UFRRJ
INSTITUTO DE FLORESTAS
CURSO DE PÓS-GRADUAÇÃO EM CIÊNCIAS AMBIENTAIS E FLORESTAIS

TESE

Neotropical palms in the Anthropocene Age: tracking a changing world

Gabriela Akemi Macedo Oda

2019

UNIVERSIDADE FEDERAL RURAL DO RIO DE JANEIRO
INSTITUTO DE FLORESTAS
CURSO DE PÓS-GRADUAÇÃO EM CIÊNCIAS AMBIENTAIS E FLORESTAIS

Neotropical palms in the Anthropocene Age: tracking a changing world

GABRIELA AKEMI MACEDO ODA

Sob orientação da Professora
Alexandra Pires

Co-orientação
Rita de Cassia Quitete Portela

Marinez Ferreira de Siqueira

Tese submetida como requisito parcial para obtenção do grau de **Doutora em Ciências Ambientais e Florestais,** no Curso de Pós-Graduação em Ciências Ambientais e Florestais, Área de Concentração em Conservação da Natureza.
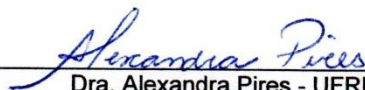
Seropédica, RJ

Fevereiro de 2019

UNIVERSIDADE FEDERAL RURAL DO RIO DE JANEIRO
INSTITUTO DE FLORESTAS
CURSO DE PÓS-GRADUAÇÃO EM CIÊNCIAS AMBIENTAIS E FLORESTAIS
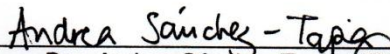
GABRIELA AKEMI MACEDO ODA

Tese submetida como requisito parcial para obtenção do grau de **Doutora em Ciências Ambientais e Florestais**, no Curso de Pós-Graduação em Ciências Ambientais e Florestais, área de Concentração em Conservação da Natureza.

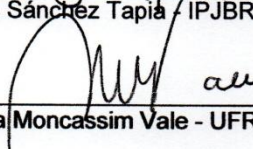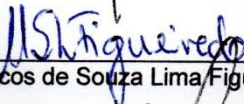TESE APROVADA EM 18/02/2019

_____
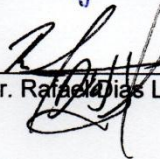Dra. Alexandra Pires - UFRRJ
(Orientadora)

_____
Dra. Andrea Sánchez Tapia - IPJBRJ

_____
Dra. Mariana Moncassim Vale - UFRJ

_____
Dr. Marcos de Souza Lima Figueiredo - UNIRIO

_____
Dr. Rafael Dias Loyola - UFG

RESUMO GERAL

As alterações no planeta promovidas pelo homem são tão significativas que justificaram a criação de uma nova era geológica: o Antropoceno. A perda e fragmentação de habitats, invasão de espécies exóticas e as mudanças climáticas estão entre os principais impactos à biodiversidade. Ao sofrer determinado impacto, as espécies podem responder de diferentes formas, e a estratégia adotada por cada uma está relacionada com características intrínsecas das mesmas. Dado o crescente risco de extinções globais, vários métodos de avaliação de risco têm sido propostos, mas poucos levam em consideração as características fisiológicas das espécies. Esses atributos podem auxiliar a entender adaptações à heterogeneidade ambiental e, consequentemente, a resposta das espécies às mudanças climáticas. Nesse estudo buscou-se identificar atributos ecológicos e fisiológicos que auxiliem na avaliação da sensibilidade de palmeiras neotropicais aos impactos antrópicos, em especial às mudanças climáticas. Com uma abordagem abrangente e integrada, foram utilizadas metodologias baseadas em revisão bibliográfica, medidas de atributos funcionais e Modelagem de Nicho Ecológico. Os principais resultados encontrados – que permitiram entender melhor as estratégias ecológicas de escape e a relação dos atributos foliares com o espaço, clima, microhabitats e adequabilidade ambiental - foram: (1) palmeiras tendem a apresentar mais estratégias de escape do que de aclimatização; (2) atributos foliares não são espacialmente distribuídos; (3) a correlação de atributos foliares com o clima se dá com mais intensidade em microhabitats em que os atributos estão mais expostos ao clima; (4) espécies com folhas mais grossas e menor área específica foliar (SLA) são menos sensíveis às mudanças climáticas; (5) espécies com folhas mais grossas apresentam maior expansão de adequabilidade ambiental do que as com folhas finas, em um cenário de mudanças climáticas; (6) espessura foliar de palmeiras pode ser bom preditor de impactos das mudanças no clima, e deve ser utilizado em analises de sensibilidade; (7) palmeiras tendem a ser favorecidas num cenário de mudanças climáticas, através de um aumento na adequabilidade ambiental, no entanto outros impactos antrópicos devem ser mensurados. É incentivada a busca de novos atributos que sejam de fácil obtenção, para uma avaliação da ampla gama de espécies, e que apresentem estreita relação com variáveis climáticas associadas às mudanças climáticas.

