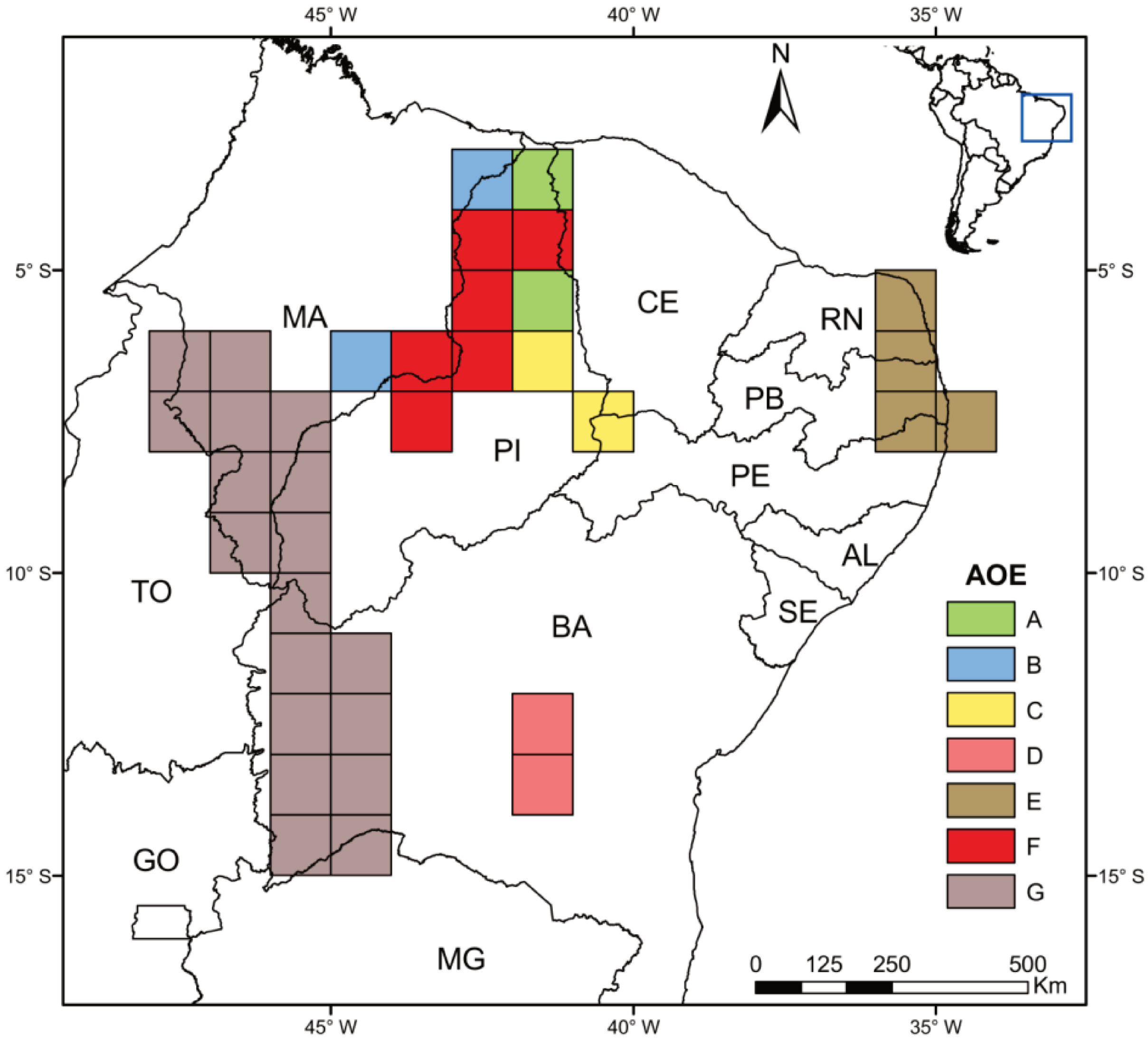

Fig. 6. Map of the operating units from Parsimony Endemism Analysis using grid-cells of 1° x 1° latitude-longitude for the woody species of the northeastern cerrado of Brazil.

Considering both the indices of endemism and the results of the PAE, we can indicate five areas of endemism in the NE cerrado: (1) the coastal cerrados of Rio Grande do Norte and Paraiba states; (2) the hinterland of Pernambuco and Ceará states; (3) the central Bahia; (4) the northern Piauí; and the (5) southwestern portion of the NE cerrado, which includes western Bahia and southwestern Piauí and Maranhão (Fig. 7).

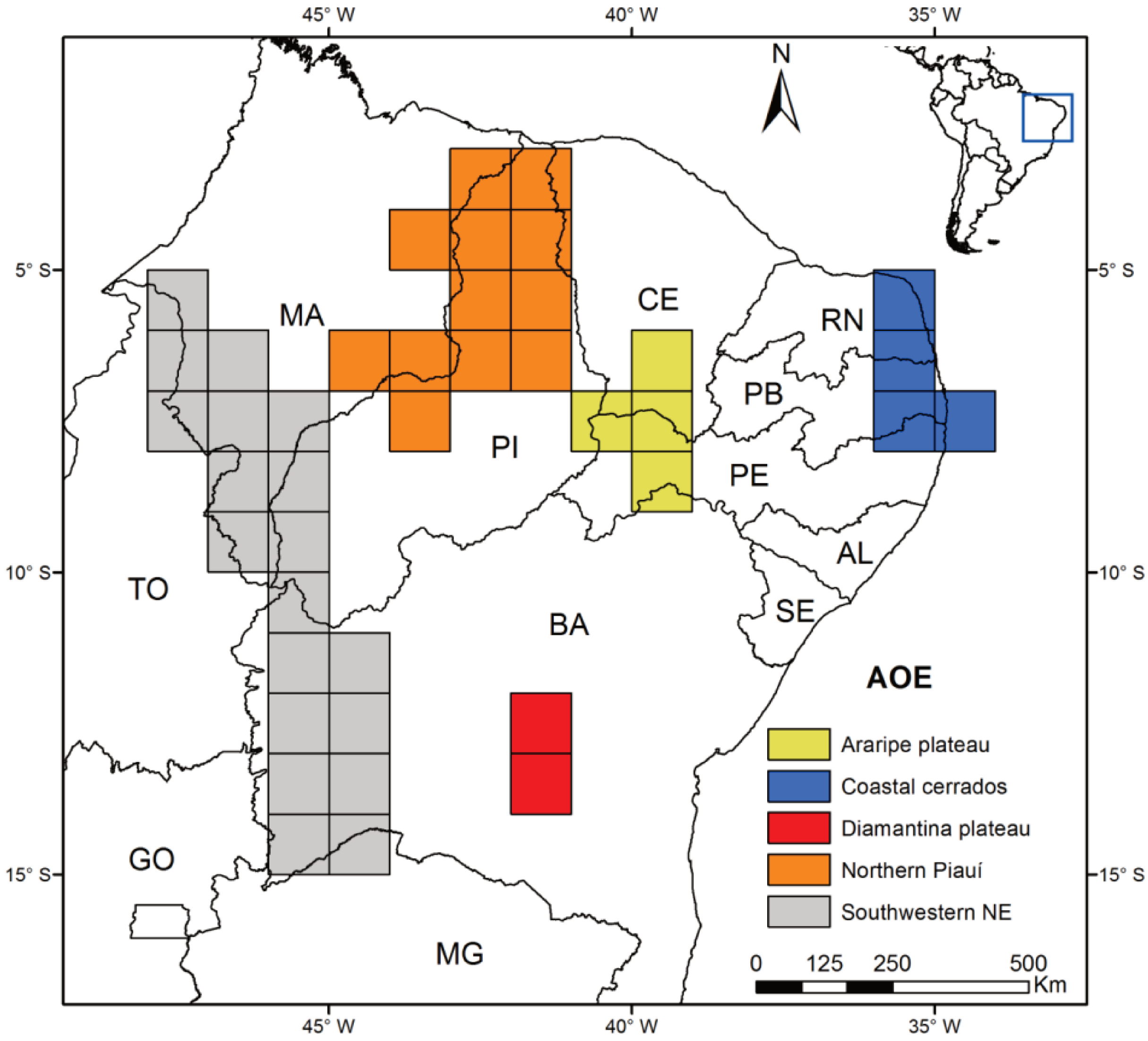

Fig. 7. Map of the five Areas of Endemism using grid-cells of 1º x 1º latitude-longitude for the woody species of the northeastern cerrado of Brazil. These AOEs are a conjecture of the endemism indices and parsimony analysis of endemism

The coastal cerrados had the lowest indices of species richness and high indices of endemism and is a concise group in PAE. The hinterland of Pernambuco and Ceará states (hereafter Araripe plateau) also had the lowest indices of species richness and high indices of endemism, but the relation among the grid-cells in PAE was not clear. The central Bahia, (hereafter Diamantina plateau) had high indices of endemism in both grid-cells with high-intermediate species richness and were grouped together in the PAE. The consensus AOE of the cerrados of northern Piauí and the closer grid-cells in Maranhão (hereafter only northern Piauí) is a union of four AOE (groups A, B, C and F) from PAE and is supported by relatively high indices of endemism, although with some grid-cells with high species richness. The southwestern AOE of the NE cerrado had the lowest indices endemism and much variable richness indices but a very concise grouping in in PAE.

Considering all areas of endemism, 611 species were restricted to only one AOE, whereas 170 species would be considered as a widespread species occurring in more than one AOE. The others 150 species were restricted to grid-cells that were not gathered with any AOE. The northern Piauí AOE had highest number of restricted species (303), followed by southwestern NE (117), Diamantina plateau (117), coastal cerrados (43) and Araripe plateau (31). The southwestern NE AOE had the highest proportion of peculiar species (23.93%), followed by Diamantina plateau (16.24%), northern Piauí (6.6%) and Araripe plateau (3.23%), and coastal cerrados had no peculiar species (Table 1).

Each AOE had different influences from adjacent phytogeographic domains. The coastal cerrados had 25% of its restricted species recorded previously only for Atlantic forest. Southwestern NE and Diamantina plateau AOE were no influenced by others phytogeographic domain since there were higher proportion of peculiar species of Cerrado (24% and 16% respectively). Araripe plateau was influenced by Caatinga species (26%) and northern Piauí AOE was more equally influenced by Amazon, Atlantic forest and Caatinga (7%, 4%, 7% respectively). All species restricted to each AOE and its origin, when is the case, are listed in online Appendix B.

Table 1. Total restricted species to each of the five areas of endemism (AOE) of NE Cerrado. Numbers and proportion in brackets refers to species that has its origin from its respective phytogeographic domain. WO: without origin. Data compared to Forzza et al. (2010).

AOE	WO	Amazon	Atlantic forest	Caatinga	Cerrado	Total
Coastal cerrados	31 (72.09%)	0 (0%)	11 (25.59%)	1 (2.32%)	0 (0%)	43
Diamantina plateau	91 (77.78%)	1 (0.85%)	1 (0.85%)	5 (4.27%)	19 (16.24%)	117
Araripe plateau	21 (67.74%)	0 (0%)	1 (3.23%)	8 (25.80%)	1 (3.23%)	31
Northern Piauí	227 (74.92%)	21 (6.93%)	13 (4.29%)	22 (7.26%)	20 (6.6%)	303
Southwestern NE	79 (67.52%)	6 (5.13%)	3 (2.57%)	1 (0.85%)	28 (23.93%)	117
Total	449	28	29	37	68	611

The more widespread species were *Byrsonima verbascifolia* (L.) DC. and *Miconia albicans* (Swartz) Triana that were present in all five AOE. Nine species were present in four AOE, 30 in three AOE and 129 in two (Appendix B). Out of 170 widespread species, only thirteen is peculiar species or endemic to cerrado, which *Maprounea guianensis* Aubl. was present in four AOE, *Ouratea spectabilis* (Mart. Ex Engl.) Engl. and *Vochysia gardneri* Warm. were present in three AOE. The widespread species are listed in online Appendix C.

4. Discussion

4.1. Species richness, endemism indices, PAE and endemic species

The 48 grids-cells in the Brazilian northeastern cerrado encompass almost the entire cerrado area of northeastern Brazil. The empty cells were produced by the absence of floristic surveys (central Maranhão and some patches in Bahia) and for not occurring in areas of cerrado vegetation. Although each survey was performed on a fine scale, we consider the grid-cell size we adopted to be adequate since few areas of cerrado were not gridded, but new surveys on these areas must be encouraged. Smaller grids would have produced many empty spaces.

The species richness variation observed among the grid-cells would be directly affected by the number of surveys and differences of the sampling effort and methods among the surveys similarly to what was observed in the Brazilian Atlantic Forest (see Caiafa & Martins 2007). The pattern we obtained with the corrected richness (CR) – proposed by Ramírez-Barahona et al. (2011) to diminish the influence of land area differences among grid-cells – did not differ from the pattern obtained with pure richness. Thus, the administrative limits of the Northeastern Region of Brazil did not affect the results. Perhaps, the corrected richness would be more efficient if we considered the land area of cerrado, however, much of the surveys are in zone of ecological tension and the limits of phytogeographic domain are still unclear.

Both *corrected-weight endemism* (CWE) and the *range-corrected endemism* (RCE) indicated the same four great areas of endemism: (1) the coastal cerrados; (2) the Diamantina plateau; (3) Araripe plateau; and (4) the northern Piauí state. These areas of endemism were supported by the positive autocorrelation at short distances. Although both CWE and RCE indices were correlated each other and indicated the same pattern, we are inclined to point the

RCE as a better metric due to less correlation with species richness and higher spatial structure. The autocorrelation in short distances would indicate that there are hotspots areas for endemism (Crisp et al. 2001), but not to richness.

On the other hand, the parsimony analysis of endemism indicated seven AOE with no clear relationship among them. We could only interpret two distinct types of areas: a local pattern with the areas A, B, and C surrounding the area F; and a regional pattern with the sequence of areas E, D and G from east to west (Fig. 5 and 6). Thus, the main assumption of PAE – the hierarchical pattern among the areas (Nihei 2006) – could not be fully understood in ours results. Thus, bearing in mind that PAE is just a first step towards an historic biogeographic approach and considering only the areas supported by indices of endemism, we can indicate five areas of endemism for the northeastern cerrado of Brazil.

Each of five area of endemism had different floristic influences from adjacent phytogeographic domains and different restricted species and different endemic species corroborating the assumption of areas of endemism. We considered the assessment of adjacent phytogeographic domains from online database (Forzza et al. 2010) extremely useful and recommendable since practically all herbarium collection data of Brazil were used to construct this database.

4.2. The areas of endemism

1) The NE coastal cerrados are floristically distinct from the core cerrado and even the NE cerrado (Castro 1994b), although they can have some Cerrado characteristic species (Castro 1994b; Moro et al. 2011; Oliveira-Filho 1993; Oliveira-Filho & Carvalho 1993). Many species present in the NE coastal cerrados come from the neighbor “restinga”, a vegetation complex including thicket, scrub and forest physiognomies (Oliveira-Filho 1993).

These cerrados occur on pre-coastal tablelands – regionally called “tabuleiro” (literally “tray”) – with 20-60 m of altitude, originated from the Barreiras geological formation (Oliveira-Filho 1993) constituted by sandstones, shales, and clay sedimentary rocks from the Tertiary period (Mabesoone & Castro 1975). These cerrados normally occur on terrains that are well protected against sea wind (Oliveira-Filho 1993) and should not be confounded with the “restinga”, which occur in the coastal plain constituted mainly by sandy deposition during the Quaternary (Araujo & Henriques 1984). The influence of restinga is confirmed with presence of almost 26% of the species from Atlantic forest, since restinga is a physiognomy of Atlantic forest.

2) The AOE of hinterland Pernambuco and Ceará states is a disjunction of the Cerrado that occurs on elevations higher than 800 m on the Araripe plateau (Costa et al. 2004; Figueiredo 1997). These sedimentary formations occur within the Caatinga Domain, which is a province dominated by the xerophilous thorny woodland (Figueiredo 1997). In these reliefs rainfall is greater and temperature is lower than they are in the surrounding Caatinga (Costa et al. 2004). The influence of surroundings is confirmed with almost 26% of species from Caatinga.

3) The Diamantina plateau is a mosaic of vegetation types, which includes cerrado and “campo rupestre” (Neves & Conceição 2010). Also named as “rocky field” (Gottsberger & Silberbauer-Gottsberger 2006), campo rupestre is a herb-shrub savanna that occurs generally on quartz sand soils in elevations higher than 900 m altitude (Harley & Simmons 1986). The Diamantina plateau constitutes tablelands in the south-center portion of Bahia state with a mean altitude of 1,000 m, but reaching 2,100 m in the Pico das Almas; it is the northern portion of the Espinhaço Chain, a disjunct mountain set that elongates northward from Minas Gerais state to the São Francisco river (Misi & Silva 1994; Rocha et al. 2005). The

Diamantina plateau is already known by its high number of endemic species (Giulietti & Pirani 1988; Harley 1995; Harley et al. 2005; Harley & Simmons 1986), and we just confirmed its high level of endemism with 117 restricted woody species out of almost 17% were considered as endemic species. This number of endemic woody species is really great since most endemic species recorded in Diamantina plateau are herbaceous species (Harley et al. 2005).

4) The northern Piauí AOE occurs at Parnaíba basin in low altitudes with soils that are different from the soils of other cerrado regions (Castro et al. 1998). The predominant soil in northern Piauí is Plinthosol (Reatto et al. 2008), but most soils have light colors and concretions. The presence of plinthite, concretions, and light colors in soils of strongly seasonal climates indicates large fluctuations of the water-table during pedogenesis (Castro et al. 1999). Although we indicated the northern Piauí state as an area of endemism, PAE did not consider it as “natural”, since the groups did not show any hierarchy in the cladogram, however, it was supported by high values of the range-corrected endemism. The unclear relationships among the groups indicated by PAE could be an outcome of the geographic position of this local AOE in a zone of ecological tension among Caatinga, Amazonian forest, and Cerrado. This pattern is clear since this local AOE was the most equitable of accessory species from adjacent phytogeographic domains. From PAE results we inferred that the three peripheral A, B, and C groups receive species from different neighbor formations, whereas the core of this AOE (group F) is influenced by all neighbor formations. In other words, the group B was mainly influenced by Amazonian forest, whereas the groups A and C have species from the Caatinga; hence, the group F receives influence of the Caatinga at east and Amazonian forest at west, but in lower levels than the peripheral groups. Further analyses are necessary to confirm this issue. The fact is that the northern Piauí AOE is particularly

complex, for instance due to the occurrence of the "Campo Maior Complex" in the central area, where many different formations are interspersed with the cerrados (Farias & Castro 2004). Another example of the complexity of this AOE is the "National Park of Seven Cities" (ca 6,200 ha), in which six vegetation types occur, although 48.1% of the area is cerrado (Oliveira et al. 2007).

5) The AOE of southwestern NE occurs at two different hydrological basins: in western Bahia state at São Francisco basin, with altitudes varying from 550 to 900 m (Felfili et al. 2004); and in southwestern Piauí state at the southwestern Parnaíba basin, but with higher altitudes (400-650 m) than northern part of the basin (50-300 m). Although there are two mountain chains (Serra Geral de Goías and Mangabeira plateau) which separates the southwestern NE cerrado from the cerrado core, this local AOE can be considered an continuum of the cerrado core, or specifically of the cerrados of Goiás and Tocantins states (Harley et al. 2005). For instance, Felfili et al. (2004) found a high level of plant similarity between sites distant about 500km in cerrados of central Brazil, thus, this similarity among distant sites could explain the low level of endemism we found with the RCE but a concise group in PAE with high number of synapomorphies, in other words, many species shared by all the AOE grid-cells. Also, this AOE soils are similar to central Brazil, with high aluminum and low nutrient contents (Harley et al. 2005). The southwestern NE was the local AOE with highest proportion of peculiar species, almost 24%, additionally there was not influenced by others phytogeographic domains, indicating the continuum of the cerrado core. This confirm the hypothesis that cerrado core has higher proportion of peculiar species than marginal areas (Rizzini 1963), although further investigations are needed to distinguish if this local AOE is really different from core cerrado.

4.3. The biogeographic pattern

The five areas of endemism have distinct environments regarding local climate, soil, relief, elevation, and surrounding formations. The general climate in the NE cerrado is similar to that of the core cerrado in regard to yearly total rainfall and seasonality, but rainfall is concentrated in fewer months (Castro et al. 1998) and temperatures are higher (Silva et al. 2008); it differs from the Caatinga climate due to higher rainfall (Sampaio 1995). As general pattern, the water availability seems to predominant to distinct the Cerrado from Caatinga: in higher elevation, such as Diamantina and Araripe plateau, temperature is lower, and the cerrados receive relief rains and frequent mists due to orographic condensation (Alves & Kolbek 1994); the coastal cerrados receive humidity from the sea; the northern Piauí has waterlogging due soil properties; and the southwestern NE occurs at humid valleys of São Francisco and Parnaíba hydrological basins. Therefore, each AOE of the NE cerrado has a particular environment conditions – altitude, soil, temperature – but always more humidity than the surrounding formations in the NE region. Baselga et al. (2011) analyzed the shapes of species distribution ranges for multiple taxa on a global scale and suggested that macroclimate is more important as a determinant of widespread species whereas the intrinsic dispersal limitation would be more important for restricted-range species. In other words, the 170 widespread species of NE cerrado would be more related to humidity similarity among AOE, whereas the 611 restricted-range species would be more related to particular environmental conditions of each AOE.

Three out of the five areas of endemism we detected can be considered disjunct, isolated areas: the Diamantina plateau, the coastal cerrados, and the Araripe plateau. Disjunctions in the ranges of plant species shows that there is some similarity of the habitats among the disjunct areas (Raven 1972). Although disjunct, a great part of the characteristic species of these three areas of endemism is widespread in the northeastern cerrado, showing some similarity among the AOE within this province. However, disjunct areas are often argued as a result of biogeographic history, thus, not surprisingly, many authors have argued that the current endemism in the NE cerrado is a result of climatic oscillations during Tertiary and Quaternary.

A classical model claims that in the interglacial phases higher altitudes, such as the Diamantina plateau, could be refugia for cerrado and rocky field vegetation, which during glacial phases would disperse to lower sites, producing thus a high level of endemism as an outcome of the recurrent alternation of vicariant and dispersal events (Conceição et al. 2005; Giulietti & Pirani 1988; Giulietti et al. 1997; Harley 1995; Harley & Simmons 1986). The same model could be applied for the area of endemism in the Araripe plateau. However, on Diamantina and Araripe plateaus, only climatic oscillations would not have been sufficient for the cerrado to expand onto lower areas since its species are very dependent upon soil conditions and have restricted dispersal; hence, these disjunct areas of endemism would be ancient (prior to Quaternary) and their endemic species would have originated *in situ* from ancestral species (Alves & Kolbek 1994). This probably would be the case, at least partially, of the 611 restricted-range species related to particular environmental conditions of each AOE.

As we found an important influence of adjacent phytogeographic domains flora in the NE cerrado, we suggest that this could be an outcome of "savanna capture processes" when the expanding savanna environment would have selected some lineages from the contracting rainforests or seasonally dry forests (This thesis, chapter 1). As there are few endemic genera in the Cerrado comparing to Atlantic forest and Amazon (Fiaschi & Pirani 2009), we must investigate whether these accessory species are present in their respective cerrado AOE due the constant influx of propagules from adjacent phytogeographic domains or they are present permanently in these areas. If these species are well established on these areas, the savanna capture processes would be in course, however, a lot of studies are needed to answer this question. Additionally, based on endemic species of each AOE, we may observed that many species in NE cerrado has sister groups in Amazon and Atlantic forests and Caatinga, corroborating Simon et al. (2009), that studying plant phylogenies, have shown that cerrado lineages have sister groups in largely fire-free nearby wet forest, seasonally dry forest, subtropical grassland, or wetland vegetation. Although many species would have evolved *in situ* (Simon et al. 2009), this genera relation among phytogeographic domains would confirm that savanna environmental would selected species from adjacent phytogeographic domains during evolutionary history, and this processes would be more important in marginal areas of the Cerrado, such as NE cerrado.

5. Conclusion

Our results agree with the initial hypothesis of influence of adjacent phytogeographic domains on the areas of endemism. The widespread species would be consequence of the wide ecological amplitude of these species, although related similarity of humidity among AOE. On the other hand, each area of endemism of the NE cerrado has a special environment and typical endemics restricted-range species. Although we agree that many species would have evolved *in situ* (Simon et al. 2009), in the marginal areas of the Cerrado, species from adjacent formations of each AOE found in NE cerrado may be related to the recurrent alternation of dispersal and vicariant events during the climatic oscillations of the Tertiary and Quaternary. We consider ours to be a first systematic approach to the issue of endemism in the NE cerrado with indication of areas of endemism that deserve special attention from conservation policies.

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Appendix A. Species richness and endemism indices of the Brazilian NE cerrado woody flora for the 48 grid-cells of 1º latitude-longitude. States: MA-Maranhão, PI-Piauí, CE-Ceará, RN-Rio Grande do Norte, PB-Paraíba, PE-Pernambuco, AL-Alagoas, SE-Sergipe, BA-Bahia, MG-Minas Gerais, GO-Goiás, TO-Tocantins; N: numers of surveys for each grid-cell; AreaClip: land area (km^2) clipped the coastlines and administrative limits of NE Region of Brazil; R: species richness; CR: corrected-richness; CWE: corrected-weight endemism; RCE: range-corrected endemism.

Grid-cell	States	N	AreaClip	R	CR	CWE	RCE
1	MA	2	4465.11	28	3.331727	0.050933	0.080628
2	MA	1	12286.4	36	3.823179	0.194192	0.085311
3	PI	6	12286.4	181	19.22209	0.482754	0.094272
4	PI	3	12286.4	55	5.840968	0.134789	0.0844
5	CE	2	2960.12	74	9.258118	0.386599	0.098656
6	MA	2	12271.8	62	6.585195	0.257303	0.087236
7	PI	24	12271.8	163	17.31269	0.270045	0.089844
8	PI	13	12271.8	211	22.41091	0.307894	0.09125
9	MA	1	8230.65	35	3.882151	0.408402	0.094275
10	PI	10	12253.6	197	20.92722	0.334849	0.091709
11	PI	3	12253.6	71	7.542299	0.142207	0.08537
12	RN	1	8013.17	21	2.33623	0.345365	0.095141
13	MA	1	5580.52	63	7.302623	0.089997	0.082762
14	MA	2	12231.8	96	10.19997	0.135721	0.085112
15	MA	1	12231.8	156	16.57495	0.393789	0.092051
16	MA	3	12231.8	70	7.437477	0.100104	0.082943
17	PI	3	12231.7	82	8.71248	0.176321	0.085938
18	PI	3	12231.7	88	9.349979	0.406705	0.093925
19	CE	1	12231.7	28	2.974993	0.072287	0.082115
20	PB	2	11902.3	36	3.836118	0.373795	0.094355
21	MA	7	5267.86	105	12.25293	0.148023	0.085933
22	MA	3	11873.8	92	9.805918	0.100449	0.083953
23	MA	7	12206.3	135	14.34689	0.193877	0.08691
24	PI	3	12206.3	59	6.270121	0.122038	0.08339
25	PI	3	12206.3	52	5.526208	0.102476	0.083062
26	PE	1	12206.3	44	4.676022	0.59614	0.09903
27	PE	3	12206.3	81	8.608132	0.264202	0.088751
28	PE	2	12206.2	41	4.357206	0.464696	0.09693
29	PB	2	2200.28	41	5.327208	0.451855	0.104014
30	MA	1	9279.47	56	6.129893	0.081245	0.082793
31	PI	2	12177.1	106	11.26783	0.254264	0.087701
32	PI	1	12177.1	27	2.870108	0.050672	0.080187

Grid-cell	States	N	AreaClip	R	CR	CWE	RCE
33	PI	1	12177.1	35	3.72051	0.057818	0.080619
34	PE	1	12177.1	20	2.126006	0.22779	0.087128
35	MA	1	8326.11	62	6.868169	0.07845	0.082717
36	PI	5	12144.4	109	11.59004	0.142869	0.085163
37	PI	2	12144.4	44	4.67855	0.087929	0.082588
38	BA	2	11467.8	56	5.991036	0.082206	0.08242
39	BA	2	12068.1	83	8.831365	0.154087	0.085699
40	BA	1	12068.1	48	5.107295	0.104846	0.083427
41	BA	1	12024.6	66	7.02523	0.136501	0.084834
42	BA	3	12024.6	75	7.983216	0.101347	0.083819
43	BA	3	12024.6	69	7.344559	0.291611	0.089756
44	BA	5	11977.4	101	10.75523	0.140485	0.085149
45	BA	6	11977.4	113	12.03308	0.152925	0.085652
46	BA	4	11977.4	163	17.35746	0.706073	0.100067
47	BA	2	10586.9	59	6.366421	0.084166	0.083249
48	BA	2	4478.18	67	7.969576	0.084179	0.082997

Appendix B. The 611 species restricted to each of five areas of endemism (AOE). The species are sorted alphabetically by family within each AOE. PD column indicates the phytogeographic domain where the specie was exclusively recorded according Species List of Flora of Brazil (Forzza et al. 2010).

Coastal cerrados

Family	Specie	PD
Anacardiaceae	*Thyrsodium spruceanum* Benth.	
Annonaceae	*Anaxagorea dolichocarpa* Sprague & Sandwith	
	Annona pickelli (Diels) H.Rainer	
	Duguetia lanceolata A. St. -Hil.	
Araliaceae	*Schefflera morototoni* (Aubl.) Maguire	
Burseraceae	*Protium bahianum* Daly	Atlantic forest
Chrysobalanaceae	*Licania octandra* (Hoffmanns. ex Schult.) Kuntze	
Clusiaceae	*Clusia dardanoi* G. Mariz & Maguire	
Euphorbiaceae	*Chaetocarpus myrsinites* Baill.	
	Pogonophora schombugkiana Miers ex Benth.	
Fabaceae	*Andira legalis* (Vell.) Toledo	Atlantic forest
	Caesalpinia echinata Lam.	Atlantic forest
	Chamaecrista bahiae (H. S. Irwin) H. S. Irwin & Barneby	
	Inga capitata Desv.	
	Stryphnodendron pulcherrimum (Willd) Hocher	
	Zollernia ilicifolia (Brongn.) Vogel	
Humiriaceae	*Sacoglottis mattogrossensis* Malme	
Hypericaceae	*Vismia cayennensis* (Jacq.) Pers.	
Lamiaceae	*Aegiphila pernambucensis* Moldenke	Atlantic forest
	Vitex rufescens A. Juss.	
Lauraceae	*Ocotea duckei* Vatt.	Caatinga
	Ocotea nitida (Meisn.) Mez	
Lecythidaceae	*Eschweilera ovata* (Cambess.) Miers	
Malvaceae	*Eriotheca macrophylla* (K.Schum.) A.Robyns	Atlantic forest
Myrtaceae	*Campomanesia dichotoma* (O. Berg) Mattos	
	Myrcia bergiana O.Berg.	
	Myrciaria tenella (DC.) O. Berg	
Nyctaginaceae	*Guapira laxa* (Netto) Furlan	
	Guapira nitida (Schmidt) Lundell	Atlantic forest
	Guapira pernambucensis (Casar.) Lundell	Atlantic forest
Ochnaceae	*Ouratea cuspidata* Tiegh.	
Polygonaceae	*Coccoloba alnifolia* Casar	
	Coccoloba cordifolia Meisn.	
	Coccoloba ramosissima Wedd.	
Rubiaceae	*Guettarda platypoda* A .DC.	

Family	Specie	PD
Rubiaceae	*Psychotria bahiensis* DC.	
	Salzmannia nitida DC.	Atlantic forest
Rutaceae	*Esenbeckia grandiflora* Mart.	
Sapindaceae	*Allophylus edulis* (A. St.-Hil., A. Juss. & Cambess.) Hieron. ex Niederl.	
Sapotaceae	*Manilkara salzmannii* (A. DC.) H.J. Lam	Atlantic forest
	Pouteria grandiflora (A. DC.) Baehni	Atlantic forest
	Pouteria peduncularis (Mart. & Eichler ex Miq.) Baehni	Atlantic forest
Schoepfiaceae	*Schoepfia brasiliensis* A. DC.	

Araripe plateau

Family	Specie	PD
Acanthaceae	*Anisacanthus trilobus* Lindau	Caatinga
Boraginaceae	*Cordia alliodora* (Ruiz Lopez & Pavon) Oken	
	Cordia bicolor A. DC.	
Cactaceae	*Arrojadoa rhodantha* (Gürke) Britton & Rose	Caatinga
	Pilosocereus pachycladus Ritter	
	Pilosocereus tuberculatus (Werdem.) Byles & Rowley	Caatinga
Euphorbiaceae	*Cnidoscolus vitifolius* (Mill.) Pohl	
	Croton argyrophylloides Müll. Arg.	Caatinga
	Jatropha mollissima (Pohl) Baill.	
	Jatropha mutabilis (Pohl) Baill.	Caatinga
	Manihot carthaginensis subsp. *glaziovii* (Müll.Arg.) Allem	
	Maprounea brasiliensis A. St.-Hil.	
Fabaceae	*Ateleia glazioveana* Baillon	Atlantic forest
	Bauhinia acuruana Moric.	Caatinga
	Bauhinia subclavata Benth.	
	Calliandra umbellifera Benth.	Caatinga
	Chamaecrista apoucouita (Aubl.) H.S. Irwin & Barneby	
	Cratylia mollis Mart. ex Benth.	Caatinga
	Dalbergia cearensis Ducke	
	Mimosa arenosa (Willd.) Poir.	
	Pterodon abruptus (Moric.) Benth.	
	Senegalia riparia (Kunth) Britton & Rose	
	Senna barnebyana Lass.	
	Senna gardneri (Benth.) H.S.Irwin & Barneby	
Lauraceae	*Ocotea pallida* (Meiss.) Mez.	
Malvaceae	*Waltheria ferruginea* A.St.-Hill.	Cerrado
Myrtaceae	*Psidium australe* var. *suffruticosum* (O.Berg) Landrum	
	Psidium salutare var. *pohlianum* (O.Berg) Landrum	
Rutaceae	*Zanthoxylum gardneri* Engl.	
	Zanthoxylum riedelianum Engl.	
Salicaceae	*Casearia guianensis* (Aublet) Urban	

Diamantina plateau

Family	Specie	PD
Acanthaceae	*Ruellia incompta* (Ness) Lindau	
Amaranthaceae	*Pfaffia acutifolia* (Moq.) O. Stützer	
Anacardiaceae	*Tapirira obtusa* (Benth.) J.D. Mitch.	
Apocynaceae	*Barjonia erecta* (Vell.) K. Schum.	
	Ditassa acerosa Mart.	
Aquifoliaceae	*Ilex velutina* Mart.	
Arecaceae	*Acrocomia hassleri* (Barb. Rodr.) W.J. Hahn	
	Allagoptera campestris (Mart.) Kuntze	Cerrado
	Syagrus werdermannii Burret	
Asteraceae	*Acritopappus confertus* (Gardner) R.M. King & H. Rob.	Caatinga
	Baccharis aphylla (Vell.) DC.	
	Chromolaena horminoides DC.	
	Eremanthus incanus (Less.) Less.	
	Eremanthus pohlii (Baker) MacLeish	Cerrado
	Gochnatia blanchetiana (DC.) Cabrera	
	Lepidaploa cotoneaster (Willd. ex Spreng.) H. Rob.	Cerrado
	Lepidaploa nitens (Gardner) H. Rob.	
	Lessingianthus rosmarinifolius (Less.) H. Rob.	Cerrado
	Lychnophora bahiensis Mattf.	
	Lychnophora salicifolia Mart.	Cerrado
	Mikania luetzelburgii Mattf.	
	Platypodanthera melissifolia (DC.) R.M. King & H. Rob.	Cerrado
	Porophyllum obscurum (Spreng.) DC.	
	Symphyopappus compressus (Gardner) B.L. Rob.	
	Trixis vauthieri DC.	
Bignoniaceae	*Anemopaegma album* Mart. ex DC.	Cerrado
	Anemopaegma scabriusculum Mart. ex DC.	
	Jacaranda irwinii A.H.Gentry	Cerrado
	Jacaranda ulei Bureau & K. Schum	Cerrado
Calophyllaceae	*Kielmeyera neriifolia* Cambess.	
Clusiaceae	*Clusia sellowiana* Schltdl.	Atlantic forest
Convolvulaceae	*Evolvulus elegans* Moric.	
	Evolvulus glomeratus Nees & C. Mart.	
	Evolvulus pterocaulon Moric.	
	Jacquemontia agrestis (Mart. ex Choisy) Meisn.	
	Merremia digitata (Spreng.) Hallier f.	
Erythroxylaceae	*Erythroxylum vacciniifolium* Mart.	
Euphorbiaceae	*Alchornea triplinervia* (Spreng.) Müll. Arg.	
	Croton betulaster Müll. Arg.	
	Microstachys corniculata (Vahl) Griseb.	
	Microstachys serrulata (Mart.) Müll.Arg.	
Euphorbiaceae	*Sapium glandulosum* (L.) Morong	

Family	Specie	PD
Euphorbiaceae	*Sebastiania brevifolia* (Müll. Arg.) Müll. Arg.	
Fabaceae	*Aeschynomene paniculata* Willd. ex Vogel	
	Calliandra bahiana Renvoize	Caatinga
	Calliandra longipinna Benth.	Caatinga
	Calliandra sessilis Benth.	
	Camptosema pedicellatum var. *longibothrys* Benth.	
	Camptosema pedicellatum var. *pedicellatum* Benth.	
	Chamaecrista desvauxii (Collad.) Killip	
	Chamaecrista ramosa (Vogel) H.S. Irwin & Barneby	
	Chamaecrista repens var. *multijuga* (Benth.) H.S. Irwin & Barneby	
	Mimosa gemmulata Barneby	
	Mimosa honesta Mart.	
	Mimosa polydidyma Barneby	
	Stylosanthes gracilis Kunth	
	Swartzia apetala Raddi	
Hypericaceae	*Vismia confertiflora* Spruce ex Reichardt	Amazon
Lamiaceae	*Eriope hypenioides* Mart. ex Benth.	Cerrado
	Eriope latifolia (Mart. ex Benth.) Harley	Cerrado
	Eriope macrostachya Mart. ex Benth.	
	Eriope polyphylla Mart. ex Benth.	
	Hypenia vitifolia (Pohl ex Benth.) Harley	Cerrado
	Hyptis crinita Benth.	Cerrado
Lauraceae	*Ocotea percoriacea* (Meisn.) Kosterm.	
Loganiaceae	*Spigelia pulchella* Mart.	
Lythraceae	*Diplusodon parvifolius* DC.	
Malpighiaceae	*Banisteriopsis angustifolia* (A. Juss.) B. Gates	
	Banisteriopsis campestris (A. Juss.) Little	
	Banisteriopsis harleyi B. Gates	Cerrado
	Banisteriopsis malifolia (Nees & Mart.) B. Gates	Cerrado
	Byrsonima dealbata Griseb.	Cerrado
Malvaceae	*Ayenia angustifolia* A. St.-Hil. & Naudin	
	Sida angustissima A.St.-Hil.	
Melastomataceae	*Cambessedesia membranacea* Gardner	Cerrado
	Cambessedesia purpurata DC.	Caatinga
	Leandra blanchetiana Cogn.	
	Marcetia lanuginosa Wurdack	Caatinga
	Marcetia taxifolia (A. St.-Hil.) DC.	
	Miconia leucocarpa DC.	
	Miconia ligustroides (DC.) Naudin	
	Microlicia sincorensis Mart.	
Myrtaceae	*Campomanesia sessiliflora* (O. Berg) Mattos	
	Myrcia blanchetiana (O.Berg) Mattos	
	Myrcia venulosa DC.	

Family	Specie	PD
Myrtaceae	*Psidium grandifolium* Mart. ex DC.	
Ochnaceae	*Ouratea semiserrata* (Mart. & Nees) Engl.	
Orobanchaceae	*Esterhazya splendida* J.C. Mikan	
Polygalaceae	*Bredemeyera brevifolia* (Benth.) A.W. Benn.	
	Polygala harleyi var. *intermedia* Marques	Cerrado
	Polygala multiceps Mart. ex A.W. Benn.	
	Coccoloba brasiliensis Nees & Mart.	
Primulaceae	*Myrsine monticola* Mart.	
	Myrsine umbellata Mart.	
	Myrsine venosa A. DC.	
Rosaceae	*Prunus myrtifolia* (L.) Urb.	
Rubiaceae	*Declieuxia aspalathoides* Müll. Arg.	
	Palicourea marcgravii A. St.-Hil.	
	Psyllocarpus asparagoides Mart. & Zucc.	
	Rudgea jacobinensis Müll. Arg.	
Rutaceae	*Dictyoloma vandellianum* A.H.L. Juss.	
Santalaceae	*Phoradendron interruptum* (DC.) B.D.Jacks.	
Sapindaceae	*Cupania paniculata* Cambess.	
	Cupania rugosa Radlk.	
	Dodonaea viscosa Jacq.	
Sapotaceae	*Chrysophyllum rufum* Mart.	
	Micropholis gardneriana (A. DC.) Pierre	
Solanaceae	*Cestrum obovatum* Sendtn.	
	Schwenckia americana Rooyen ex L.	
	Solanum stenandrum Sendtn.	
Symplocaceae	*Symplocos oblongifolia* Casar.	
Trigoniaceae	*Trigonia nivea* Cambess.	
Verbenaceae	*Lippia rigida* Schauer	
	Lippia subracemosa Mansf.	
	Stachytarpheta lychnitis Mart.	
Vochysiaceae	*Qualea dichotoma* (Mart.) Warm.	
	Qualea selloi Warm.	Cerrado

Northern Piauí state

Family	Specie	PD
Acanthaceae	*Justicia pectoralis* Jacq.	
	Ruellia ochroleuca Mart. ex Ness.	Caatinga
Anacardiaceae	*Apterokarpos gardneri* (Engl.) Rizzini	Caatinga
	Spondias purpurea L.	
	Spondias tuberosa Arruda	
Annonaceae	*Annona dioica* A. St.-Hil.	
	Annona squamosa L.	

Family	Specie	PD
Annonaceae	*Duguetia echinophora* R. E. Fries	Amazon
	Ephedranthus pisocarpus R.E. Fr.	Amazon
	Oxandra sessiliflora R.E. Fr.	
	Rollinia sylvatica (A. St.-Hil.) Martius	
Apocynaceae	*Allamanda blanchetti* DC.	
	Allamanda polyantha Müll. Arg.	Atlantic forest
	Aspidosperma multiflorum A. DC.	
	Catharanthus roseus (L.) G. Don	
	Forsteronia pubescens A. DC.	
	Himatanthus sucuuba (Spruce ex Müll. Arg.) Woodson	
	Matelea maritima (Jacq.) Woodson	Amazon
	Nerium oleander L.	
	Rauvolfia ligustrina Willd. ex Roem. & Schult.	
	Tabernaemontana hystrix Steud	
	Tabernaemontana solanifolia A.DC.	
Araceae	*Taccarum peregrinum* (Schott) Engl.	Atlantic forest
Arecaceae	*Astrocaryum campestre* Mart.	
	Cocos nucifera L.	Atlantic forest
	Desmoncus phoenicocarpus Barb. Rodr.	Amazon
	Elaeis guineensis W.J.Jacq.	Atlantic forest
	Mauritia flexuosa L. f.	
	Syagrus botryophora (Mart.) Mart.	Atlantic forest
Asteraceae	*Aspilia riedelii* Baker	Cerrado
	Bidens riparia Kunth	
	Centratherum punctatum Cass.	
	Chromolaena maximilianii (Schad. ex DC.) R. M. Kieg. & H. Rob.	
	Elephantopus piauiensis R. Barros & Semir	
	Eupatorium clematideum Griseb.	
	Eupatorium odoratum L.	
	Lepidaploa remotiflora (Rich.) H. Rob.	Cerrado
	Lepidaploa rufogrisea (A. St.-Hil.) H. Rob.	Cerrado
	Melampodium divaricatum (Rich.) DC.	
	Pithecoseris pacourinoides Mart.	Caatinga
	Rolandra fruticosa (L.) Kuntze	
	Stilpnopappus pratensis Mart. ex DC.	Caatinga
	Stilpnopappus trichospiroides Mart. ex DC.	
	Tilesia baccata (L.) Pruski	
Bignoniaceae	*Adenocalymma pedunculatum* (Vell.) L. Lohmann	
	Jacaranda praetermissa Sandwith	Cerrado
	Tabebuia pilosa A.Gentry	Amazon
	Tabebuia roseoalba (Ridl.) Sw.	
Bixaceae	*Bixa orellana* L.	
Boraginaceae	*Cordia scabrifolia* A. DC.	Amazon

Family	Specie	PD
Boraginaceae	*Cordia sellowiana* Cham.	
	Cordia toqueve Aubl.	
	Heliotropium lanceolatum Ruiz & Pav.	
	Tournefortia rubicunda Salzm. ex DC.	
	Varronia guazumaefolia Desv.	
Cactaceae	*Nopalea cochenillifera* (L.) Salm-Dyck	
	Pilosocereus flavipulvinatus (Buining & Brederoo) F. Ritter	
	Pilosocereus piauhyensis (Gürke) Byles & G.D. Rowley	Caatinga
Capparaceae	*Capparis flexuosa* (L.) L.	
	Capparis hastata Jacq.	
	Crateva tapia L.	
Caricaceae	*Carica papaya* L.	
Celastraceae	*Celastrus maytenus* Willd.	
	Salacia amygdalina Peyr.	
	Tontelea micrantha (Mart. ex Schult.) A.C. Sm.	
Chrysobalanaceae	*Exellodendron gardneri* (Hook. f.) Prance	
Cleomaceae	*Cleome spinosa* Jacq.	
Clusiaceae	*Clusia panapanari* (Aubl.) Choisy	
Combretaceae	*Buchenavia grandis* Ducke	
	Combretum ellipticum Sim.	
	Combretum fruticosum (Loefl.) Stuntz	
	Combretum lanceolatum Pohl ex Eichler	
	Combretum mellifluum var. *mellifluum* Eichler	
	Terminalia actinophylla Mart.	
	Terminalia glabrescens Mart.	
Connaraceae	*Rourea doniana* Baker.	
	Rourea gardneriana Planh.	Atlantic forest
Convolvulaceae	*Evolvulus latifolius* Ker Gawl.	
	Ipomoea carnea Jacq.	
	Operculina alata Urb.	
	Operculina macrocarpa (Linn) Urb.	
Cucurbitaceae	*Cayaponia tayuya* (Vell.) Cogn.	
Dilleniaceae	*Davilla cearensis* Huber	
Ebenaceae	*Diospyros brasiliensis* Mart. ex Miq.	Atlantic forest
	Diospyros coccolobaefolia Mart. ex Miq.	
Erythroxylaceae	*Erythroxylum bezerrae* Plowmann	
	Erythroxylum buxus Peyr.	Cerrado
	Erythroxylum daphnites Mart.	
	Erythroxylum laetevirens O.E.Schulz	
Euphorbiaceae	*Croton betaceus* Baill.	
	Croton celtidifolius Baill.	Atlantic forest
	Croton essequiboensis Klotzsch	Amazon
	Croton heliotropiifolius Kunth	