Palavras-chave: atributos ecológicos, estratégias de escape, atributos foliares, área específica foliar, espessura foliar, mudanças climáticas, parâmetros de sensibilidade, avaliação de risco

GENERAL ABSTRACT

The changes in the planet promoted by humans are so significant that they justified the creation of a new geological Age: the Anthropocene. Habitat loss, fragmentation, expansion of alien species and climate change are among the major impacts on biodiversity. When experiencing an impact, species can respond in different ways, and the strategy adopted by each species is related to their intrinsic characteristics. Given the increasing risk of global extinction, several standardized methods of risk assessment have been proposed, however, few consider the physiological characteristics of the species. These traits may help to understand adaptations to environmental heterogeneity and consequently to species responses to climate change. In this study, we sought to identify ecological and physiological traits that aid in the evaluation of the sensitivity of neotropical palms to anthropic impacts, especially climate change. With a broad and integrated approach, methodologies based on bibliographic review, functional traits measures and Ecological Niche Modeling were used. The results obtained provided important insights on ecological escape strategies and the relationship of leaf traits with space, climate, microhabitats and environmental suitability, among the main results are: (1) palm tend to present more escape strategies than acclimatization strategies; (2) leaf traits are not spatially distributed; (3) the correlation of leaf traits with climate occurs more strongly when the traits are more exposed to the climate; (4) species with thicker leaves and less specific leaf area (SLA) are less sensitive to climate change; (5) thicker leaf species showed a greater expansion of environmental suitability than thin leaf species in a climate change scenario; (6) leaf thickness of palms can be a good predictor of impacts of climate changes, and should be used in sensitivity analyzes; (7) palms tend to be favored climatically, with an increase of environmental suitability in a climate change scenario, however other anthropic impacts must be measured. In addition, it is encouraged the search for new traits that present features that are easy to obtain, for a wide evaluation of species, and that are closely related to climatic variables associated with climate change.

Key words: ecological traits, escape strategies, leaf traits, specific leaf area, leaf thickness, climatic changes, sensitivity parameters, risk assessment

SUMÁRIO

1. INTRODUÇÃO GERAL

As palmeiras estão entre as monocotiledôneas mais antigas, muito comuns nos hemisférios norte e sul no final do Cretáceo. Sua exuberância e diversidade de formas forneceram uma variedade de produtos alimentícios, estruturais e paisagístico ao homem ao longo de toda a sua história evolutiva. No entanto as modificações no planeta que vieram conosco, foram tão aceleradas e impactantes que nomeamos essa Era como de Antropoceno. A perda e fragmentação de habitats, a superexploração de fauna e flora, a introdução de espécies exóticas invasoras e as mudanças climáticas são os principais processos mediados pelo homem que têm levado a perdas de biodiversidade.