Family	Specie	PD
Euphorbiaceae	*Croton lundianus* (Didr.) Müll. Arg.	
	Croton pedicellatus Kunth	
	Croton sonderianus Müll. Arg.	Caatinga
	Jatropha curcas L.	
	Jatropha gossypiifolia L.	
	Manihot anomala Pohl	Cerrado
	Manihot caerulescens Pohl	
	Manihot esculenta Crantz.	
	Manihot pruinosa Pohl	Cerrado
	Manihot tripartita (Spreng.) Müll. Arg.	
Fabaceae	*Aeschynomene sensitiva* Sw.	
	Albizia polycephala (Benth.) Killip	
	Amburana cearensis (Alemão) A. C. Sm.	
	Bauhinia aculeata L.	
	Bauhinia cheilantha (Bong.) Steud.	
	Bauhinia cupulata Benth.	
	Bauhinia cuyabensis (Bong.) Steudel	
	Bauhinia pentandra (Bong.) Vogel ex Steud.	
	Caesalpinia pulcherrima (L.) Sw.	
	Calliandra abbreviata Benth.	
	Calliandra fernandesii Barneby	Caatinga
	Calliandra parviflora Benth.	
	Chamaecrista desvauxii var. *malacophylla* (Vogel) H.Irwin & Barneby	Cerrado
	Chamaecrista fagonioides (Vogel) H.Irwin & Barneby	
	Chamaecrista hispidula (Vahl.0 H. S. i rwin & Barn.	
	Chamaecrista langsdorffii (Kunth ex Vogel) Britton ex Pittier	
	Chamaecrista nictitans (L.) Moench	
	Chamaecrista viscosa (Kunth) H.S. Irwin & Barneby	
	Chloroleucon acacioides (Ducke) Barneby & J.W. Grimes	
	Chloroleucon foliolosum (Benth.) G.P.Lewis	
	Chloroleucon mangense (Jacq.) Britton & Rosé	Amazon
	Copaifera elliptica Mart.	Cerrado
	Cratylia argentea (Desv.) Kuntze	
	Crotalaria holosericea Nees & Mart.	Caatinga
	Delonix regia (Bojer ex Hook.) Raf.	Atlantic forest
	Desmodium triflorum (L.) DC.	
	Dialium guianense (Aubl.) Sandwith	
	Dipteryx lacunifera Ducke	
	Diptychandra aurantiaca subsp. *epunctata* (Tul.) H.C.Lima et al.	Caatinga
	Enterolobium ellipticum Benth.	
	Enterolobium schomburgkii (Benth.) Benth	
	Erythrina velutina Willd.	
	Holocalyx balansae Micheli	

Family	Specie	PD
Fabaceae	*Hymenaea courbaril* var. *longifolia*(Benth.) Y.T. Lee & Andrade-Lima	
	Hymenaea stigonocarpa var. *pubescens* Benth.	
	Indigofera blanchetiana Benth.	Caatinga
	Libidibia ferrea (Mart. ex Tul.) L.P.Queiroz	
	Machaerium acutifolium var. *acutifolium* Vogel	
	Mimosa caesalpiniifolia Benth.	Caatinga
	Mimosa ophthalmocentra Mart. ex Benth.	Caatinga
	Mimosa polycarpa Kunth.	
	Moldenhawera acuminata Afr. Fernandes & P. Bezerra	Cerrado
	Phanera flexuosa (Moric.) L.P.Queiroz	
	Phanera glabra (Jacq.) Vaz	
	Phanera trichosepala L.P. Queiroz	Caatinga
	Piptadenia viridiflora (Kunth.) Benth.	
	Poincianella pyramidalis (Tul.) L.P.Queiroz	Caatinga
	Pterocarpus rohrii Vahl	
	Senegalia piauhiensis (Benth.) Seigler & Ebinger	Caatinga
	Senna acuruensis (Benth.) Irwin & Barneby	Caatinga
	Senna cana var. *hypoleuca* H. S. Irwin & Barneby	
	Senna latifolia (G. Meyer) H. S. Irwin & Barneby	
	Senna obtusifolia (L.) H.S.Irwin & Barneby.	
	Senna occidentalis (L.) Link	
	Senna rostrata (Mart.) H. S. Irwin & Barneby	Cerrado
	Senna siamea (Lamarck) H.S.Irwin & Barneby.	
	Senna spectabilis (DC.) H. S. Irwin & Barneby	
	Stylosanthes capitata Vogel	
	Stylosanthes guianensis (Aubl.) Sw.	Cerrado
	Tachigali goeldiana (Huber) L.G.Silva & H.C.Lima	Amazon
	Tachigali subvelutina (Benth.) Oliveira-Filho	Cerrado
	Tamarindus indica L.	
	Taralea oppositifolia Aubl.	Amazon
	Vachellia farnesiana (L.) Wight & Arn.	
Humiriaceae	*Humiria balsamifera* Aublet	
Hydroleaceae	*Hydrolea spinosa* L.	
Hypericaceae	*Vismia magnoliifolia* Cham. & Schldl.	Atlantic forest
Lamiaceae	*Aegiphila hastingsiana* Moldenke	
	Amasonia campestris (Aubl.) Moldenke	
	Hypenia salzmannii (Benth.) Harley	
	Leonotis nepetifolia (L.) R. Br.	
	Vitex flavens Kunth	Cerrado
	Vitex panshaniana Mold.	
	Vitex trifolia L.	
Lauraceae	*Mezilaurus itauba* (Meisn.) Taub. ex Mez	Amazon
	Nectandra cuspidata Nees	

Family	Specie	PD
Lauraceae	*Ocotea brachybotrya* (Meisn.)Mez	Atlantic forest
	Persea americana Mill.	
Lecythidaceae	*Lecythis idatimon* Aubl.	Amazon
	Lecythis lurida (Miers.) Mori	
Loganiaceae	*Strychnos mitscherlichii* var. *amapensis* Krukoff & Barneby	Amazon
Loranthaceae	*Phthirusa stelis* (L.) Kuijt	
	Psittacanthus robustus (Mart.) Mart.	
	Struthanthus marginatus (Desr.) Blume	
	Struthanthus oerstedii (Oliv.) Standl.	
Lythraceae	*Cuphea antisyphilitica* Humb., Bonpl. & Kunth	
	Cuphea campestris Koehne	Caatinga
	Cuphea ericoides Cham. & Schltdl.	
	Cuphea laricoides Koehne	
	Lafoensia vandelliana Cham. & Schltdl.	Amazon
	Punica granatum L.	
Malpighiaceae	*Banisteriopsis gardneriana* (A. Juss.) W.R. Anderson & B. Gates	
	Banisteriopsis lutea (Griseb.) Cuatrec.	
	Banisteriopsis nummifera (A. Juss.) B. Gates	
	Barnebya harleyi W. R. Anderson & B. Gates	Caatinga
	Bunchosia armeniaca (Cav.) DC.	
	Byrsonima blanchetiana Miq.	
	Byrsonima chrysophylla Kunth	
	Byrsonima coriacea (Sw.) DC.	
	Byrsonima laevis Nied.	Amazon
	Byrsonima spicata (Cav.) DC.	
	Byrsonima vacciniifolia A. Juss.	Cerrado
	Camarea affinis A. St.-Hil.	Cerrado
	Diplopterys pubipetala (A. Juss.) W.R. Anderson & C.Cav. Davis	
	Heteropterys anoptera Adr. Juss.	
	Malpighia glabra L.	
	Tetrapterys styloptera A. Juss.	Amazon
Malvaceae	*Abelmoschus esculentus* (L.) Moench	
	Gossypium mustelinum Miers ex Watt	Caatinga
	Helicteres aspera A. St.-Hil. & Naudin	Cerrado
	Helicteres baruensis Jacq.	
	Helicteres heptandra L. B. Sm.	
	Helicteres macropetala A. St.-Hil.	
	Helicteres sacarolha A. St.-Hil., A. Juss. & Cambess.	
	Luehea alternifolia (Mill.) Mabb.	
	Sida acuta Burm.F.	
	Sida cordifolia L.	
	Sida glomerata Cav.	
	Sida rhombifolia L.	

Family	Specie	PD
Malvaceae	*Sida ulei* Ulbr.	
	Sida viarum A. St.-Hil	
Melastomataceae	*Clidemia capitata* Benth.	Amazon
	Miconia pepericarpa Mart. ex DC.	Cerrado
	Miconia theaezans (Bonpl.) Cogn.	
	Mouriri acutiflora Naudin	
	Pterolepis glomerata (Rottb.) Miq.	
	Rhynchanthera cordata DC.	
	Rhynchanthera grandiflora (Aubl.) DC.	
Meliaceae	*Trichilia elegans* A. Juss.	
Moraceae	*Brosimum guianense* (Aubl.) Huber	
	Brosimum lactescens (S. Moore) C.C. Berg	
	Ficus gomelleira Kunth & Bouche ex Kunth	
	Ficus guianensis Desv. ex Ham.	
	Maclura tinctoria (L.) Don. exSteud.	
Myristicaceae	*Virola surinamensis* (Rol. ex Rottb.) Warb.	
Myrtaceae	*Campomanesia lineatifolia* Ruiz Lopez & Pavon	
	Campomanesia pubescens (DC.) O.Berg	
	Campomanesia velutina (Cambess.) O. Berg.	
	Campomanesia xanthocarpa O. Berg	
	Eugenia biflora (L.) DC.	
	Eugenia flavescens A. DC.	
	Eugenia uniflora L.	
	Eugenia warmingiana Kiaersk.	
	Myrcia bella Cambess.	Cerrado
	Myrcia laruotteana Cambess.	
	Myrcia multiflora (Lam.) DC.	
	Myrcia mutabiliis (O. Berg) N. Silveira	
	Myrcia polyantha DC.	
	Myrcia rotundifolia (O. Berg) Kiaersk.	Atlantic forest
	Myrcia rufipes A. DC.	
	Myrcia selloi (Spreng.) N.Silveira	
	Myrciaria cuspidata O.Berg.	
	Psidium guajava L.	
	Psidium nutans O. Berg	
Nyctaginaceae	*Bougainvillea glabra* Choisy	
Ochnaceae	*Ouratea cearensis* (Tiegh.) Sastre	
Olacaceae	*Cathedra rubricaulis* Miers	Atlantic forest
Onagraceae	*Ludwigia hyssopifolia* (G. Don) Exell	
	Ludwigia octovalvis (Jacq.) P.H. Raven	
Opiliaceae	*Agonandra silvatica* Ducke	Amazon
Pedaliaceae	*Sesamum indicum* L.	
Picramniaceae	*Picramnia sellowii* Planch.	

Family	Specie	PD
Plumbaginaceae	*Plumbago scandens* L.	
Polygalaceae	*Bredemeyera laurifolia* (A. St.-Hil.) Klotzsch ex A.W. Benn.	
Polygonaceae	*Triplaris americana* L.	
	Triplaris weigeltiana (Rchb.) Kuntze	Amazon
Rhamnaceae	*Ziziphus cotinifolia* Reissek	Caatinga
	Ziziphus joazeiro Mart.	Caatinga
Rubiaceae	*Cordiera rigida* (K. Schum.) Kuntze	
	Coutarea hexandra (Jacq.) K. Schum	
	Faramea crassifolia Benth.	Amazon
	Faramea nitida Benth.	
	Psychotria colorata (Willd. ex Schult.) Müll.Arg.	
	Randia armata (Sw.) DC.	
	Tocoyena bullata (Vell.) Mart.	
	Tocoyena hispidula Standl.	Amazon
Rutaceae	*Zanthoxylum syncarpum* Tul.	Caatinga
Salicaceae	*Casearia commersoniana* Cambess.	
	Casearia gossypiosperma Briq.	
	Casearia mollis Kunth	
	Casearia ulmifolia Vahl ex Vent.	
	Xylosma ciliatifolia (Clos) Eichler	
Sapindaceae	*Allophylus quercifolius* Radlk.	
	Allophylus semidentatus (Miq.) Radlk.	
	Cupania oblongifolia Mart.	
	Sapindus saponaria L.	
Solanaceae	*Physalis heterophylla* Nees.	
	Solanum asperum Rich.	
	Solanum cordifolium Dunal	
	Solanum palinacanthum Dunal	
	Solanum stramonifolium var. *stramonifolium* Jacq.	
Urticaceae	*Cecropia glaziovi* Snethl.	
Velloziaceae	*Vellozia tubiflora* (A. Rich.) Kunth	
Verbenaceae	*Aloysia virgata* (Ruiz & Pav.) Juss.	
	Lantana camara L.	
	Lantana canescens Kunth	
	Lippia alba (Mill.) N.E.Br.	
Verbenaceae	*Lippia origanoides* Kunth	
	Stachytarpheta angustifolia (Mill.) Vahl.	
Vochysiaceae	*Vochysia divergens* Pohl	Cerrado

Southwestern NE

Family	Specie	PD
Achariaceae	*Lindackeria latifolia* Benth.	
Annonaceae	*Duguetia marcgraviana* Mart.	
Apocynaceae	*Aspidosperma australe* Müll.Arg.	
Araliaceae	*Schefflera vinosa* (Cham. & Schltdl.) Frodin & Fiaschi	
Arecaceae	*Acrocomia aculeata* (Jacq.) Lodd. ex Mart.	
	Attalea funifera Mart.	Atlantic forest
	Mauritiella armata (Mart.) Burret	
	Syagrus comosa (Mart.) Mart.	
	Syagrus flexuosa (Mart.) Becc.	
Asteraceae	*Clibadium rotundifolium* A. DC.	
	Eremanthus glomerulatus Less.	
	Eremanthus goyazensis (Gardner) Sch. Bip.	Cerrado
	Eremanthus graciellae MacLeish & H. Schumacher	
	Piptocarpha rotundifolia (Less.) Baker	Cerrado
	Pseudobrickellia brasiliensis (Spreng.) R.M.King & H.Rob.	
	Trichogonia campestris Gardner	
	Vernonanthura ferruginea (Less.) H. Rob.	Cerrado
Bignoniaceae	*Handroanthus albus* (Cham.) Mattos	Atlantic forest
Boraginaceae	*Cordia glabrata* (Mart.) A. DC.	
Burseraceae	*Protium ovatum* Engl.	Cerrado
Calophyllaceae	*Kielmeyera lathrophyton* Saddi	
	Kielmeyera speciosa A. St.-Hil.	Cerrado
Caricaceae	*Jacaratia spinosa* (Aubl.) A. DC.	
Caryocaraceae	*Caryocar villosum* (Aubl.) Pers.	Amazon
Celastraceae	*Cheiloclinium cognatum* (Miers) A. C. Sm.	
Combretaceae	*Buchenavia tomentosa* Eichler	
	Terminalia argentea Mart.	
Connaraceae	*Connarus regnellii* Schellenb.	Atlantic forest
Erythroxylaceae	*Erythroxylum betulaceum* Mart.	
	Erythroxylum campestre A. St.-Hil.	
	Erythroxylum deciduum St. Hil.	
	Erythroxylum tortuosum Mart.	Cerrado
Euphorbiaceae	*Cnidoscolus cnicodendron* Griseb.	
	Mabea nitida Spruce ex Benth.	
	Mabea pohliana (Benth.) Müll. Arg.	
Fabaceae	*Albizia niopoides* (Spruce ex Benth.) Burkart	
	Andira paniculata Benth.	
	Bauhinia brevipes Vogel	
	Bauhinia burchellii Benth.	Cerrado
	Bauhinia longifolia (Bong.) Steud.	
	Bauhinia rufa (Bong.) Steud.	Cerrado
	Bauhinia tenella Benth.	Cerrado

Family	Specie	PD
Fabaceae	*Bocoa ratteri* H.E. Ireland	Cerrado
	Cassia grandis L. F.	
	Chamaecrista claussenii (Benth.) H.S. Irwin & Barneby	Cerrado
	Chamaecrista juruenensis (Hoehne) H. Irwin & Barneby	
	Chamaecrista orbiculata (Benth.) H.S. Irwin & Barneby	Cerrado
	Chamaecrista rotundata (Vogel) H. Irwin & Barneby	Cerrado
	Chamaecrista zygophylloides (Taubert) H. Irwin & Barneby	
	Diptychandra aurantiaca Tul.	
	Hymenaea eriogyne Benth.	
	Inga scabriuscula Benth.	
	Inga vera Willd.	
	Leptolobium elegans Vogel	Cerrado
	Machaerium aculeatum Raddi	
	Machaerium scleroxylon Tul.	
	Mimosa exalbescens Barneby	Caatinga
	Mimosa lasiophylla Benth.	
	Pterodon pubescens (Benth.) Benth.	Cerrado
	Senegalia polyphylla (DC.) Britton & Rose	
	Senegalia tenuifolia (L.) Britton & Rose	
	Senna pendula (Humb. & Bonpl. ex Willd.) H.S. Irwin & Barneby	
	Senna silvestris (Vell. Conc.) H. S. Irwin & Barneby	
	Senna velutina (Vogel) H.S. Irwin & Barneby	
	Stryphnodendron adstringens (Mart.) Coville	
	Tachigali hypoleuca (Benth.) Zarucchi & Herend.	Amazon
	Vigna firmula (Benth.) Marechal, Mascherpa & Stainier	
Humiriaceae	*Sacoglottis guianensis* Benth.	Amazon
Lecythidaceae	*Eschweilera nana* (O. Berg) Miers	
Malpighiaceae	*Banisteriopsis latifolia* (A. Juss.) B. Gates	Cerrado
	Byrsonima basiloba A. Juss.	Cerrado
	Byrsonima intermedia A. Juss.	
	Byrsonima oblongifolia A. Juss.	Cerrado
	Heteropterys byrsonimifolia A. Juss.	
Malvaceae	*Ceiba pentandra* (L.) Gaertn.	Amazon
	Eriotheca gracilipes (K. Schum.) A. Robyns	
	Eriotheca pubescens (Mart. & Zucc.) Schott & Endl.	Cerrado
	Helicteres brevispira A. St.-Hil.	
	Hibiscus furcellatus Lam.	
	Luehea grandiflora Mart.	
	Sterculia apetala (Jacq.) H.Karst.	Amazon
Melastomataceae	*Macairea radula* (Bonpl.) DC.	
	Miconia ferruginata DC.	
	Miconia rubiginosa (Bonpl.) DC.	
	Miconia stenostachya DC.	

Family	Specie	PD
Melastomataceae	*Tibouchina candolleana* Cogn.	Cerrado
Meliaceae	*Cabralea canjerana* (Vell.) Mart.	
Myristicaceae	*Virola sessilis* (A. DC.) Warb.	
Myrtaceae	*Eugenia aurata* O. Berg.	
	Myrcia albotomentosa DC	Cerrado
	Myrcia decorticans DC.	
	Myrcia fenzliana O.Berg.	
	Myrcia ochroides O. Berg	
	Psidium laruotteanum Cambess.	
Nyctaginaceae	*Guapira graciliflora* (Schmidt) Lundell	
	Neea theifera Oerst.	Cerrado
Olacaceae	*Chaunochiton kappleri* (Sagot ex Engl.) Ducke	Amazon
	Heisteria citrifolia Engl.	Cerrado
Proteaceae	*Euplassa inaequalis* (Pohl) Engl.	
Rhamnaceae	*Rhamnidium elaeocarpum* Reissek	
Rubiaceae	*Chomelia parviflora* Müll. Arg.	
	Ferdinandusa elliptica (Pohl) Pohl	
	Ferdinandusa speciosa Pohl	
	Guettarda pohliana Müll. Arg.	
Sapindaceae	*Dilodendron bipinnatum* Radlk.	
	Toulicia crassifolia Radlk.	Cerrado
	Toulicia tomentosa Radlk.	Cerrado
Sapotaceae	*Pouteria torta* (Mart.) Radlk.	
Simaroubaceae	*Simaba blanchetii* Turcz.	
	Simaba warmingiana Engl.	Cerrado
Siparunaceae	*Siparuna guianensis* Aubl.	
Styracaceae	*Styrax ferrugineus* Nees & Mart.	Cerrado
Velloziaceae	*Vellozia squamata* Pohl	Cerrado
Vochysiaceae	*Callisthene minor* Mart.	
	Qualea cordata (Mart.) Spreng.	
	Vochysia elliptica Mart.	
	Vochysia pyramidalis Mart.	

Appendix C. The 170 widespread species of the NE cerrado. The species are sorted alphabetically by family. N AOE indicates the number of area of endemism (AOE) that the specie was present. Species in bold are peculiar species of Cerrado.

Family	Specie	N AOE
Anacardiaceae	*Myracrodruon urundeuva* Allemão	2
	Spondias mombin L.	2
Annonaceae	*Annona leptopetala* (R.E. Fr.) H. Rainer	2
	Annona tomentosa R.E. Fr.	2
	Duguetia furfuracea (A. St.-Hil.) Saff.	4
	Xylopia aromatica (Lam.) Mart.	3
	Xylopia sericea A.St.-Hil.	2
Apocynaceae	*Aspidosperma cuspa* (Kunth) S.T. Blake	2
	Aspidosperma discolor A. DC.	2
	Aspidosperma pyrifolium Mart.	2
	Aspidosperma subincanum Mart. ex A. DC.	2
	Aspidosperma tomentosum Mart.	2
	Himatanthus articulatus (Vahl) Woodson	4
	Himatanthus phagedaenicus (Mart.) Woodson	2
Arecaceae	*Attalea speciosa* Mart.	2
Asteraceae	*Vernonanthura brasiliana* (L.) H. Rob.	2
Bignoniaceae	***Anemopaegma velutinum* Mart. ex DC.**	2
	Fridericia dispar (Bureau ex K.Schum.) L.G.Lohmann	2
	Fridericia platyphylla (Cham.) L.G.Lohmann	2
	Godmania dardanoi (J.C.Gomes) A.H.Gentry	2
	Handroanthus impetiginosus (Mart. ex DC.) Mattos	2
	Handroanthus serratifolius (Vahl) S.O.Grose	3
	Jacaranda brasiliana (Lam.) Pers.	3
	Jacaranda jasminoides (Thunb.) Sandwith	2
	Zeyheria tuberculosa (Vell.) Bureau ex Verl.	2
Bixaceae	*Cochlospermum regium* (Schrank) Pilger	2
Boraginaceae	*Cordia superba* Cham.	3
	Cordia trichotoma (Vell.) Arráb. ex Steud.	2
	Varronia curassavica Jacq.	2
	Varronia polycephala Lam.	2
Cactaceae	***Cereus albicaulis* (Britton & Rose) Luetzelb.**	2
	Pilosocereus gounellei (F.A.C. Weber) Byles e Rowley	2
Calophyllaceae	*Kielmeyera coriacea* Mart. & Zucc.	2
Caryocaraceae	*Caryocar cuneatum* Wittm.	3
Celastraceae	*Maytenus obtusifolia* Mart.	2
	Plenckia populnea Reissek	2
	Salacia crassifolia (Mart. ex Schult.) G. Don	2

Family	Specie	N AOE
Celastraceae	*Salacia elliptica* (Mart. ex Schult.) G.Don.	2
Chrysobalanaceae	***Couepia grandiflora*** **(Mart. & Zucc.) Benth. Ex Hook.f.**	2
	Exellodendron cordatum **(Hook. f.) Prance**	2
	Hirtella glandulosa Spreng.	2
	Hirtella gracilipes (Hook. f.) Prance	2
Combretaceae	*Buchenavia tetraphylla* (Aubl.) R. Howard	3
	Combretum duarteanum Cambess.	2
Connaraceae	***Connarus suberosus*** **var.** ***fulvus*** **(Planchon) Forero**	2
	Rourea induta Planh.	2
Dilleniaceae	*Davilla macrocarpa* Eichler	2
Ebenaceae	*Diospyros inconstans* Jacq.	2
	Diospyros sericea A. DC.	3
Erythroxylaceae	*Erythroxylum barbatum* O.E.Schuz	2
	Erythroxylum subracemosum Turcz	3
Euphorbiaceae	*Croton campestris* A. St.-Hil.	2
	Mabea fistulifera Mart.	2
	Maprounea guianensis **Aubl.**	4
	Pera glabrata (Schott.) Poepp. ex Baill.	2
Fabaceae	*Abarema cochleata* (Willd.) Barneby & J.W. Grimes	2
	Abarema cochliacarpos (Gomes) Barneby & J. W. Grimes	2
	Anadenanthera colubrina (Vell.) Brenan	3
	Anadenanthera colubrina var. *cebil* (Griseb.) Altschul	2
	Andira cordata **Arroyo ex R.T. Penn. & H.C. Lima**	2
	Andira cujabensis Benth.	2
	Andira fraxinifolia Benth.	2
	Andira humilis Mart. ex Benth.	3
	Andira nitida Mart. ex Benth.	2
	Andira vermifuga Mart. ex Benth.	3
	Apuleia leiocarpa (Vogel) J. F. Macbr.	2
	Bauhinia forficata Link	2
	Bauhinia ungulata L.	2
	Bionia coriacea (Nees & Mart.) Benth.	2
	Cenostigma macrophyllum Tul.	3
	Chamaecrista eitenorum (H.S. Irwin & Barneby) H.S. Irwin & Barneby	2
	Chamaecrista flexuosa (L.) Greene	2
	Copaifera langsdorffii Desf.	4
	Dimorphandra mollis Benth	3
	Dipteryx alata Vogel	2
	Harpalyce brasiliana Benth.	2
	Hymenaea courbaril var. *stilbocarpa* (Hayne) Y.T. Lee & Langenh.	2
	Hymenaea maranhensis Lee & Langenh.	2
	Inga laurina (Sw.) Willd.	2
	Lonchocarpus araripensis Benth.	2

Family	Specie	N AOE
Fabaceae	*Machaerium acutifolium* Vogel	4
	Machaerium opacum Vogel	2
	Mimosa acutistipula (Mart.) Benth.	3
	***Mimosa sericantha* Benth.**	2
	Mimosa tenuiflora (Willd.) Poir.	2
	Piptadenia stipulacea (Benth.) Ducke	2
	Platypodium elegans Vogel	3
	Poeppigia procera Presl.	2
	Pterocarpus villosus (Mart. ex Benth.) Benth.	2
	Senna alata (L.) Roxb.	2
	Senna cearensis A.Fern.	2
	Senna macranthera (DC. ex Collad.) H.S. Irwin & Barneby	2
	Senna macranthera var. *pudibunda* (Benth.) H.S.Irwin & Barneby	2
	Senna rugosa (G. Don.) H. S. Irwin & Barneby	4
	Senna spectabilis var. *excelsa* (Schrader) H. S. Irwin & Barneby	2
	Senna trachypus (Mart. ex Benth.) H.S. Irwin & Barneby	3
	Stryphnodendron guianense (Aubl.) Benth.	2
	Stryphnodendron obovatum Benth.	4
	Stryphnodendron rotundifolium Mart.	2
	Swartzia psilonema Harms	2
Lamiaceae	*Vitex cymosa* Bertero ex Spreng.	3
	Vitex polygama Cham.	2
Loganiaceae	*Strychnos parvifolia* Spruce ex Benth.	2
Malpighiaceae	*Banisteriopsis stellaris* (Griseb.) B. Gates	2
	Byrsonima coccolobifolia Kunth	2
	***Byrsonima cydoniifolia* A. Juss.**	2
	Byrsonima gardnerana A. Juss.	2
	Byrsonima pachyphylla A. Juss.	3
	Byrsonima verbascifolia (L.) DC.	5
	Stigmaphyllon paralias Adr. Juss.	2
Malvaceae	*Apeiba tibourbou* Aubl.	2
	Helicteres muscosa Mart.	2
	Luehea divaricata Mart.	2
	Luehea paniculata Mart.	3
	Pseudobombax longiflorum (Mart. & Zucc.) A. Robyns	2
	Pseudobombax marginatum (A. St.-Hil., Juss. & Cambess.) A. Robyns	2
Melastomataceae	*Miconia albicans* (Swartz) Triana	5
	Miconia macrothyrsa Benth.	2
	Mouriri guianensis Aublet	2
Moraceae	*Brosimum gaudichaudii* Trécul	4
Myrtaceae	*Eugenia stictopetala* A. DC.	2
	Myrcia guianensis (Aubl.) DC.	2
	Psidium acutangulum Mart. ex DC.	2

Family	Specie	N AOE
Myrtaceae	*Psidium myrtoides* O. Berg	3
Ochnaceae	*Ouratea castanaefolia* (DC.) Engl.	2
	Ouratea parvifolia (A.St.-Hil.) Engl.	2
	***Ouratea spectabilis* (Mart. Ex Engl.) Engl.**	3
Olacaceae	*Heisteria ovata* Benth.	2
Polygalaceae	*Bredemeyera floribunda* Willd.	3
Polygonaceae	*Coccoloba mollis* Casar	3
Primulaceae	*Cybianthus detergens* Mart.	3
	Myrsine guianensis (Aubl.) Kuntze	2
Proteaceae	*Roupala montana* Aubl.	2
Rubiaceae	*Alibertia edulis* (Rich.) A. Rich. ex DC.	3
	Alibertia myrciifolia (K. Schum.) C.H. Perss. & Delprete	2
	Alibertia rotunda (Cham.) K.Schum.	2
	Chiococca alba (L.) Hitchc.	2
	Chomelia obtusa Cham. & Schldl.	2
	Cordiera concolor (Cham.) Kuntze	2
	Cordiera elliptica (Cham.) Kuntze	2
	Cordiera obtusa (K. Schum.) Kuntze	2
	***Cordiera sessilis* (Vell.) Kuntze**	2
	Coussarea hydrangaefolia (Benth.) Benth. & Hook. f. ex Müll. Arg.	2
	Diodella apiculata (Willd. ex Roem. & Schult.) Delprete	2
	Guettarda viburnoides Cham. & Schltdl	3
	Palicourea rigida Kunth	2
	Psychotria hoffmannseggiana (Willd. ex Schult.) Müll.Arg.	2
Rutaceae	*Spiranthera odoratissima* A. St.-Hil.	2
	Zanthoxylum stelligerum Turcz.	2
Salicaceae	*Casearia arborea* (Rich.) Urban	2
	Casearia grandiflora Cambess.	4
	Casearia javitensis Kunth	2
Sapindaceae	*Cupania impressinervia* Acev.-Rodr.	2
	Matayba guianensis Aubl.	3
	***Matayba heterophylla* (Mart.) Radlk.**	2
Sapotaceae	*Pouteria gardneriana* (A.DC.) Radlk.	2
Simaroubaceae	*Simaba ferruginea* A. St.-Hil.	2
	Simaba floribunda A. St.-Hil.	2
	Simarouba amara Aublet	2
Solanaceae	*Solanum crinitum* Lam.	2
	Solanum lycocarpum A. St.-Hil.	3
	Solanum rhytidoandrum Sendtn.	2
Styracaceae	*Styrax camporum* Pohl	2
Verbenaceae	*Lippia salviifolia* Cham.	2
Vochysiaceae	*Callisthene fasciculata* Mart.	3
	Callisthene microphylla Warm.	2

Family	Specie	N AOE
Vochysiaceae	*Qualea multiflora* Mart.	2
	***Vochysia gardneri* Warm.**	3
	Vochysia haenkeana Mart.	2
	Vochysia thyrsoidea Pohl	2

CAPÍTULO 3

Pattern of phylogenetic structure in plant community is driven by climate and soil on regional scale. A case study in the Brazilian northeastern cerrado. †

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Abstract

Recent research on community assembly has focus to explicit trait-based and phylogenetic-based determinants of diversity. For instance, if closely related species share similar physiological limitations, then abiotic filtering tends to cause phylogenetic clustering in the community. In contrast, if species compete for the same limiting resources, then competitive exclusion should lead the community to phylogenetic overdispersion. The Cerrado is the largest Brazilian Hotspot with an evolution *in situ* of plant species through adaptation against fire from lineages coming from adjacent forests. Its woody flora is distributed into six floristic provinces. The northeastern (NE) cerrado province is floristically different from the core cerrado and the others five provinces and has boundaries with seasonally dry tropical forests, rainforests and core cerrado. We asked whether phylogenetic clustering has emerged from several environmental stresses that the NE cerrado is faced, or the potential evolutionary influence of lineages coming from very different adjacent formations produced a phylogenetic overdispersion in the community. We calculated the Net Relatedness Index NRI and Nearest Taxon Index NTI of 48 grid-cells of 1° latitude-longitude across the NE cerrado using 936 species as species pool. Positive values indicate phylogenetic clustering whereas negative values indicate phylogenetic overdispersion. To assess which environmental factors are related to phylogenetic structure we build models with a generalized additive model (GAM) after selecting the informative explanatory variables with the hierarchical partitioning analysis (HP). The results indicate a slight overall trend to phylogenetic clustering for NRI and NTI, although only few grid-cells were significantly phylogenetic clustered, but none overdispersed. The NRI had a high concentration of positive values in central Piauí state and the NTI in two regions: in N Piauí-SW Ceará-W Pernambuco states and in W Bahia state. The GAM model for NRI indicated a positive relationship with maximum temperature of the warmest month and total organic carbon, and negative relationship with the aridity index and soil silt content. The GAM for NTI included negative relationship with isothermality and soil silt content, and positive with precipitation seasonality. As a general pattern for Brazilian NE cerrado woody flora, harsh climatic and soil conditions related to drought may be acting as abiotic filters, leading to phylogenetic clustering.

Keywords: Abiotic filtering, Brazilian savanna, core cerrado, digital soil map of the world (DSMW), drought, FLORACENE, generalized additive model (GAM), global-aridity and global-PET, hierarchical partitioning analysis (HP), spatial autocorrelation analysis (SAC), worldclim database.

Resumo

Pesquisas recentes sobre assembléias de comunidades têm focado em estudos explícitos de filogenia e de traços fenotípicos como determinantes da diversidade. Por exemplo, se espécies estreitamente relacionadas compartilham semelhantes limitações fisiológicas, então filtragem abiótica tende a causar agrupamento filogenético na comunidade. Em contraste, se as espécies competem pelos mesmos recursos limitantes, então exclusão competitiva deve levar a comunidade à dispersão filogenética. O Cerrado é a maior domínio fitogeográfico brasileiro com uma evolução *in situ* de espécies vegetais através da adaptação contra o fogo de linhagens provenientes de florestas adjacentes. A flora lenhosa é distribuída em seis províncias florísticas. A província do cerrado do nordeste é floristicamente diferente do cerrado central e das outras cinco províncias e têm fronteiras com florestas tropicais estacionais secas, florestas chuvosas e com o cerrado central. Foi perguntado se o agrupamento filogenético surge a partir dos vários estresses ambientais que o cerrado nordestino enfrenta, ou se a potencial influência evolutiva de linhagens provenientes de diferentes formações adjacentes produziria uma dispersão filogenética na comunidade. Foi calculado o índice de parentesco líquido (*net relatedness index* - NRI) e do índice do táxon mais próximo (*nearest taxon index* - NTI) em 48 células de 1 º de latitude-longitude ao longo de todo o cerrado nordestino utilizando 936 espécies como o *pool* de espécies. Os valores positivos indicam agrupamento filogenético, enquanto que valores negativos indicam dispersão filogenética. Para avaliar quais fatores ambientais estão relacionados com a estrutura filogenética construímos modelos aditivos generalizados (MAG) após a seleção das variáveis explicativas mais informativas usando a análise de particionamento hierárquico (PH). Os resultados indicam uma ligeira tendência geral de agrupamento filogenético para NRI e NTI, embora apenas algumas células foram filogeneticamente agrupadas de modo significativo, e nenhuma célula teve dispersão filogenética. O NRI teve uma alta concentração de valores positivos no centro do Estado do Piauí e o NTI em duas regiões: no norte do Piauí sudoeste Ceará oeste de Pernambuco, e no oeste da Bahia. O modelo MAG para NRI indicou uma relação positiva com a temperatura máxima do mês mais quente e carbono orgânico total, e relação negativa com o índice de aridez e silte no solo. O MAG para NTI incluiu relação negativa com isotermalidade e silte no solo, e positiva com a sazonalidade da precipitação. Como um padrão geral para a flora lenhosa do cerrado nordestino brasileiro, o clima severo e as condições do solo relacionadas com a seca podem estar agindo como filtros abióticos, levando ao agrupamento filogenético.

Palavras-chave: filtragem abiótica, savana brasileira, cerrado nuclear, mapa digital de solos do mundo (DSMW), seca, FLORACENE, modelo aditivo generalizado (MAG), aridez-global e evapotranspiração potencial global, análise de particionamento hierárquico (PH), a análise de autocorrelação espacial (ACE), banco de dados worldclim.

Introduction

Biodiversity indices have been used as a base for conservation strategies (Brooks et al. 2006, Loyola et al. 2007, Kier et al. 2009, Ramírez-Barahona et al. 2011), although biodiversity is a complex, multifaceted concept that includes scales in space and time and entities such as species, traits and evolutionary units (Pavoine and Bonsall 2011). Hence, recent research on community assembly has shifted the emphasis away from simple measurements of species diversity to explicit trait-based and phylogenetic-based determinants of diversity (Pavoine and Bonsall 2011).

Different methods to assess the trait-phylogeny issue have been proposed in the last few years (e.g.:Faith 1992, Webb 2000, Helmus et al. 2007a, Cadotte et al. 2010). The greatest advantage of these new methods is that they render ecological processes more easily interpretable. For instance, if closely related species share similar physiological limitations and exhibit evolutionary niche conservatism, then abiotic filtering tends to cause closely related species to co-occur, a process known as phylogenetic clustering (Cavender-Bares et al. 2006). In this process, traits are conserved within the lineage, and communities with clustered phylogenetic structures and phenotypic attraction are assembled (Webb et al. 2002). In contrast, if species compete for the same limiting resources, competitive exclusion should limit the coexistence of closely related species, leading to the opposite pattern of phylogenetic overdispersion (Cavender-Bares et al. 2006) or, according to Kraft et al. (2007), phylogenetic even dispersion. In this case, there can be either phenotypic attraction or repulsion, if the traits of the distantly related taxa have converged under the prevalence of abiotic filtering or have diverged in response to the prevalence of biotic filtering via competitive exclusion (Webb et al. 2002). Nevertheless, the challenge to understand how species can co-occur and how a community can be structured is still very debatable (Belyea and Lancaster 1999, Hubbell 2001, Leigh et al. 2004, Tilman 2004).

However, rather than searching for global patterns of evolutionary and ecological factors across all communities, researches should ask which traits, lineages and environmental variables are responsible for phylogenetic structure within a region (Pavoine and Bonsall 2011). Batalha et al. (2011b) for instance, found that many lineages of cerrado species, had trait clustering promoted by nutrient-poor soil, assembling taller trees with thinner barks and lighter woods, and compound, large, tender, nutrient-richer leaves.

The Cerrado is the largest Brazilian hotspot and the world third in high richness and endemism, but has a low percentage of protected areas (Myers et al. 2000). Most of Cerrado woody flora has evolved only ca. 4mya, synchronically with expanding dominance of flammable C4 grasses in the Pliocene (Simon et al. 2009), hence, is thought to have evolved *in situ* through adaptation against fire from lineages coming from adjacent forests (Simon et al. 2009, Batalha et al. 2011a, Cianciaruso et al. 2012). Nowadays, the Cerrado phytogeographic domain are distributed into six floristic provinces (Ratter et al. 2003, Bridgewater et al. 2004) and each province can be considered a distinct area of endemism based on its woody flora (This thesis, chapter 2). We used “cerrado” or “cerrados”, in lowercase, to refer to the complex of vegetation types (Castro et al. 1999, Batalha 2011) which varies from pure grassland (campo limpo), through savanna (campo sujo, campo cerrado, cerrado *sensu stricto* in order of growing woody biomass), to pure forest (Cerradão; Coutinho 1978, 1990).

As one of the cerrado floristic provinces, the northeastern (NE) cerrado has been poorly studied, although it has a woody flora that is very different from the core cerrado (Rizzini 1976, Heringer et al. 1977, This thesis, chapter 1) and other provinces (Ratter et al.

2003, Bridgewater et al. 2004). The NE cerrado has boundaries with seasonally dry tropical forests (Caatinga) at east, rainforests at west (Amazon) and southeast (Atlantic forest), the core cerrado at southwest. Also, within the NE cerrado there are enclaves of disjunct areas of Caatinga and Atlantic forest. Rainy season is shorter and rainfall is more concentrated and unpredictable, although the average annual rainfall is similar to that of the core cerrado (Castro et al. 1998), leading to frequent long dry periods (Assad et al. 2001). The temperature is the highest all over the Cerrado, attaining 23º C to 27º C of annual averages (Silva et al. 2008). The altitudes range from 1200 m on the central plateau to zero on the coast (Castro et al. 1999). Nutrient-poor, metal-toxic Latosols and Arenosols predominate the in whole cerrado (Reatto et al. 2008), but in the NE cerrado soil characteristics indicate overspread waterlogging in the rainy season, indicating a shallow soil (Sarmiento 1983, Reatto et al. 2008).

Therefore, the NE cerrado communities are faced with opposite periodic stresses represented by frequent waterlogging during the unpredictable rainy season and a strong dry season associated with relatively shallow soils, recurrent fire stresses, and permanent high-evaporative demand, nutritional and metal-toxicity stresses. Also, its present woody flora is likely to have suffered a potential evolutionary influence of lineages coming from very different adjacent formations (This thesis, chapter 2). All these characteristics render the NE cerrado province a worthwhile object of study.

Our aim was to address the following issues. Space clearly influences all the characteristics stated above, especially because most environmental variables are spatially autocorrelated (Legendre 1993), which means that pairs of observations at given distances are more or less similar than expected by chance. Also, phylogenetic structure is considered to be strongly influenced by resources and factors that vary across space; hence, we wonder whether the NE cerrado would have a spatial-dependent phylogenetic structure. If so, would those environmental variables act as a strong abiotic filter that a pattern of phylogenetic clustering would have emerged? However, the NE cerrado is a complex ecotone among seasonally tropical dry forests, rainforests, and the core cerrado. If the cerrado woody flora evolved *in situ* from lineages coming the adjacent forests (Simon et al. 2009), an pattern of phylogenetic overdispersion is expected as suggested in Kembel and Hubbell (2006). Then, we wonder whether the NE cerrado community phylogenetic patterns are clustered, overdispersed or random, since abiotic filtering, competitive exclusion, phylogenetic history of niches, traits, and habitat associations can lead to different phylogenetic structures (Kembel and Hubbell 2006).

Methods

Floristic data

We used a databank with 6,962 individuals sampled in 160 surveys across the NE cerrado, which had 936 woody species completely identified to binomials in 376 genera and 84 families. Out of these 160 surveys, 64 were field surveys from our team (Biodiversity Program of the Northeastern Ecotonal Tropic - BIOTEN) and 96 were gathered as metadata from literature. This databank, called FLORACENE (This thesis, chapter 1), is one of the results of a 10 year-long project under the Brazilian Long Term Ecological Research Program (LTER). After plotting species presence onto map grid-cells of 1º latitude-longitude (Fig. 1), we built a binary presence-absence matrix with 48 grid-cells and 936 species (This thesis, chapter 2).

Community phylogenetic structure

We used the compiled phylogenetic supertree R20100701 (available at http://svn.phylodiversity.net/tot/megatrees/R20100701.new), which is based on the phylogenetic relationship (APG III 2009), to generate our phylogenetic supertree using Phylomatic 2 software (Webb and Donoghue 2005) incorporated within Phylocom 4.1 software (Webb et al. 2008a). We used the BLADJ algorithm to calibrate each species in our supertree by applying known molecular and fossil dates (Wikstrom et al. 2001) to nodes on the supertree. Although dates are applied to "unknown" nodes on the supertree by evenly spacing the dates between "known" nodes (Swenson et al. 2006), the calibration of the supertree provides a substantial advantage over using nodal distances with all branch lengths set to one (Webb et al. 2002). BLADJ algorithm is also incorporated within Phylocom 4.1 software (Webb et al. 2008a).

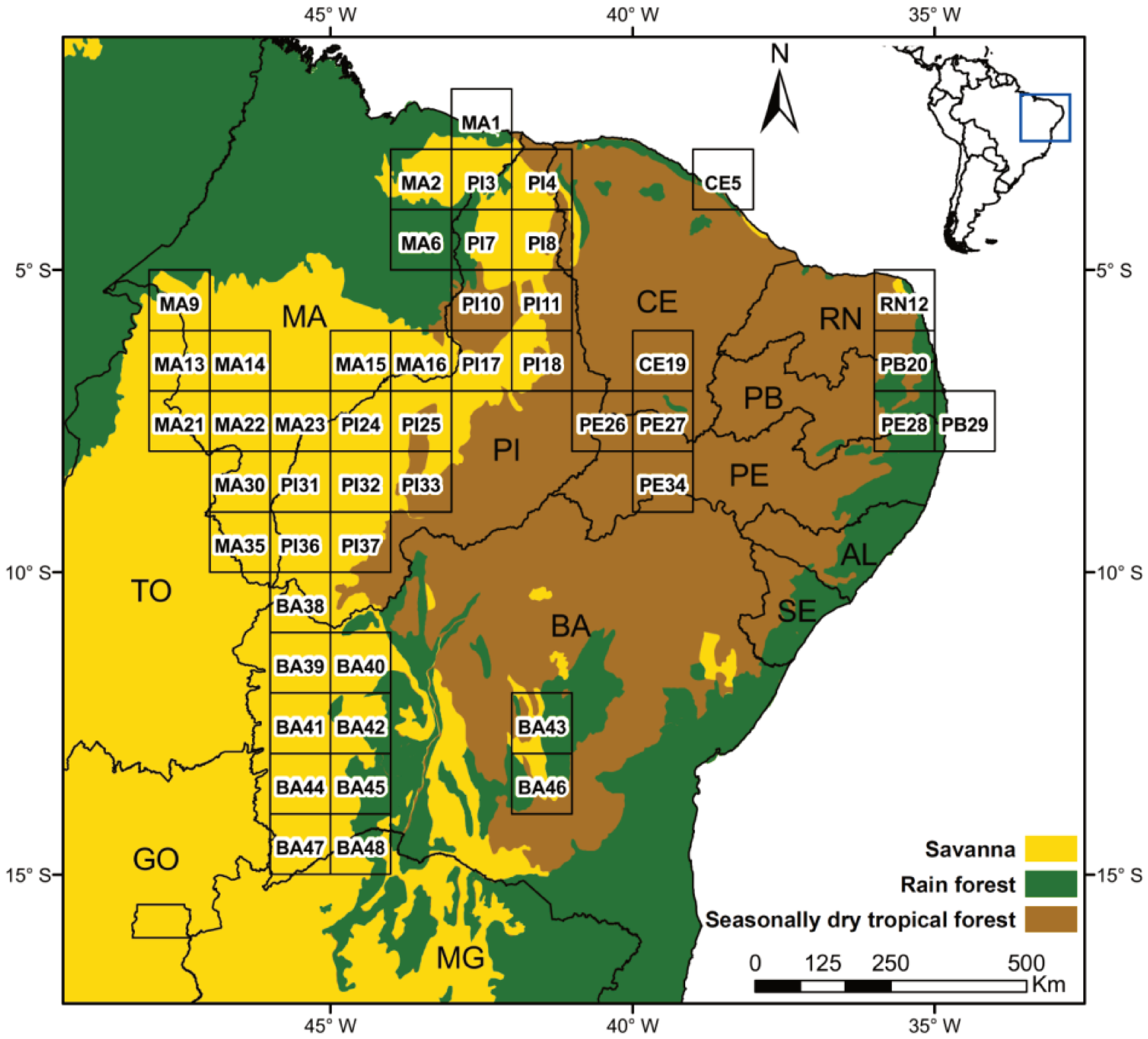

Fig. 1. Map of the NE Cerrado Province in Brazil showing the labels of grid-cells. States: MA-Maranhão, PI-Piauí, CE-Ceará, RN-Rio Grande do Norte, PB-Paraíba, PE-Pernambuco, AL-Alagoas, SE-Sergipe, BA-Bahia, MG-Minas Gerais, GO-Goiás, TO-Tocantins. Map based on Olson et al. (2001).

Once our supertree using all the 936 species as the species pool was built, we considered the species set in each grid-cell as a metacommunity to assess its phylogenetic structure and investigate its variation across space in order to search a pattern. We assessed the phylogenetic structure of each grid-cell through the Net Relatedness Index NRI and Nearest Taxon Index NTI (Webb 2000) and performed the analyses in the R statistical language and environment (R Development Core Team 2011) with the “picante” package (Kembel et al. 2010). The NRI and NTI (Webb 2000, Webb et al. 2002) are calculated as follow:

$$NRI = -1 \times \frac{MPD - MPD_{rnd}}{sdMPD_{rnd}}, \text{ and}$$

$$NTI = -1 \times \frac{MNTD - MNTD_{rnd}}{sdMNTD_{rnd}},$$

where MPD is the Mean Pairwaise Distance among all pairs of species in the assemblage; MPDrnd is the MPD obtained from 999 randomly generated assemblages, and sdMPDrnd is their standard deviation. The MNTD is the Mean Nearest Taxon Distance for each taxon in the assemblage; MNTDrnd is the MNTD obtained from 999 randomly generated assemblages, and sdMNTDrnd is their standard deviation. To generated these randomly assemblages, we used the phylogeny pool as null model, which randomize assemblage data matrix by drawing species from pool of species occurring in the distance matrix (phylogeny pool – 936 species) with equal probability (Kembel et al. 2010). Null models that randomly place species occurrences in a grid of equiprobable cells will generate a uniform distribution of species richness values (Gotelli and Ulrich 2012), hence these calculations are standardized effect sizes in which null values are expected for phylogenetically random communities (Kembel and Hubbell 2006).

For both NRI and NTI, positive values indicate greater phylogenetic clustering of a community than expected by the null model, negative values indicate that community is higher overdispersed than expected by the null model, and null values indicate a phylogenetically random assemblage of species (Kamilar and Guidi 2010). Thus, the indices measure the degree of the phylogenetic “clumpedness” of taxa over the whole pool phylogeny (Webb 2000), hence, an interpretation of pattern of the phylogenetic structure from overdispersed through random to clustered is useful (Horner-Devine and Bohannan 2006, Graham et al. 2009, Cardillo 2011, Stevens et al. 2012). The values of NRI and NTI were plotted on the map with the software Arc-GIS 10.0 (ESRI 2010). The statistical significance of each observed NRI or NTI value for each grid-cell were assessed simply by the quantile distribution since these metrics are given in units of standard deviation under the null model, thus, positive NRI or NTI values > 1.96 indicate phylogenetic clustering, while negative values <-1.96 indicate phylogenetic overdispersion at $\alpha = 0.05$ (Vamosi et al. 2009). Following Kembel and Hubbell (2006), we tested whether the average phylogenetic structure of the NE Cerrado woody flora differed from random phylogenetic structure (NRI or NTI equal to zero) by applying a one-sample *t* test considering the NRI or NTI values for each grid-cell. This test was performed in the R statistical language and environment (R Development Core Team 2011) in order to indicate an overall trend for the whole community (Kembel and Hubbell 2006).

Differences of the frequency distribution and significant values between NRI and NTI may be related to the way these indices are calculated (Swenson 2009). The NRI is calculated from pairwise distances based on the number of nodes, thus its power increases as the number of taxa increases (Swenson 2009). The NTI is calculated from the nearest neighbor distances, which are expected to be more sensitive to the degree of the phylogeny resolution, especially if the lack of resolution lies on the tips of the phylogeny (Swenson 2009). To be easily interpreted, NRI and NTI were termed respectively as “whole-tree clustering” and “tip-clustering” by Webb et al. (2008b). However, the metrics can be very sensitive only if the lack of resolution is basal and the phylogeny is large (Swenson 2009). As our phylogeny has only unresolved nodes at terminal levels (e.g. species and genera), the loss of statistical power was greatly minimized for both metrics (Swenson 2009).

Environmental variables

In order to assess whether the pattern of phylogenetic structure of the woody flora of the Brazilian NE cerrado is related to environmental factors we compiled variables from WorldClim 1.4 database (Hijmans et al. 2005), CGIAR-CSI geo-spatial database (Trabucco and Zomer 2009), Hydro1k database (USGS 2011), and Digital Soil Map of the World (FAO-UNESCO 2007). For each grid-cell we calculated the mean of each variable with Arc-GIS 10.0 (ESRI 2010). All environmental variables are listed in Table 01, and the values for each grid-cell are in Appendix A. From Worldclim we used all the 19 bioclimatic variables (BIOCLIM) and elevation data with 30 arc-seconds of resolution (about 1 km spatial resolution). From CGIAR-CSI geo-spatial database, we highlighted that the Aridity Index (AI) values increase for more humid conditions, and decrease with more arid conditions (Trabucco and Zomer 2009), thus, we interpreted this index as humidity index. From Digital Soil Map we used only topsoil variables extracted for each site from generalized soil unit information to calculate the mean for each grid-cell.

Table 1. List of environmental variables used in statistical analyses.

Abbreviation	**Environmental variable**	**Database**
Bio01	Annual mean temperature	Worldclim (Hijmans et al. 2005)
Bio02	Mean diurnal temperature range (mean of monthly (max temp - min temp)	
Bio03	Isothermality ((Bio02/Bio07)*100)	
Bio04	Temperature seasonality (standard deviation of monthly mean temperatures*100)	
Bio05	Maximum temperature of the warmest month	
Bio06	Minimum temperature of the coldest month	
Bio07	Temperature range (Bio05-Bio06)	
Bio08	Mean temperature of the wettest quarter	
Bio09	Mean temperature of the driest quarter	
Bio10	Mean temperature of the warmest quarter	
Bio11	Mean temperature of the coldest quarter	
Bio12	Annual precipitation	

Abbreviation	Environmental variable	Database
Bio13	Precipitation of the wettest month	Worldclim (Hijmans et al. 2005)
Bio14	Precipitation of the driest month	
Bio15	Precipitation seasonality (standard deviation of monthly precipitation*100)	
Bio16	Precipitation of the wettest quarter	
Bio17	Precipitation of the driest quarter	
Bio18	Precipitation of the warmest quarter	
Bio19	Precipitation of the coldest quarter	
Alt	Elevation data	
PET	Global potential evapo-transpiration ([PET=0.0023 • RA • (Tmean + 17.8) • TD0.5 (mm / day], where "RA" is mean monthly radiation on top of atmosphere, "Tmean" is mean monthly temperature and "TD" is mean monthly temperature range)	CGIAR-CSI (Trabucco and Zomer 2009)
AI	Global aridity index (AI = MAP / MAE, where "MAP" is mean annual precipitation and "MAE" is mean annual potential evapo-transpiration.	
CTI	Compound topographic index (function of the upstream contributing area and the slope of the landscape)	Hydro1k (USGS 2011)
Sand	Percentages of soil sand	Digital Soil Map of the World (FAO-UNESCO 2007)
Silt	Percentages of soil silt	
Clay	Percentages of soil clay	
pH-H20	Soil water-soluble pH	
OC	Percentage of soil organic carbon	
N	Percentage of soil nitrogen	
BS	Percentage of soil base saturation	
CEC	Soil cation exchange capacity	
BD	Soil bulk density	
CN	Soil carbon/nitrogen ratio	

Spatial autocorrelation

Spatial autocorrelation is the property of random variables taking values, at pairs of locations a certain distance apart, that are more similar (positive autocorrelation) or less similar (negative autocorrelation) than expected for randomly associated pairs of observations (Legendre 1993). When testing statistical hypotheses using standard methods (e.g. anova, correlation and regression), the standard errors are usually underestimated when positive autocorrelation is present, and, consequently, Type I errors may be strongly inflated (Legendre 1993, Diniz-Filho et al. 2003). Thus, spatially autocorrelated data can create false positive results in the analyses and thus should always be investigated in ecological studies (Diniz-Filho et al. 2003, Diniz-Filho et al. 2012). Also, the spatial autocorrelations analysis (SAC) should not be performed with fewer than 30 samples due to the small number of pairs of localities (Legendre and Fortin 1989). Thus, regarding this premises, the reduction of 160 floristic surveys to 48 grid-cells did not constrain our analysis.

We assessed the spatial autocorrelation of the pattern of phylogenetic structure, both NRI and NTI, with Moran´s I coefficient (Moran 1950), which is used in univariate autocorrelation analysis based on Pearson correlation coefficient (Legendre and Legendre 1998). Moran´s I coefficient, which tests the null hypothesis of spatial independency, varies between -1 and +1, indicating negative or positive autocorrelation in the data (Legendre and Legendre 1998). Moran's I coefficient is given by:

$$I = \left(\frac{n}{S}\right)\left[\frac{\sum_i \sum_j w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{\sum_i (y_i - \bar{y})^2}\right]$$

where n is the number of samples (grid-cells), y_i and y_j are values of the variable at pairs of grid-cells $_i$ and $_j$, $\bar{y}$ is the average of y, and w_{ij} is an element of matrix W. In this matrix, w_{ij}=1 if the pair $_i$ and $_j$ of grid-cells is within a given distance class interval (indicating grid-cells that are connected in this class). S indicates the number of entries (connections) in the W matrix (Diniz-Filho et al. 2003). The analyses were performed in the R statistical language and environment (R Development Core Team 2011) with the package "ncf" (Bjørnstad 2009) setting the correlogram with 200 kilometers distance classes and a two-sided permutation test with 1000 resampling and α = 0.05. The correlogram is considered to be globally significant if at least one correlation coefficient is lower than α divided by the number of distance classes (Bonferroni corrected level; Legendre and Fortin 1989). Although we set the distance class to 200 km, the method tries to maximize the similarity in S values (number of connections) for the different coefficients; so, the arbitrariness in the number of distance classes is not important in most cases, because the purpose of the analysis is to describe a continuous spatial process (Diniz-Filho et al. 2003). We also assess the spatial autocorrelation of environmental variables in order to confirm the statement of Legendre (1993) that these variable are structured on the space.

Generalized additive models (GAM)

In an attempt to build a model that could explain the pattern of phylogenetic structure for NE cerrado woody flora, we performed a generalized additive model (GAM; Hastie and Tibshirani 1986). Generalized additive models are a nonparametric extension of generalized linear models (GLMs). As our environmental data are heterogeneous, some variables may not present normal distribution, which is not a problem in GAMs because they can model a mix of parametric and nonparametric variables together (Yee and Mitchell 1991). The essential difference among GLM and GAM is simply that linear functions of the variables on GLM are replaced by unspecified smooth functions, which gives flexibility for the modelling process with GAMs, although, if the smoother fits a linear function, then GAM is equivalent to GLM (Yee and Mitchell 1991). GAMs allow the data to determine the shape of the response curves rather than being limited by the shapes available in a parametric class (Yee and Mitchell 1991). Additionally, the regression surface in GAM is expressed as a sum of functions of each variable, so that each explanatory variable has an additive effect and can be interpret separately, but the assumption to do this is the lack of interaction among the explanatory variables (Yee and Mitchell 1991). For each environmental variable in the model 95% Bayesian confidence intervals can be plotted (Wood 2006). GAM returns *p-value* for each term based on F-ratio test according to the estimated degrees of freedom under a null hypothesis that the estimator parameter is equal to zero (Wood 2006).

Generalized additive model is given by:

$$g(E(Y)) = \alpha + \sum_{j=1}^{p} f_j(x_j),$$

where, Y is the response variable, g is a pre-specified function called the link function, α is the intercept or constant term and f_j are the unspecified smooth functions of the independent explanatory variables x. The right hand side of the formula is a plane in a p-dimensional space. The purpose of the link function is to transform (to link) the mean of the response variable to lie on a plane in this p-dimensional space (Yee and Mitchell 1991). The independent response variable has a distribution belonging to an exponential family, which in our case was set to Gaussian distribution, then “identity” was the link function. Although a p-dimensional smoother can be set by the user to model the regression surface, the p-dimension or basis dimension of smoothers must be large enough for the model structure to include a reasonable approximation to the truth and simultaneously small enough to avoid power loss (Wood 2006). Thus, we set to five the basis dimensions for smooth functions.

Although GAMs are a powerful data-driven class of models for explanatory data analysis and inference (Hastie and Tibshirani 1990), we first ran an hierarchical partitioning (HP) using the “hier.part” package version 1.0-3 (Walsh and MacNally 2012) implemented in the R statistical language and environment (R Development Core Team 2011) in order to select the more informative environmental variables. The HP employs a goodness of fit measure as root-mean-square prediction error for the entire hierarchy of models using all combinations of N independent variables (Walsh and MacNally 2012) following an algorithm proposed by Chevan and Sutherland (1991). These measures are partitioned so that the total independent contribution (I) of a given predictor variable is estimated (Mac Nally 2002) as its conjoint contribution (J) with all other variables (Walsh and MacNally 2012). The greatest advantage is the alleviating of multicollinearity problems that are effectively ignored by using any single-model-seeking technique (Mac Nally 2002). However, analyses with more than 9 independent variables shows a considerable inconsistency (Olea et al. 2010). Thus, for each response variable (NRI and NTI), we proceed to the hierarchical partitioning analyses of sets of environmental variables (Table 1): (1) temperature part 1(Bio01, Bio02, Bio03, Bio04, Bio07); (2) temperature part 2 (Bio05, Bio06, Bio08, Bio09, Bio10, Bio11); (3) precipitation (Bio12 to Bio19); (4) climate indices and altitude (AI, PET and Alt); (5) soil texture (sand, silt, clay and CTI); and (6) soil properties (pH-H2O, OC, N, BS, CEC, BD, CN). Since the normality is not required for explanatory variables in regression analysis (Borcard et al. 2011), we did not procedure any data transformation. We conducted the HP analyses using root-mean-square prediction error as the goodness of fit measure.

We performed GAM analyses starting with the two most independent informative variables for each environmental group from HP analyses. However, if these two variables remained still strongly correlated (Pearson or Spearman coefficient $r > 0.80$), then we used the first and third or fourth most informative variables for each environmental group, except for soil texture (sand, silt, and clay), which are all inescapably highly correlated. Once selected the variables, we ran a few GAM analyses excluding sequentially the variables with the highest *p-value* in order to obtain the best model. We adopted the selection using *p-value* because different variables may have different degrees of freedom. This is a backward stepwise elimination procedure, which we performed through Akaike information criterion

(AIC; Akaike 1974). These analyses were performed using the R statistical language and environment (R Development Core Team 2011) and HP analyses with “mgcv package” version 1.7-13 (Wood 2012). However, models ignoring the spatial dependence of ecological data may be inappropriate because they might overestimate the importance of covariates and include variables that have little or no relevance to the response variable, thus creating false ecological conclusions (de Frutos et al. 2007). Therefore, we assessed the autocorrelation of GAM residuals using Moran´s I statistics as described above, in order to check whether the models violates the independent error assumption, which could lead to inflation of type I errors (Legendre 1993).

Results

The phylogenetic tree of the Brazilian NE cerrado woody flora shows a high species concentration on few clades such as fabids, malvids and asterids (Fig. 2). Specifically, the 936 species are distributed in major 11 clades: Magnoliids was represented by 28 species, Monocots by 23, Proteales 2, Dilleniales 4, Santalales 14, Caryophyllales 27, Ericales 29, Lamiids 165, Campanulids 43, Malvids 209, Fabids 392. The data are in Appendix B.

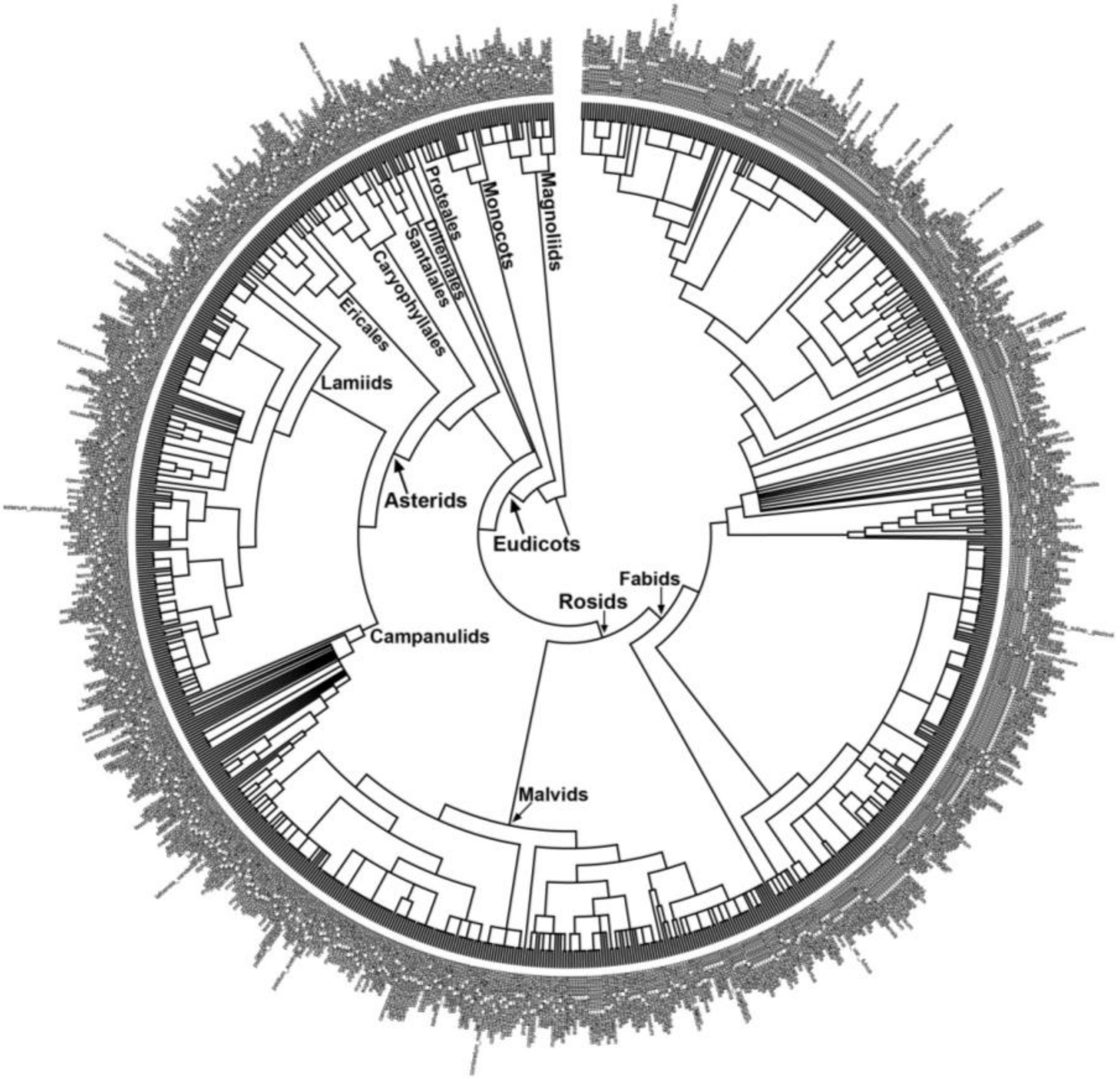

Fig. 2. Phylogenetic tree of the Brazilian NE cerrado woody flora. Branch lengths were calibrated according to BLADJ algorithm (Webb et al. 2008a) based on dates of Wikstrom et al. (2001). The data are available in Appendix B for better visualization.

Both NRI and NTI metrics displayed a normal distribution (Fig. 3).The NRI had positive values in 70% of the grid-cells, but only five of them differed statistically from the random null model (PI-17, PI-18, MA-23, PE-26, PI-37; Fig. 4; Appendix A). The variation of NTI was very similar to NRI, being positive in 65% of the grid-cells, but also only five of them differed statistically from the random null models (PI-08, MA-16, PE-26, PE-27, BA-44; Fig. 5). There was no significant negative value (Appendix A). The NRI values of the 48 grid cells ranged from -1.47 to 2.31, with a mean of 0.50 (sd = 0.98), which statistically differed from zero (t = 3.5175, p = 0.001). The NTI ranged from -1.78 to 2.71 with a mean of 0.48 (sd = 1.08), and also differed from zero (t = 3.0952, p = 0;003). This results indicates an slight overall trend to phylogenetic clustering of in Brazilian NE cerrado woody flora for both metrics, although few grid-cells were significantly phylogenetic clustered.

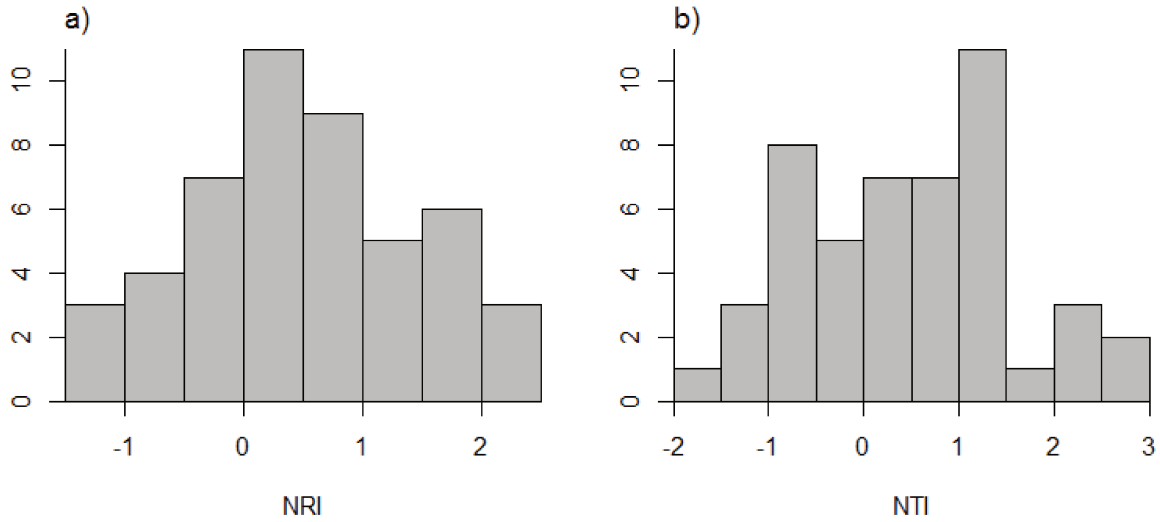

Fig. 3. Frequency distribution of the (a) Net Relatedness Index (NRI) and (b) Nearest Taxon Index (NTI of the Brazilian NE cerrado woody species in the 48 grid-cells.

Although both NRI and NTI had almost the same proportion of positive values and the same number of significant grid-cells, their geographic patterns were different. Whereas the NRI had a high concentration of positive values in central Piauí state (Fig. 4), the NTI had a high concentration of positive values in two regions: in N Piauí-SW Ceará-W Pernambuco states and in W Bahia state (Fig. 5).

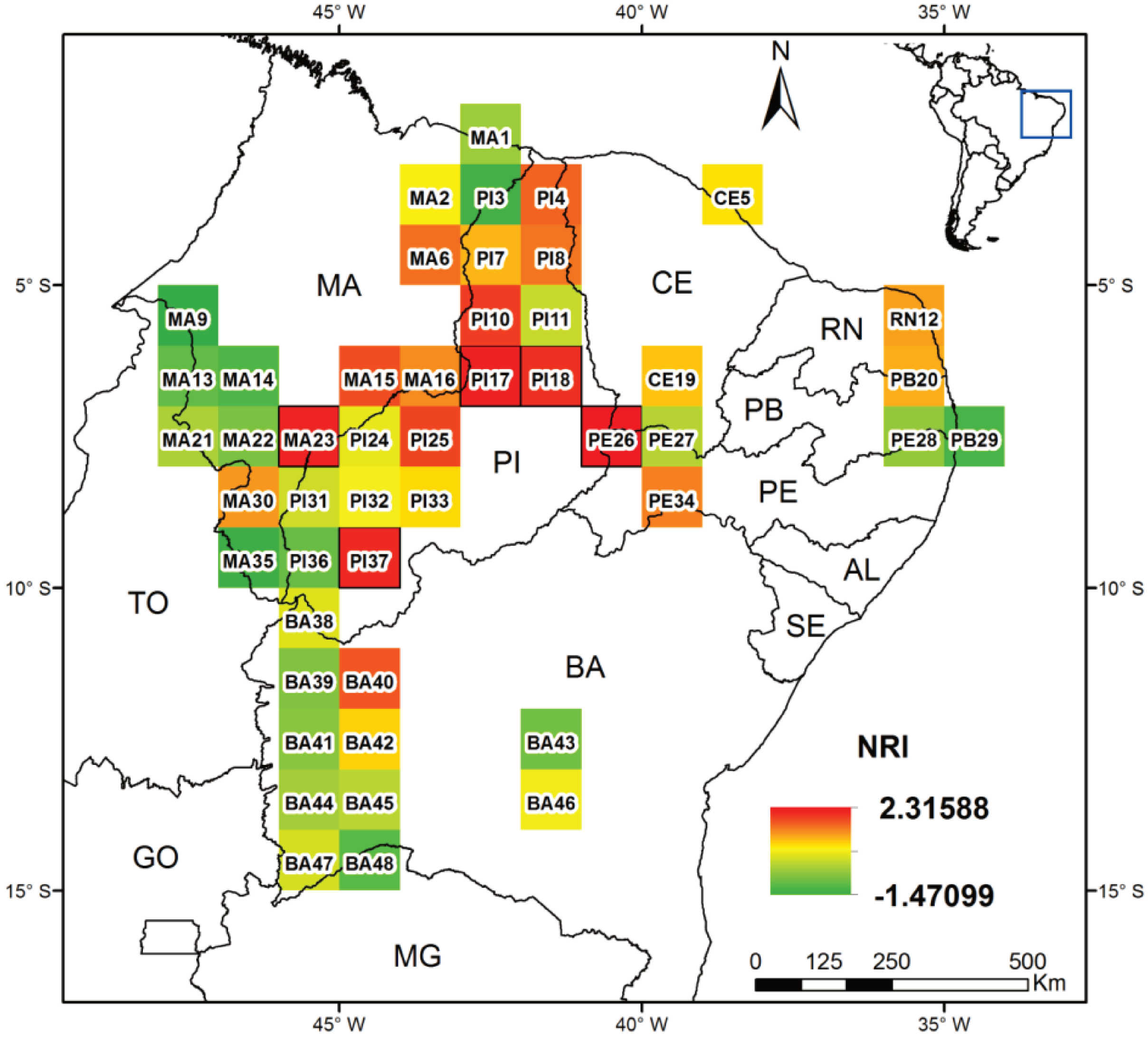

Fig. 4. Net Relatedness Index (NRI) of the 1° latitude-longitude 48 grid-cells in the Brazilian NE cerrado woody flora. Grid cells with borderlines had NRI significantly different from random null model. Absolute values are in Appendix A

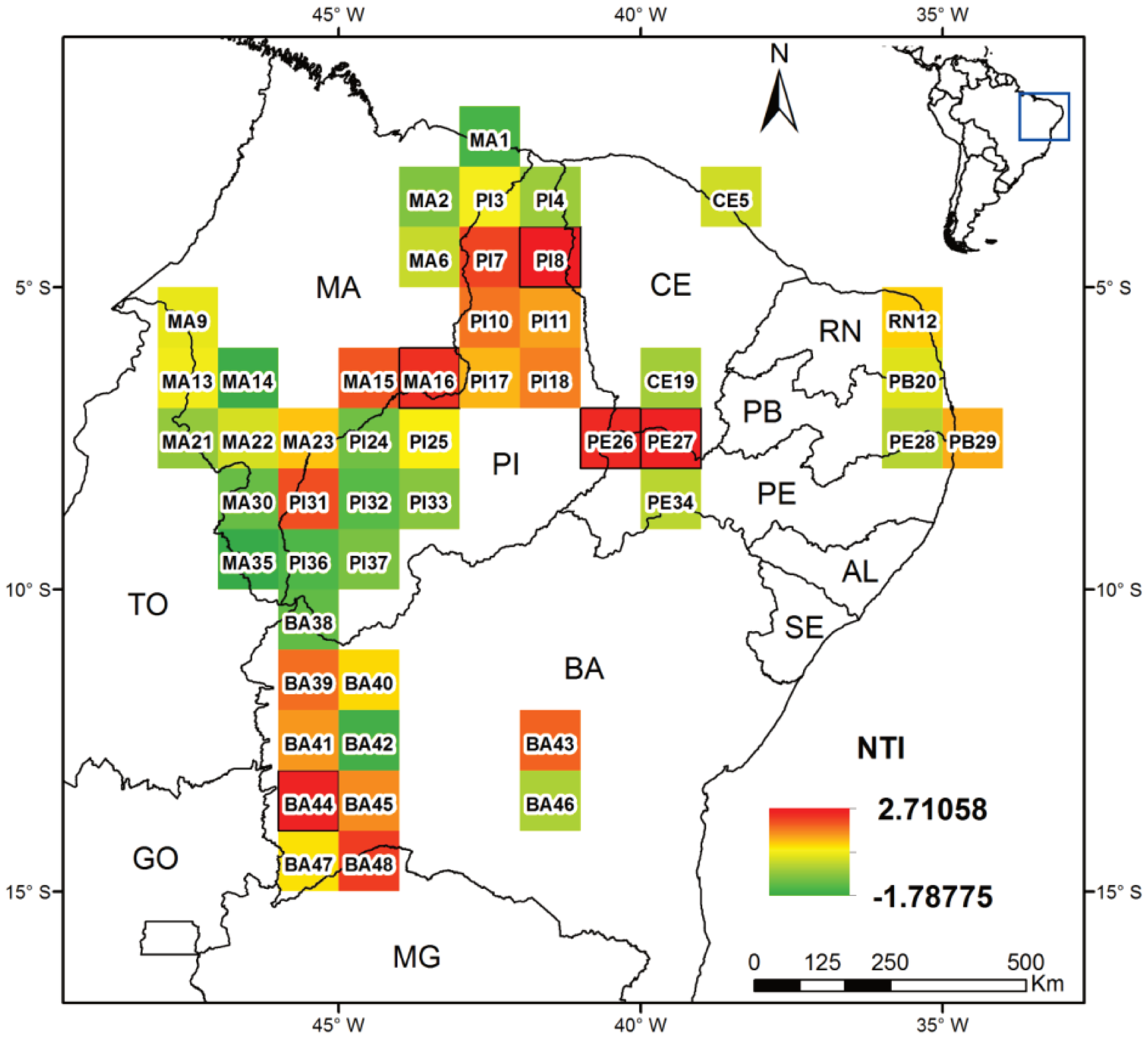

Fig. 5. Nearest Taxon Index (NTI) of the 48 1° latitude-longitude grid-cells in the Brazilian NE cerrado woody flora. Grid-cells with borderlines had NTI significantly different from random null model. Absolute values are in Appendix A.

The NRI had a significant positive spatial autocorrelation at distances as far as 300 km (Fig. 6), which encompassed three grid-cells, and a negative spatial autocorrelation at 700 km. The NTI showed a significant positive spatial autocorrelation at the first distance class and negative spatial autocorrelation at 500 and 700 km. Differently from NRI, the NTI showed again a positive autocorrelation at 900 km (Fig. 6), which is congruent with the concentration of positive values in the two regions described above. Both metrics we considered globally significant at Bonferroni corrected level (p< 0.00625). All environmental variables were also autocorrelated (data not shown), however, clearer pattern were found in climatic variables: positive at first three classes and negative at five and six classes.

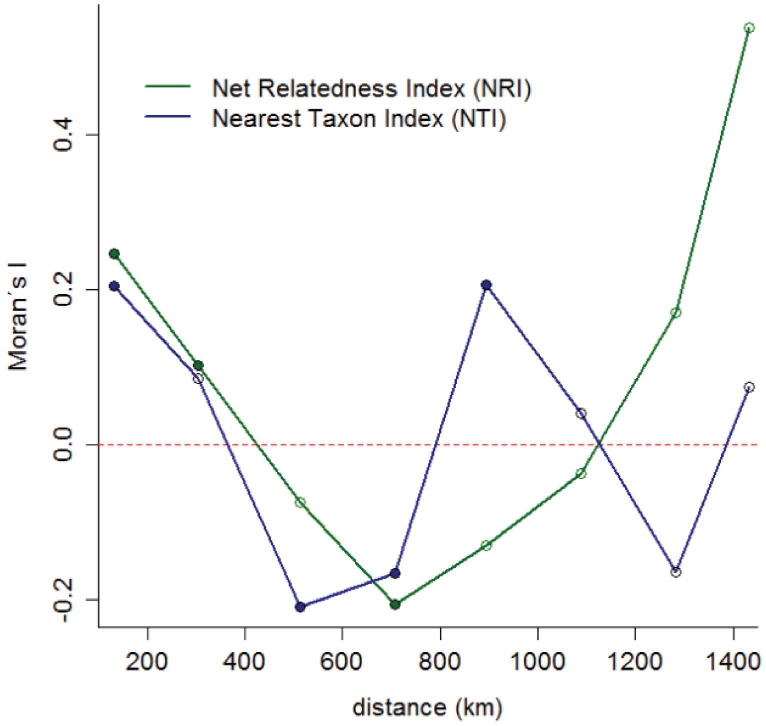

Fig. 6. Net Relatedness Index (green) and Nearest Taxon Index (blue) spatial autocorrelation showed by the correlogram based on Moran´s I coefficient. Significant autocorrelation distance classes at α = 5% are represented by solid circles.

The hierarchical partitioning showed different independent effects between NRI and NTI measures (Fig. 7 and 8). For the NRI the most relevant environmental variables used initially in GAM were the annual mean temperature (Bio01) and temperature seasonality (Bio04), mean temperature of the warmest quarter (Bio10) and maximum temperature of the warmest month (Bio05), annual precipitation (Bio12) and precipitation seasonality (Bio15), altitude (Alt) and aridity index (AI), soil silt and sand, and soil water-soluble pH (pH-H20) and organic carbon (OC) (Fig. 7). Bio11, Bio09 and BS were not used because they were highly correlated with the respective main variables. For the NTI the environmental variables used initially in GAM were isothermality (Bio03) and temperature seasonality (Bio04), maximum temperature of the warmest month (Bio05) and mean temperature of the warmest quarter (Bio10), precipitation of the wettest month (Bio13) and precipitation seasonality (Bio15), altitude (Alt) and potential evapo-transpiration (PET), soil sand and silt, and organic carbon (OC) and cation exchange capacity (CEC) (Fig. 8). We did not use Bio 08, Bio09, Bio11, Bio16, N and BD due to their high correlation with the respective main variables.

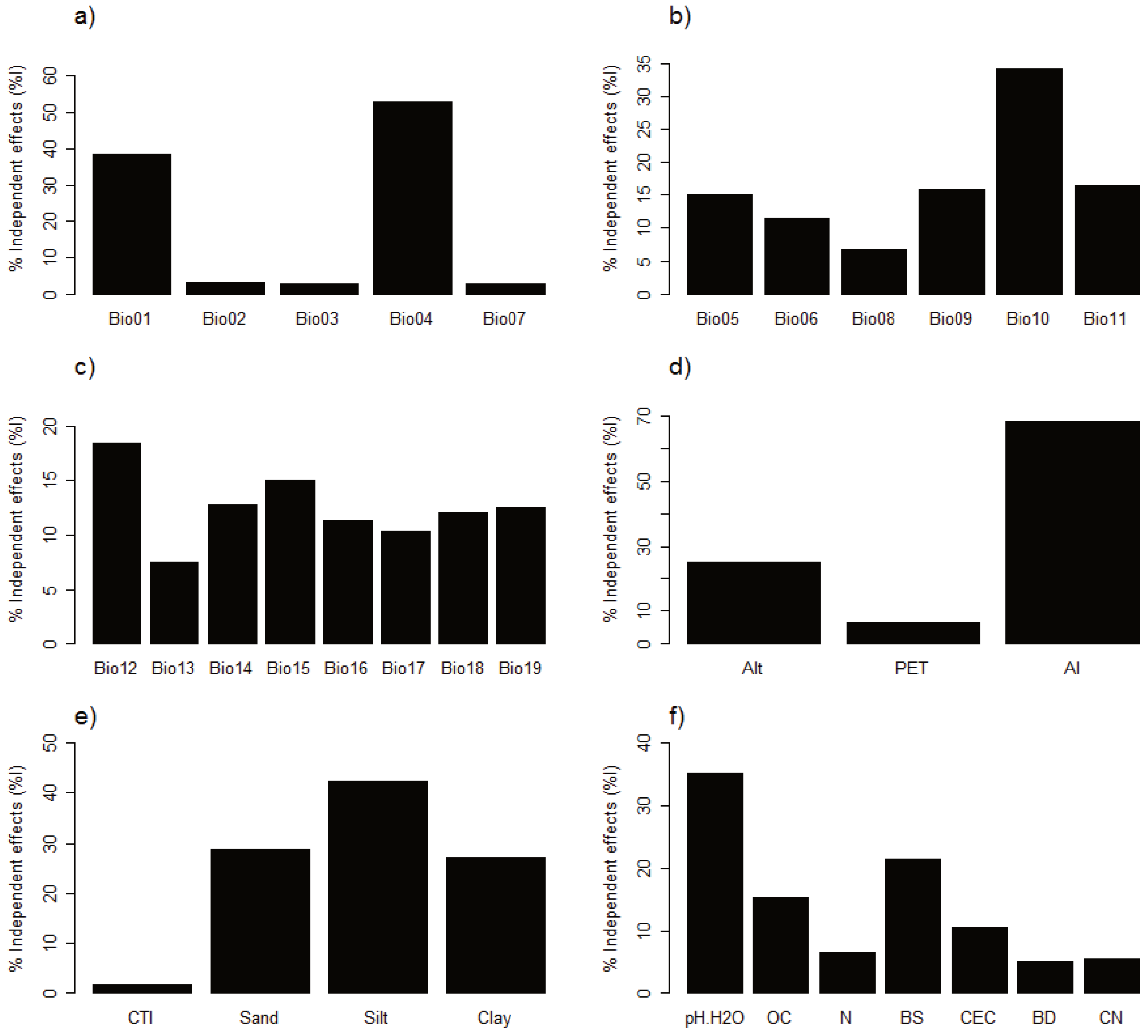

Fig. 7. Results of the hierarchical partitioning analyses showing independent effects for six groups of environmental variables for the Net Relatedness Index (NRI): a) temperature part 1, b) temperature part 2, c) precipitation, d) indexes and altitude, e) soil texture, and f) soil properties. Abbreviations are in Table 1.

The best general additive model for NRI included five terms and attained an AIC = 109.504 (Table 2a). The NRI had a positive relationship with the maximum temperature of the warmest month (Bio05), soil water-soluble pH and organic carbon (OC), and negative relationship with the aridity index (AI) and soil silt content (Fig. 09). The model explained 57.5% of the deviance in NRI, but soil pH.H2O was not statistically significant at α = 0.05 (Table 3a). Therefore, the NRI increased as the maximum temperature of the warmest month increased and humidity conditions decreased. Although silt content was the soil variable

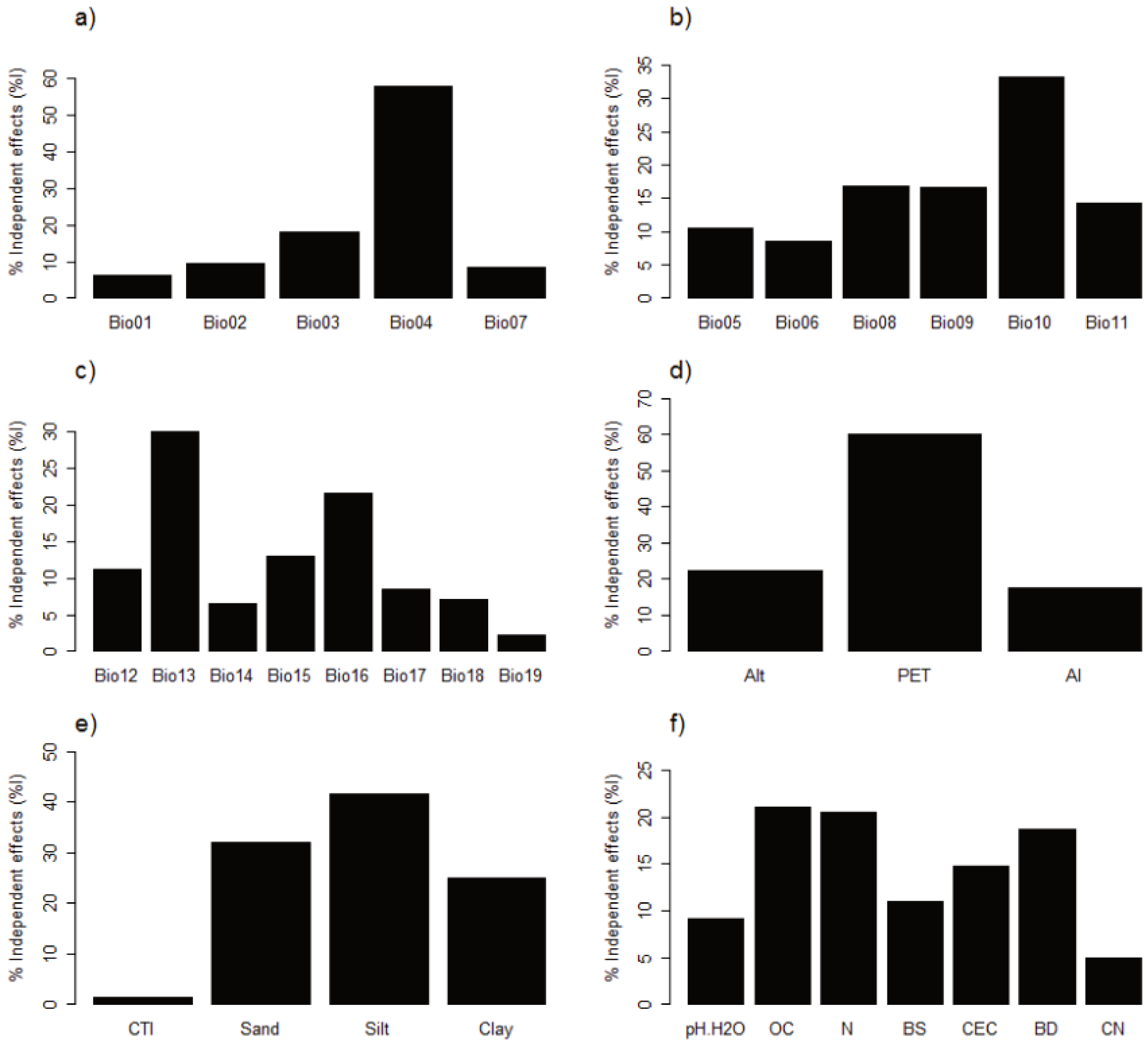

Fig. 8. Results of the hierarchical partitioning analyses showing independent effects for six groups of environmental variables for the Nearest Taxon Index (NTI): a) temperature part 1, b) temperature part 2, c) precipitation, d) indexes and altitude, e) soil texture, and f) soil properties. Abbreviations are in Table 1.

selected by the model, it was more correlated to sand content (rs = -0.90) than to clay content (rs = 0.85), according to Spearman test. Sand was by far predominant in NE cerrado soils with mean of 69.67% (sd = 20). Thus, indirectly the NRI increased as sand content increased. Also

Table 2. Backward stepwise elimination of uninformative environmental predictors and model evaluated by Akaike information criterion (AIC) for a) NRI and b) NTI. The bold line indicates the best model.

a) **Net Relatedness Index (NRI)**

	AIC
NRI~Bio01+Bio04+Bio05+Bio10+Bio12+Bio15+Alt+AI+Sand+Silt+pH.H2O+OC	118.4422
NRI~Bio01+Bio04+Bio05+Bio10+Bio15+Alt+AI+Sand+Silt+pH.H2O+OC	115.5494
NRI~Bio01+Bio04+Bio05+Bio10+Bio15+AI+Sand+Silt+pH.H2O+OC	115.4601
NRI~Bio04+Bio05+Bio10+Bio15+AI+Sand+Silt+pH.H2O+OC	113.5717
NRI~Bio04+Bio05+Bio10+AI+Sand+Silt+pH.H2O+OC	111.6539
NRI~Bio04+Bio05+AI+Sand+Silt+pH.H2O+OC	110.8657
NRI~Bio04+Bio05+AI+Silt+pH.H2O+OC	110.2922
NRI~Bio05+AI+Silt+pH.H2O+OC	**109.504**
NRI~Bio05+AI+Silt+OC	110.870
NRI~AI+Silt+OC	121.7307
NRI~AI+Silt	128.9344
NRI~AI	131.4809

b) **Nearest Taxon Index (NTI)**

	AIC
NTI~Bio03+Bio04+Bio05+Bio10+Bio13+Bio15+Alt+PET+Sand+Silt+OC+CEC	138.8924
NTI~Bio03+Bio04+Bio05+Bio10+Bio15+Alt+PET+Sand+Silt+OC+CEC	137.0063
NTI~Bio03+Bio04+Bio05+Bio10+Bio15+Alt+PET+Silt+OC+CEC	135.1437
NTI~Bio03+Bio04+Bio05+Bio10+Bio15+Alt+PET+Silt+CEC	133.1806
NTI~Bio03+Bio04+Bio05+Bio10+Bio15+Alt+PET+Silt	131.8464
NTI~Bio03+Bio04+Bio05+Bio10+Bio15+PET+Silt	131.1051
NTI~Bio03+Bio05+Bio10+Bio15+PET+Silt	131.2416
NTI~Bio03+Bio10+Bio15+PET+Silt	131.1531
NTI~Bio03+Bio15+PET+Silt	**129.2716**
NTI~Bio03+Bio15+Silt	131.4291
NTI~Bio15+Silt	136.4844
NTI~Silt	136.6018

in GAM results, the NRI increased as the soil total organic carbon increased, however, OC was not correlated to soil carbon/nitrogen ratio (rs = 0.21, p = 0.14), which is a good indicator of soil quality (Batjes 1996).

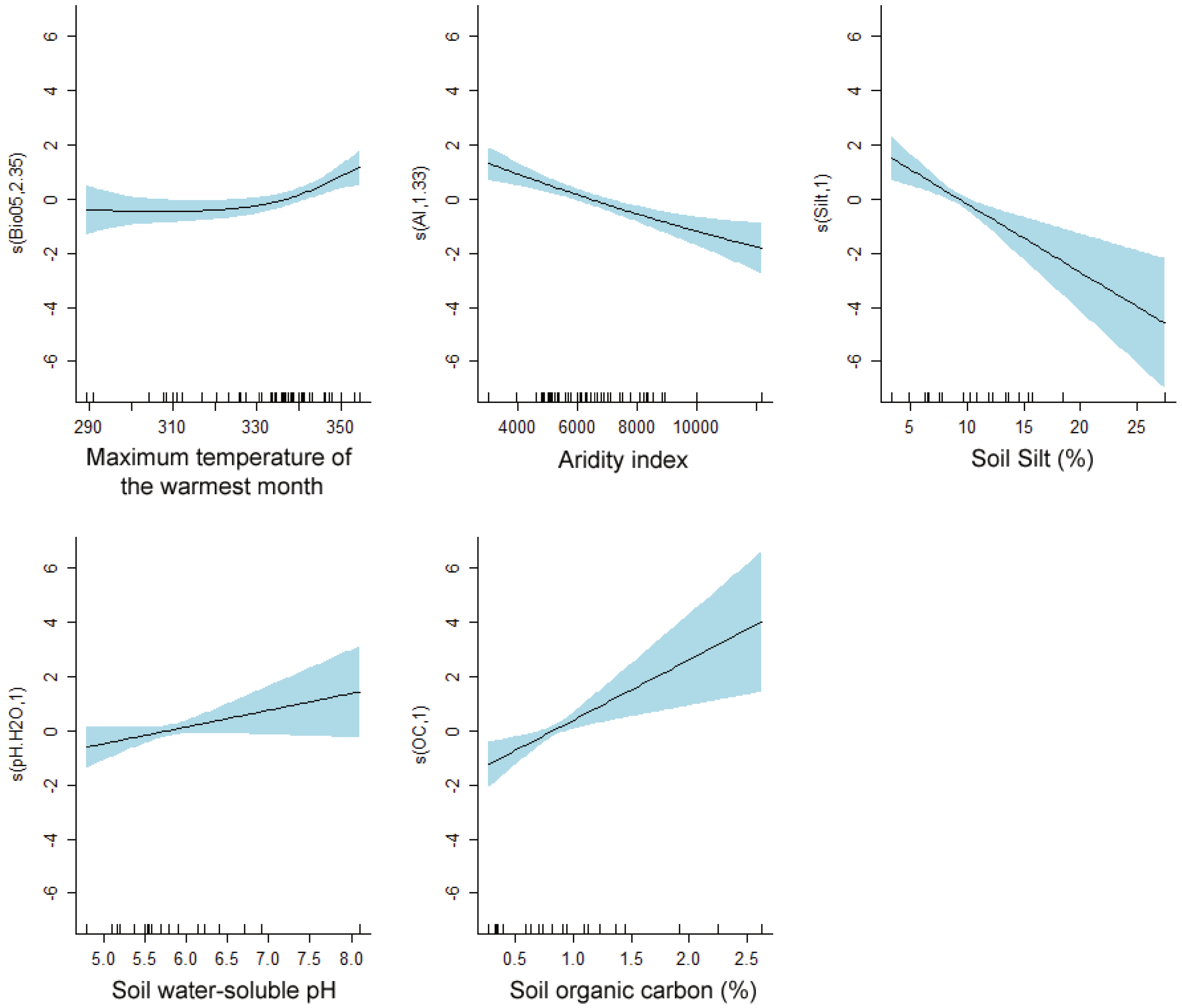

Fig. 9. GAM plots for the relationship of NRI with six environmental predictors. The y label is the smoothing of covariate and their estimated degrees of freedom. Blue shade represents the 95% confidence interval for each response curve.

For the NTI the best GAM included four terms with AIC = 129.27 (Table 2b). The NTI had negative relationship with isothermality (Bio03), potential evapo-transpiration (PET) and soil silt content, and positive relationship with precipitation seasonality (Bio05; Fig. 10). The model explained 43.3% of the deviance in NTI, and only PET was not statistically significant at α = 0.05 (Table3b). The residuals of both best models were not autocorrelated according to Moran´s I coefficient (Fig. 11). Therefore, the NTI increased as temperature became unstable and the precipitation variation increased. Similarly to NRI, the NTI indirectly increased as soil sand content increased.

Table 3. Approximate significance of smooth terms of generalized additive models of a) NRI and b) NTI according to F statistics and their respectively estimated degrees of freedom (edf).

a) **Net Relatedness Index (NRI)**

	edf	F	p-value
Bio05	2.350	6.384	0.001419 **
AI	1.329	16.881	0,00000187***
Silt	1.000	14.804	0.000416 ***
pH.H2O	1.000	2.860	0.098510 .
OC	1.000	9.628	0.003495 **

Significance codes: '***'=0.001, '**'=0.01, '*'=0.05, '.'=0.1. Deviance explained=57.5%

b) **Nearest Taxon Index (NTI)**

	edf	F	p-value
Bio03	1.856	4.968	0.00883 **
Bio15	1.000	8.593	0.00543 **
PET	1.000	3.710	0.06087 .
Silt	1.000	9.469	0.00366 **

Significance codes: '***'=0.001, '**'=0.01, '*'=0.05, '.'=0.1. Deviance explained=43.3%

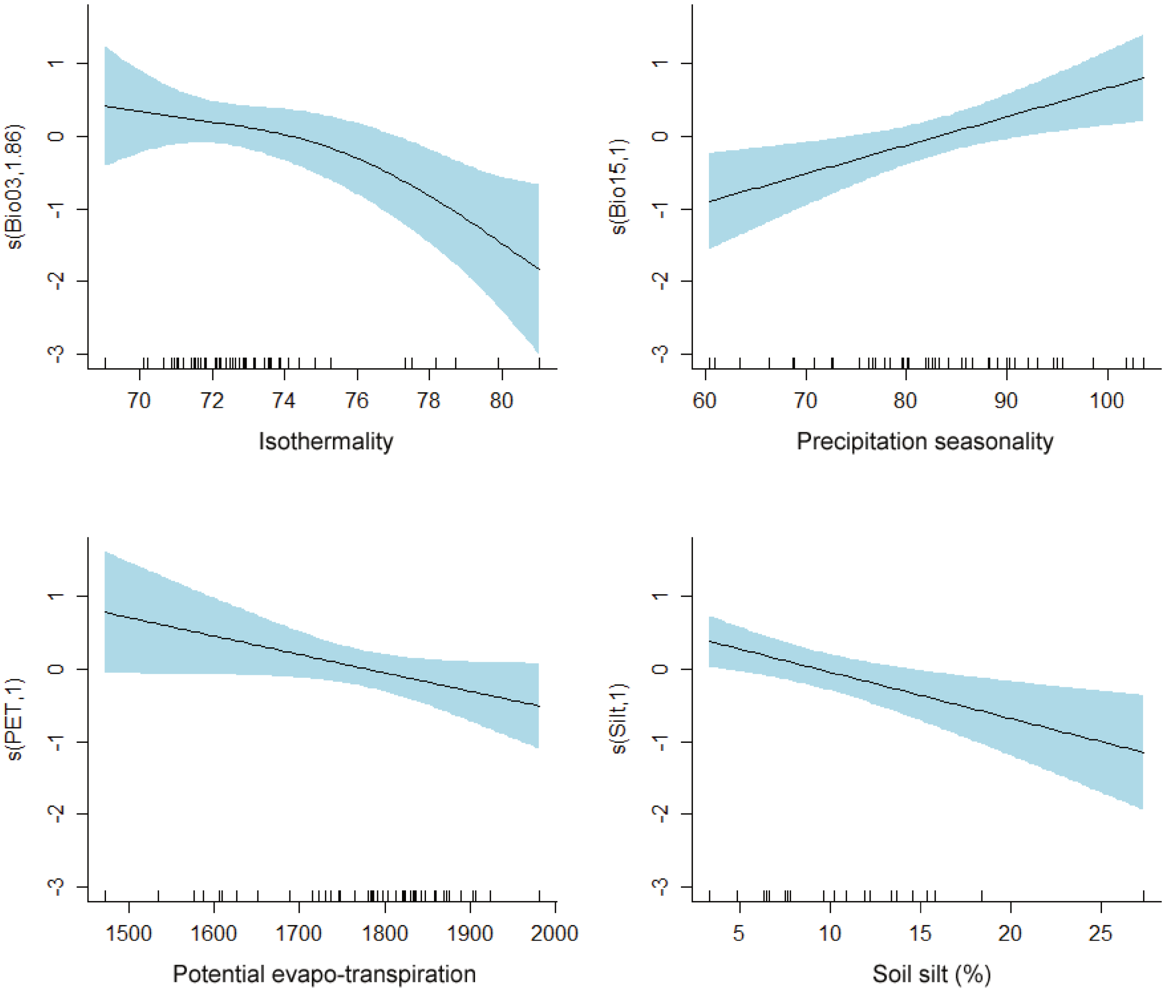

Fig. 10. GAM plots for the relationship of NTI with four environmental predictors. The *y* label is the smoothing of covariate and their estimated degrees of freedom. Blue shade represents the 95% confidence interval for each response curve.

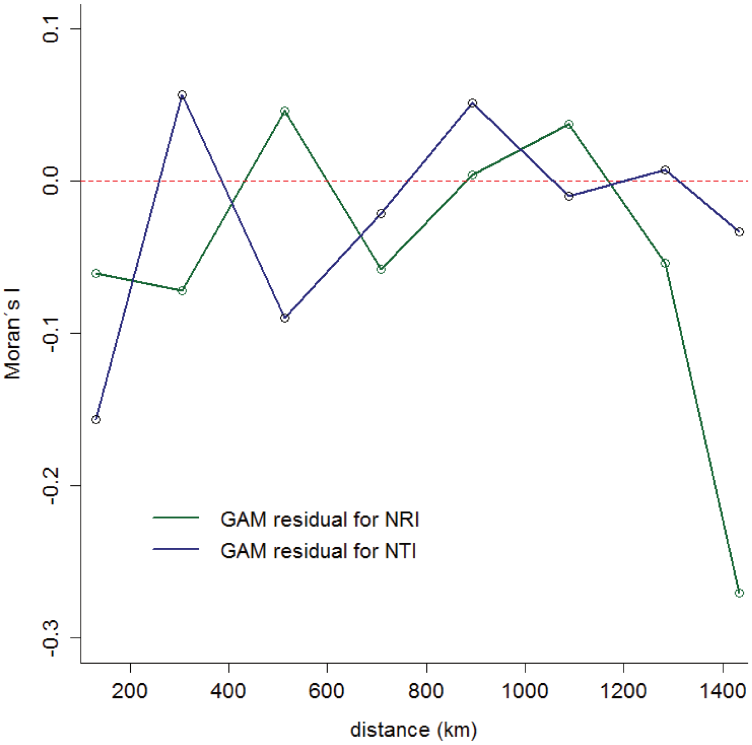

Fig. 11. Correlogram based on Moran´s I coefficient spatial autocorrelation for the GAM residuals of the Net Relatedness Index (green) and Nearest Taxon Index (blue). Significant autocorrelation distance classes at α = 5% are represented by solid circles.

Discussion

Recently, it has been argued that increasing the species pool in the phylogeny generates a bias towards phylogenetic clustering in local communities (Cavender-Bares et al. 2006, Vamosi et al. 2009). Also, Cavender-Bares et al. (2006) argued that the same happens if spatial scale is broadened to encompass greater environmental heterogeneity. In fact, we used the largest species pool and included a great environmental heterogeneity to assess a pattern of phylogenetic structure of the Brazilian NE cerrado woody flora. However, those issues apply very well to local-scale (100 m to 10 km) studies, when species should segregate into habitats according to the relative strengths of habitat filtering versus competition among similar species (Webb et al. 2002). Since we used a coarse scale (ca. 1,400 km) and a very large species pool, phylogenetic clustering of species sampled in a region reflects biogeographic processes rather than ecological local processes, as clades diversify within the sampled region and cause many taxa within the region to be, on average, more related to each other than to taxa outside the region (Webb et al. 2002). As the NRI and NTI were spatially autocorrelated, the statement of Webb et al. (2002) implies that grid-cells within short distances (until 130 km and 300 km for NRI and NTI respectively) suffered an internal diversification of clades, resulting in clades more related to each other than to clades in grid-cells at the longer distances.

Also, according simulated data, when the sizes of local communities are very small relative to species pool (near to 0% of total pool) or very close to the size of the whole species pool (near to 100%), the statistical power of NRI and NTI is reduced (Kraft et al. 2007). This may occur due to simple probability theory with a small number of species either included in the community or excluded by the assembly process, the probability of any given combination of taxa arising by chance in the null model is high (Kraft et al. 2007). The greatest statistical power is observed for communities of intermediate size, ranging from 30% to 60% of the species pool, depending on the assembly model and metric used (Kraft et al. 2007). As the woody flora of northeastern cerrado is very rare (This thesis, chapter 1), our sizes of local communities were small (mean=8,37%, sd=5) relative to total species pool (936 species), however, two considerations must be made on this issue. First, the test realized by Kraft et al. (2007) points the conclusion to a local communities scale, and second; according results of Kraft et al. (2007), in some circumstances, sizes of local communities similar to ours communities sizes had a considerable statistical power. Nevertheless, we must attend the suggestion of caution in rejecting a hypothesis of habitat filtering or competition exclusion since very species poor local community may increase the Type II error (Kraft et al. 2007).

Regarding those technical issues, our results appointed to a slight overall pattern of phylogenetic clustering for the Brazilian NE cerrado woody flora since the average of NRI and NTI values were statistically greater from the ones expected from absolute phylogenetic random community, in other words, different from zero. The phylogenetic clustering seems to be the general pattern of local communities suggesting a filtering of species into local habitats based on conserved ecological characters (Vamosi et al. 2009). Thus, habitat filtering is an important force in the organization of communities, and the investigation of the main environmental variables that select the traits to be conserved is crucial. In our study, we searched for environmental variables that could successfully generate a structure in the phylogeny. An alternative would be to search for phylogenetic signal, which is the degree of relationship between phylogeny and phenotype (Losos 2008), through considering species traits. Considering that investigating phylogenetic signal on regional scale demands a huge databank with ecological traits for all species, we sought the environmental variables that were more related with the pattern of phylogenetic structure. Hence, the traits related to these variables could be investigated more directly in the future, or they could just be inferred as discussed below. This is possible due to the traits are conserved in the phylogeny, in general (Prinzing et al. 2001, Losos 2008) and in the Cerrado (Batalha et al. 2011a, da Silva et al. 2011, Cianciaruso et al. 2012), since the traits are a legacy of their ancestors (Prinzing et al. 2001), and specially because at geographic scales it has been suggested that the evolutionary history of the species may also play a role for the composition of trait-states (Prinzing et al. 2008).

We think that the hierarchical partitioning we applied to the generalized additive models were efficient to identify the environmental variables correlated to NRI and NTI. Two climate and two soil variables were determinant to predict NRI in the model, since soil pH was not significant. Regarding the climate variables, the degree of phylogenetic clustering was associated with higher temperatures (implying in higher evaporation demand) and arid conditions, allowing us to infer that drought-resistance traits are likely to have been conserved in these habitats. This inference is confirmed by the negative relationship between NRI and soil silt content, since decreasing silt content increased soil sand percentage, which can lower the soil water storage capacity. The other soil variable, organic carbon content (OC), was also positively related to NRI. All carbon content found in soils is primarily plant-derived (Kuzyakov and Domanski 2000). The soil organic carbon content indicates the fraction of the total organic matter that is incorporated into the soil and depends on the ratio of raw organic matter added to the soil, the ratio of conversion of the raw organic matter into soil organic carbon, and the ratio of decomposition of the soil organic carbon (Sánchez and Salinas 1981). Higher contents of soil organic carbon do not mean more nutrients, because the nutrient content of the soil organic matter depends on the nutrient content of the plant tissues (Kuzyakov and Domanski 2000), and cerrado plant tissues have a very low nutrient content

(Hoffmann et al. 2005). Also, the OC was not correlated to soil carbon/nitrogen ratio which is a better soil quality indicator than soil organic carbon alone (Batjes 1996, Franzluebbers 2002). Moreover, the soil organic carbon content increases with higher precipitation and higher clay content (Franzluebbers 2002), however, the NRI was indirectly negatively correlated to these variables. Since there is no direct relationship between soil nutrient and organic carbon content (Franzluebbers 2002), the positive relationship we observed between NRI and soil organic carbon content did not disagree from the conclusion by (Batalha et al. 2011b) that nutrient poor soils lead to trait clustering.

The NTI had a similar negative correlation with soil silt content, also indicating soil water shortage as an environmental filter. Temperature and precipitation instability were the climate variables associated with high values of NTI. It has been argued that phenotypic plasticity in plants is an important trait in the adjustment to environmental conditions, such as rapid climate change (Jump and Penuelas 2005, Nicotra et al. 2010), temperature variation (Atkin et al. 2006) or humidity seasonality (Rossatto and Kolb 2009). Thus, we hypothesize that the lineages able to amplify the response range to climatic variability are likely to survive in these habitats. We suggest that further investigation comparing response ranges between tropical species living in continental and oceanic climates could render this issue more understandable.

Few environmental variables that initially we expected to drive the phylogenetic structure did not reveal any influence. For instance, the compound topographic index (CTI), which could represent waterlogging conditions, was not even selected by the hierarchical partitioning analysis. On the other hand, we could not use environmental variables that are known to be important in community assembly and phylogenetic structure such as fire regime (Silva and Batalha 2010) due to the absence of records.

An advantage of using 1° x 1° grid-cells is the possibility of comparison with other important aspects, such as species richness, endemism and distribution, and also with other organisms in space and in time. Additionally, on coarser scales, evolutionary and historical mechanisms may have an important role in the phylogenetic structure of the communities (Webb et al. 2002). For instance, altitude, which is an important factor delimiting areas of endemism in the NE cerrado (see this thesis, chapter 2), was not important for the phylogenetic structure, however, the main region with phylogenetic clustering – the central-northern Piauí state – is congruent with an area of endemism using the same species databank and grid-cell size (see this thesis, chapter 2). In this area of endemism, the higher values NRI and NTI found at coarse scale could indicate a clade diversification within the region, as expected by the model proposed by Webb et al. (2002). Although this area of endemism contains species from adjacent phytogeographic domains (This thesis, chapter 2), it is quite distant from the core cerrado and the Brazilian NE cerrado has a unique flora (Ratter et al. 2003, Bridgewater et al. 2004, This thesis, chapter 1), the flora of central-northern Piauí state is exceptional in richness, endemism and has a phylogenetic structure. Phylogenetic measures are better indicators of conservation worth than species richness (Crozier 1997), and although phylogenetic diversity (Faith 1992) is more often used for conservation strategies, the metrics of phylogenetic structure may also contributed for conservation strategies, since they may capture, at least partially, the function of the species in a community, in other words, traits of the species would be conserved within the lineages in this region.

The pattern of phylogenetic structure of the Brazilian NE cerrado woody flora is spatially autocorrelated as found for both NRI and NTI metrics. Considering our spatial scale, phylogenetic structure should be interpreted from a biogeographic viewpoint, thus the spatial structure of NRI and NTI metrics may, by itself, indicates an association with environmental variables, since they were spatially autocorrelated. Otherwise, the phylogenetic values would be random in space, indicating no biogeographic process acting upon the species. As a general pattern, harsh climatic and soil conditions related to drought can act as abiotic filters, leading to phylogenetic clustering. Although habitat filtering and competitive exclusion can operate simultaneously (Cavender-Bares et al. 2006, Helmus et al. 2007b), phylogenetic overdispersion was not as important as expected considering that the NE cerrado has some woody species that came from adjacent rainforests and seasonally tropical dry forests during its evolutionary history (Simon et al. 2009, This thesis, chapter 1, chapter 2). Thus, our results expanded the knowledge on the poorly known Brazilian NE cerrado woody flora hinting the disentangle of the environmental factors that drive a pattern of phylogenetic structure from the evolutionary history of plant communities (see Duarte et al. 2012). We highlight that the phylogenetic structure metrics may contribute to conservation strategies since in severe environmental, such as the NE cerrado with phylogenetic clustering, abiotic filtering could be acting selecting some species that probably would not occur in another place. Also, protecting areas with high phylogenetic clustering in the northeastern cerrado, whole clades with adaptations to these severe environments may occurs in these areas, then clades of plant would be protected.

Acknowledgements

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Appendix A. NRI and NTI values for each grid-cell mapped in Fig. 1. All environmental variable values for each grid-cell are shown. More details of environmental variables are in Table 1.

Grid-cell	NRI	NTI	Bio01	Bio02	Bio03	Bio04	Bio05	Bio06	Bio07	Bio08	Bio09	Bio10	Bio11	Bio12	Bio13	Bio14
1	-0.031	-1.009	271.63	92.52	81.04	569.90	331.03	217.54	113.49	265.32	277.88	279.30	265.32	1496.04	326.60	5.43
2	0.512	-0.542	270.12	97.14	77.51	666.59	336.03	211.31	124.73	264.19	278.11	279.69	263.66	1722.13	356.29	14.48
3	-1.371	0.525	270.08	99.97	77.32	706.40	336.89	208.01	128.87	262.90	276.92	279.61	262.73	1565.97	325.75	13.40
4	1.476	-0.415	263.58	107.54	79.90	681.79	333.71	199.67	134.04	256.87	268.72	272.00	255.70	1168.66	278.37	4.42
5	0.534	0.273	259.14	74.62	78.74	553.36	304.18	209.95	94.23	257.28	262.14	265.61	251.09	1225.69	284.22	8.83
6	1.307	0.249	272.00	108.39	73.46	881.72	350.06	203.38	146.68	265.41	279.89	284.62	262.68	1515.90	323.04	9.18
7	0.838	1.47	270.13	115.05	71.54	989.82	354.54	194.86	159.69	261.55	275.86	284.54	260.81	1536.59	357.90	9.27
8	1.218	2.711	255.77	115.97	74.84	855.83	336.49	182.44	154.06	248.98	258.58	267.02	246.52	1111.58	281.19	3.50
9	-1.471	0.34	257.98	118.28	73.88	382.79	336.10	176.75	159.35	256.60	255.79	262.70	252.93	1422.46	271.57	11.02
10	1.915	1.296	267.42	115.17	70.67	1009.26	353.42	191.59	161.83	258.77	269.38	282.31	257.91	1396.91	322.56	6.49
11	0.185	1.082	254.77	112.92	73.61	914.18	334.35	181.82	152.53	247.90	254.90	266.98	244.75	966.42	247.46	2.25
12	0.902	0.901	254.21	88.40	74.11	1062.86	312.00	193.48	118.52	255.88	257.69	265.59	238.43	832.84	155.13	7.51
13	-0.575	0.443	253.81	120.35	70.86	437.18	335.99	167.18	168.81	252.05	250.52	259.22	248.13	1501.35	253.58	14.57
14	-0.882	-1.281	252.29	122.38	71.20	512.91	337.36	166.54	170.83	250.08	250.40	259.22	245.91	1300.83	238.15	10.51
15	1.67	1.351	261.87	111.60	72.24	870.72	340.58	187.10	153.48	256.35	261.03	274.36	251.97	1335.84	242.83	7.30
16	1.142	2.214	267.52	109.18	72.55	937.56	347.23	197.80	149.43	260.14	267.94	280.65	257.04	1160.21	230.03	4.26
17	2.266	0.937	265.35	115.27	73.56	919.26	347.43	191.76	155.67	258.09	265.51	278.18	255.61	1184.87	252.08	2.94
18	1.967	1.181	251.68	111.24	73.17	994.91	330.43	179.29	151.14	246.14	250.38	264.68	239.92	888.41	208.67	1.56
19	0.835	-0.413	259.73	103.60	72.93	1120.22	334.59	193.49	141.09	254.28	260.71	273.98	245.65	847.00	212.82	5.86
20	0.859	0.323	245.90	94.30	73.20	1208.86	310.98	182.97	128.02	246.04	251.65	258.41	227.70	914.67	157.07	12.78
21	0.082	-0.497	261.94	113.03	72.38	463.12	340.82	185.73	155.09	258.36	265.35	268.32	257.81	1532.63	252.13	8.07
22	-0.315	0.289	256.80	117.57	72.18	521.66	338.80	176.98	161.82	253.09	258.12	264.45	251.99	1284.69	212.29	5.79
23	2.004	0.912	260.61	118.04	72.64	687.34	342.67	181.14	161.53	256.14	260.79	270.98	253.35	1103.89	193.97	3.19
24	0.324	-0.554	262.39	115.71	73.57	815.54	342.41	186.12	156.28	257.63	261.72	274.15	253.03	1052.55	178.61	2.17
25	1.748	0.576	268.63	116.85	75.29	827.95	347.99	193.81	154.18	264.79	265.93	280.08	258.61	960.27	176.42	1.42

Grid-cell	NRI	NTI	Bio01	Bio02	Bio03	Bio04	Bio05	Bio06	Bio07	Bio08	Bio09	Bio10	Bio11	Bio12	Bio13	Bio14
26	2.316	2.216	242.31	109.83	73.83	1073.18	316.99	169.17	147.82	242.87	234.37	255.31	227.62	675.41	168.28	2.02
27	0.132	2.678	235.90	104.86	71.48	1206.18	309.77	164.01	145.76	237.39	228.97	249.70	218.91	837.34	197.31	5.56
28	-0.082	-0.047	242.16	92.17	71.44	1237.16	308.42	180.29	128.13	235.00	247.45	255.12	223.73	983.68	154.97	18.61
29	-0.939	1.064	251.28	84.33	71.83	1020.73	307.66	191.16	116.49	241.44	256.91	261.38	235.51	1868.29	300.31	39.77
30	0.91	-0.602	252.98	121.35	72.94	566.69	336.03	170.69	165.34	249.17	253.13	261.55	247.81	1254.49	211.38	2.16
31	0.2	1.462	256.07	121.89	73.19	684.53	340.02	174.61	165.41	251.63	255.58	266.44	249.17	1162.89	195.97	0.94
32	0.378	-0.767	257.43	121.03	74.40	773.20	341.14	179.53	161.61	252.44	257.27	268.97	249.14	979.76	169.19	1.62
33	0.566	-0.521	260.27	128.91	78.17	720.84	342.53	178.66	163.87	258.38	255.37	270.04	251.09	886.87	158.24	1.33
34	1.167	0.074	246.42	111.36	71.05	1396.64	325.85	170.34	155.51	254.23	235.53	260.88	225.62	527.17	130.60	2.83
35	-1.443	-1.788	252.37	127.33	72.84	611.18	338.52	164.92	173.60	249.53	249.26	261.12	245.66	1303.55	228.48	0.67
36	-0.454	-0.988	252.40	131.07	72.13	714.72	343.13	162.60	180.52	249.94	247.34	262.30	243.89	1189.65	213.85	0.00
37	1.999	-0.553	254.53	131.14	72.91	770.94	346.35	167.57	178.78	251.93	249.40	265.37	245.49	974.15	164.10	1.18
38	0.244	-0.659	239.76	142.50	70.10	903.26	338.04	136.00	202.03	241.04	228.19	251.11	227.18	1098.11	187.87	0.05
39	-0.187	1.321	237.31	140.17	70.93	911.67	333.39	136.83	196.56	239.14	226.44	248.63	224.55	1148.16	205.24	0.30
40	1.51	0.87	245.37	151.04	69.05	1163.52	346.12	128.93	217.20	251.18	228.26	258.30	228.06	952.29	169.67	0.79
41	-0.174	1.084	241.85	123.86	72.73	825.78	327.38	158.07	169.31	241.16	235.27	252.95	231.41	1436.86	267.34	1.28
42	0.726	-1.118	233.09	139.54	71.69	1027.11	325.96	132.57	193.39	236.29	221.12	246.28	218.71	1034.03	187.26	0.50
43	-0.333	1.325	212.99	117.14	72.49	1253.22	290.91	130.34	160.57	221.90	199.29	223.93	193.56	785.35	131.46	12.87
44	0.069	2.221	236.60	121.94	72.08	946.22	316.98	148.89	168.09	238.77	227.05	247.63	222.62	1156.94	256.16	0.64
45	0.145	1.12	235.98	128.69	71.79	1101.59	320.29	142.31	177.97	240.49	222.77	249.07	219.76	903.97	198.09	0.51
46	0.358	-0.095	213.35	115.37	71.60	1257.03	289.33	129.26	160.07	222.07	198.41	224.00	193.77	804.08	142.90	15.73
47	0.219	0.749	231.09	125.48	71.01	1094.23	312.09	136.55	175.54	235.39	218.05	242.01	213.92	1171.63	266.39	2.53
48	-0.598	1.801	237.10	129.24	70.21	1217.42	323.13	140.30	182.83	242.70	219.84	249.85	219.00	923.20	220.32	0.49

continuing…

Grid-cell	Bio15	Bio16	Bio17	Bio18	Bio19	Alt	PET	AI	CTI	Sand	Silt	Clay	pH	OC	N	BS	CEC	BD	CN
1	94.98	879.52	18.75	20.68	879.52	30.83	1688.42	8864.51	7.86	64.95	7.60	27.55	8.10	0.32	0.04	89.50	14.20	1.60	16.00
2	85.56	942.07	53.12	67.67	752.10	75.34	1722.60	10005.20	8.06	52.60	7.80	39.50	4.80	1.23	0.09	22.00	5.30	1.30	14.00
3	86.64	862.87	45.34	57.96	771.97	73.44	1747.38	8951.06	7.44	74.68	6.57	18.80	5.58	0.70	0.08	53.67	4.78	1.38	12.17
4	101.86	729.31	17.83	47.03	682.28	178.68	1785.57	6561.22	7.32	91.70	3.30	5.10	5.90	0.27	0.04	68.00	3.10	1.50	12.00
5	95.53	743.79	30.48	133.28	162.99	63.56	1472.04	8350.28	6.38	53.60	15.80	30.60	5.10	2.25	0.18	39.00	7.60	1.30	14.00
6	89.05	878.09	46.04	81.70	490.49	98.89	1824.31	8313.66	7.52	60.20	10.85	29.00	5.50	1.09	0.13	48.00	7.05	1.25	11.50
7	93.12	910.25	41.68	75.29	509.35	106.89	1872.77	8208.18	7.32	91.70	3.30	5.10	5.90	0.27	0.04	68.00	3.10	1.50	12.00
8	103.64	713.28	18.90	64.42	375.50	292.72	1821.29	6076.03	7.32	91.70	3.30	5.10	5.90	0.27	0.04	68.00	3.10	1.50	12.00
9	76.63	735.13	54.23	183.51	154.18	231.12	1834.09	7757.69	6.73	74.60	9.60	15.90	6.40	0.39	0.05	69.00	5.30	1.50	12.00
10	90.30	801.50	32.30	117.48	371.41	162.64	1858.72	7518.11	6.72	91.70	3.30	5.10	5.90	0.27	0.04	68.00	3.10	1.50	12.00
11	102.57	614.85	13.96	66.28	141.17	322.27	1791.30	5382.05	6.68	69.83	11.90	18.30	6.70	0.74	0.10	68.67	7.97	1.30	11.33
12	76.23	414.10	30.51	236.50	263.50	90.43	1587.20	5243.69	7.06	91.70	3.30	5.10	5.90	0.27	0.04	68.00	3.10	1.50	12.00
13	68.82	719.86	57.57	201.25	171.42	222.16	1824.68	8231.03	6.11	91.70	3.30	5.10	5.90	0.27	0.04	68.00	3.10	1.50	12.00
14	72.63	636.50	44.28	127.91	128.15	334.82	1834.62	7092.15	6.27	23.50	27.40	49.10	5.20	2.63	0.19	46.00	5.80	1.00	14.00
15	75.30	651.94	33.31	119.60	267.70	316.05	1797.74	7439.70	6.09	91.70	3.30	5.10	5.90	0.27	0.04	68.00	3.10	1.50	12.00
16	79.55	589.30	27.35	112.48	334.30	246.77	1803.90	6436.20	6.30	91.70	3.30	5.10	5.90	0.27	0.04	68.00	3.10	1.50	12.00
17	85.98	649.34	19.18	139.06	333.48	222.88	1848.27	6417.79	6.39	78.67	4.80	16.57	5.53	0.59	0.06	52.67	3.83	1.43	12.67
18	95.61	529.32	11.69	95.02	62.09	414.24	1764.40	5028.49	6.84	65.63	6.30	28.03	5.17	0.91	0.07	37.33	4.57	1.37	13.33
19	98.61	534.53	25.58	70.81	147.69	354.28	1736.97	4871.62	6.57	52.60	7.80	39.50	4.80	1.23	0.09	22.00	5.30	1.30	14.00
20	68.74	424.70	49.25	191.29	307.26	196.34	1609.30	5696.97	6.98	91.70	3.30	5.10	5.90	0.27	0.04	68.00	3.10	1.50	12.00
21	70.84	713.96	37.81	76.86	620.50	249.73	1797.61	8529.59	6.42	91.70	3.30	5.10	5.90	0.27	0.04	68.00	3.10	1.50	12.00
22	72.67	605.58	28.43	138.75	271.72	353.34	1813.27	7086.86	6.53	74.60	9.60	15.90	6.40	0.39	0.05	69.00	5.30	1.50	12.00
23	77.81	532.70	14.05	107.83	170.65	328.56	1836.30	6011.43	6.09	72.21	10.19	17.67	5.70	0.94	0.08	61.71	3.87	1.36	12.57
24	78.35	497.34	11.24	96.43	169.77	360.83	1830.07	5751.40	6.24	49.70	13.37	36.97	5.37	1.37	0.16	41.33	8.37	1.17	11.33
25	82.24	491.02	9.46	132.33	167.45	296.14	1868.71	5143.76	6.46	28.70	18.40	52.90	5.10	1.92	0.22	28.00	11.00	1.00	11.00
26	95.58	402.54	13.14	140.86	33.82	583.46	1714.50	3953.90	6.84	52.60	7.80	39.50	4.80	1.23	0.09	22.00	5.30	1.30	14.00
27	90.86	496.98	26.47	174.98	71.27	602.63	1651.61	5082.79	6.54	52.60	7.80	39.50	4.80	1.23	0.09	22.00	5.30	1.30	14.00

Grid-cell	Bio15	Bio16	Bio17	Bio18	Bio19	Alt	PET	AI	CTI	Sand	Silt	Clay	pH	OC	N	BS	CEC	BD	CN
28	60.88	431.01	69.45	228.35	366.15	247.28	1575.56	6241.48	7.07	83.15	6.45	10.50	6.15	0.33	0.04	68.50	4.20	1.50	12.00
29	60.45	843.40	136.45	406.34	717.05	43.83	1533.93	12197.60	7.07	91.70	3.30	5.10	5.90	0.27	0.04	68.00	3.10	1.50	12.00
30	76.91	591.42	15.29	154.40	157.06	468.88	1822.60	6883.19	7.22	23.50	27.40	49.10	5.20	2.63	0.19	46.00	5.80	1.00	14.00
31	79.75	567.47	9.92	108.84	160.89	434.27	1843.22	6308.12	6.81	57.60	15.35	27.10	5.55	1.45	0.12	57.00	4.45	1.25	13.00
32	80.11	480.27	8.64	88.24	142.59	463.77	1847.41	5303.55	6.33	91.70	3.30	5.10	5.90	0.27	0.04	68.00	3.10	1.50	12.00
33	82.68	438.53	8.78	132.63	75.10	445.18	1923.69	4611.59	6.41	28.70	18.40	52.90	5.10	1.92	0.22	28.00	11.00	1.00	11.00
34	92.17	308.73	14.44	159.72	26.34	388.56	1745.45	3027.11	6.67	64.30	12.20	23.50	6.40	0.63	0.11	80.00	13.10	1.40	10.00
35	80.20	645.56	8.48	142.80	39.83	470.25	1859.99	7010.55	6.54	23.50	27.40	49.10	5.20	2.63	0.19	46.00	5.80	1.00	14.00
36	82.83	599.26	6.36	169.20	36.90	465.96	1889.58	6301.31	6.44	58.62	13.66	27.78	5.80	1.12	0.11	56.00	6.10	1.30	12.20
37	81.91	475.28	7.15	154.91	52.66	458.63	1903.90	5117.03	6.82	60.20	10.85	29.00	5.50	1.09	0.13	48.00	7.05	1.25	11.50
38	83.25	542.93	3.15	274.58	16.56	632.81	1906.26	5769.93	6.45	60.20	10.85	29.00	5.50	1.09	0.13	48.00	7.05	1.25	11.50
39	82.91	546.63	2.89	272.89	17.83	703.72	1875.36	6147.03	6.56	60.20	10.85	29.00	5.50	1.09	0.13	48.00	7.05	1.25	11.50
40	85.50	480.80	5.66	249.00	7.45	472.34	1981.89	4805.94	7.12	74.60	9.60	15.90	6.40	0.39	0.05	69.00	5.30	1.50	12.00
41	84.20	721.12	6.23	197.27	23.53	737.48	1779.82	8093.35	7.04	91.70	3.30	5.10	5.90	0.27	0.04	68.00	3.10	1.50	12.00
42	83.33	511.07	4.79	280.16	14.92	730.42	1848.26	5595.02	6.43	80.30	7.50	12.30	6.23	0.35	0.05	68.67	4.57	1.50	12.00
43	63.51	353.50	55.31	297.52	67.30	835.98	1625.50	4828.80	5.46	74.60	9.60	15.90	6.40	0.39	0.05	69.00	5.30	1.50	12.00
44	88.11	618.69	6.07	213.36	18.35	780.31	1736.41	6670.11	6.94	91.70	3.30	5.10	5.90	0.27	0.04	68.00	3.10	1.50	12.00
45	90.05	496.80	2.79	247.14	10.53	658.26	1783.74	5067.89	6.75	80.30	7.50	12.30	6.23	0.35	0.05	68.67	4.57	1.50	12.00
46	66.32	373.48	57.35	310.14	65.25	851.65	1606.37	5047.89	5.03	62.82	14.55	22.65	6.92	0.82	0.11	69.00	9.12	1.27	11.25
47	88.27	650.84	11.39	308.70	25.49	812.04	1730.77	6775.44	6.53	91.70	3.30	5.10	5.90	0.27	0.04	68.00	3.10	1.50	12.00
48	94.69	542.13	2.85	247.29	10.78	603.94	1787.04	5168.05	6.51	74.60	9.60	15.90	6.40	0.39	0.05	69.00	5.30	1.50	12.00

Appendix B. Data of the phylogenetic tree of the Brazilian NE cerrado woody flora based on APG III (2009).

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CONSIDERAÇÕES FINAIS

Ao longo dos três capítulos desta tese foi possível demonstrar a importância da flora lenhosa dos cerrados do nordeste do Brasil para o entendimento dos padrões e processos ecológicos em áreas marginais de um grande domínio fitogeográfico como o Cerrado. Em toda a tese, a história evolutiva do Cerrado é requerida como ponto de partida para a construção das hipóteses e argumentadas nas conclusões. No primeiro capítulo há uma descrição de como o Cerrado teria evoluído em resposta às mudanças climáticas no Terciário e Quaternário e como isso teria afetado a riqueza e estrutura da flora dos cerrados nordestinos. No segundo capítulo, como as expansões e retrações dos domínios fitogeográficos do nordeste do Brasil teriam influenciado a composição florística nas diferentes áreas de endemismo dos cerrados do nordeste. E no terceiro capítulo, como fatores ambientais restritivos poderiam ter selecionados ao longo da história espécies mais aparentadas entre si do que esperado ao acaso.

Porém, há muitas perguntas que não foram discutidas na tese. No primeiro capítulo, a estrutura florística aponta para a ocorrência de muitas espécies raras, além de famílias e gêneros com uma ou poucas espécies. Essa estrutura florística poderia levar a um padrão de dispersão filogenética. Porém, no terceiro capítulo, o que se observa é uma leve tendência ao agrupamento filogenético e de fato agrupamento filogenético significativo em algumas áreas. Já no segundo capítulo, mostrou-se a influência de espécies acessórias vindas de diferentes domínios fitogeográficos. Dessa forma, há de se supor que as espécies acessórias provenientes de domínios fitogeográficos adjacentes estariam o sendo selecionadas por um filtro abiótico, mas quase sempre dentro das mesmas famílias e gêneros das que já ocorreriam no Cerrado mais remoto. Porém, ainda não explicaria a estrutura florística. Portanto, uma possível investigação seria avaliar a estrutura filogenética considerando as espécies que ocorrem dentro de cada área de endemismo como o *pool* de espécies para o cálculo dos índices. Como cada área de endemismo tem condições ambientais particulares, seria esperado um maior agrupamento filogenético do que para todo o cerrado nordestino? Se fossem retiradas as espécies acessórias do *pool* de espécies, haveria um padrão mais forte de agrupamento filogenético? Se não houvesse mudança entre com e sem espécies acessórias, isso significaria que as espécies acessórias seriam selecionadas dentro dos mesmos clados já existentes em ambiente de cerrado, fortalecendo a teoria que o Cerrado é oriundo de outras formações vegetacionais. Outra questão a ser investigada é verificar se existe sinal filogenético relacionado a atributos de resistência a seca nas plantas dos cerrados nordestinos e comparar com os cerrados centrais ou ainda com os cerrados de São Paulo e Paraná que podem sofrer geadas periódicas.

Outro ponto importante é sobre os métodos. O índice de endemismo corrigido pela amplitude geográfica das espécies mostrou-se uma ótima ferramenta, mas sempre sendo testada por análise de autocorrelação espacial. Embora a análise de parcimônia de endemismos (PAE) tenha sido criticada nos últimos anos, ela se mostrou muito útil como uma primeira interpretação das relações entre as áreas. Análises filogeográficas com datações moleculares utilizando espécies irmãs das que ocorrem entre o Cerrado e os domínios fitogeográficos adjacentes podem revelar mais precisamente a história biogeográfica da região. No terceiro capítulo, a associação entre a análise hierárquica e modelo aditivo generalizado foi bem empregada para relacionar variáveis ambientais com os índices de estrutura filogenética. Apesar de termos testado essa relação com muitas variáveis ambientais disponíveis na rede mundial de computadores, vale ressaltar que há ainda a necessidade de melhorar a qualidade dessas variáveis ambientais, em especial das variáveis numéricas de atributos dos solos como, por exemplo, dados mais refinados de textura e concentração de nutrientes no solo. O uso de células de 1º de latitude-longitude é muito utilizado em macroecologia, porém, testes com diferentes dimensões de células poderiam ser feitas a fim de verificar se há diferença nos resultados de acordo com a resolução, como alguns trabalhos mostraram recentemente. Isso poderia ser feito tanto para áreas de endemismo como para a estrutura filogenética.

Em sumo, a flora dos cerrados do nordeste é de fato única, com alta riqueza e espécies raras, que ocorre distribuída em cinco áreas de endemismos locais influenciadas pelos domínios fitogeográficos adjacentes, além de estar relacionada a um filtro abiótico climático e de condições de solo. Visto que o cerrado do nordeste tem sofrido forte pressão antrópica promovida pelo avanço da fronteira agrícola nos últimos anos, faz-se necessário a criação de unidades de conservação ao longo de toda a região para que se possa proteger essa riqueza única de espécies e manter a herança genética do Cerrado brasileiro.