Dado que os riscos de extinção global são altos e crescentes como consequência das mudanças climáticas, vários métodos padronizados de avaliação de risco vêm sendo propostos. Isso é importante pois estudos mostram que metodologias padronizadas de avaliação de risco, muitas vezes não utilizam em seu *input* variáveis que avaliem de forma adequada os riscos às mudanças climáticas. No entanto, novas metodologias surgiram com o fim de avaliar esses riscos, e para isso utilizam-se de dois componentes principais: exposição e sensibilidade. De forma geral, o primeiro avalia o impacto climático sobre a superfície da terra, uma área geográfica determinada, independente das espécies que ali ocorrem. Enquanto o segundo componente leva em consideração características intrínsecas das espécies que podem tornar estas mais ou menos suscetíveis a esses impactos.

Atributos funcionais são relevantes em termos de resiliência das espécies aos impactos das mudanças climáticas. Os atributos a serem considerados para análise de sensibilidade às mudanças climáticas devem estar de acordo com as questões ecológicas em que estão envolvidos e para isso, é importante entender sua relação com o clima e o espaço geográfico. Mesmo assim, essa relação pode variar de um grupo taxonômico para outro, ou mesmo variar em diferentes grupos funcionais e habitats.

Usando as palmeiras como modelos de estudo, a tese foi organizada em três capítulos onde buscou-se identificar a relação de atributos ecológicos e fisiológicos com fatores antrópicos afim de sugerir seu uso em análise de sensibilidade. Os capítulos foram precedidos por uma extensa revisão bibliográfica, realizada com o apoio de um levantamento realizado nas bases de dados Scopus e Web of Science, em 21 de março de

2017, onde foram encontrados 44 artigos. Destes foram selecionados os que tinham relevância para esta revisão e outros artigos foram obtidos através de citações cruzadas. Esta revisão foi de grande importância na construção dos capítulos que se seguem.

O primeiro capítulo traz um panorama sobre a conservação das palmeiras neotropicais associando a sensibilidade destas às perturbações antrópicas. Para isso, foram utilizados atributos ecológicos considerados importantes no processo de resiliência, escape ou aclimatação destas após um distúrbio. Como produto, foi realizada uma avaliação sobre o status de 623 espécies, 65 gêneros e sete regiões de diversidade de palmeiras além de uma base de dados completa contendo todas as informações utilizadas para essa avaliação.

Visto que as mudanças climáticas são capazes de potencializar os efeitos dos outros impactos antrópicos, no segundo capítulo destinei minha atenção a este que é um dos principais desafios enfrentados pelas palmeiras no Antropoceno. Dado que as palmeiras estão distribuídas em diferentes ecossistemas em um extenso gradiente ambiental e consequentemente ao longo de sua história evolutiva desenvolveram características que as tornam mais adaptadas a determinadas condições, busquei identificar inicialmente quais destas características poderiam estar mais associadas as variações climáticas previstas. Sendo assim, no segundo capítulo verificou-se a relação de atributos foliares com o clima, espaço geográfico e microhabitats, assim como a eficácia desses atributos para futuras análises de sensibilidade. Identificamos também quais táxons teriam maior dificuldade de ultrapassar o filtro fisiológico promovido por um cenário de mudanças climáticas.

Uma vez que os atributos fisiológicos e ecológicos não são espacialmente distribuídos em todo o Neotrópico (alerta de *spoiler*) e que é esperado que cada região experimente uma exposição diferente às mudanças climáticas, no terceiro e último capítulo foram verificados: (1) o impacto dessas espécies associados ao clima (positivo, negativo ou neutro); (2) a riqueza potencial futura de palmeiras neotropicais; (3) se existe relação entre atributos foliares e o impacto previsto para estas espécies.

Finalizo reunindo os resultados dos três capítulos, trazendo considerações críticas e de forma conjunta sobre os atributos ecológicos e fisiológicos utilizados como indicadores de sensibilidade, juntamente com os modelos de nicho ecológico.

2. REVISÃO DE LITERATURA

As palmeiras são amplamente distribuídas nos trópicos, se estendendo aos subtrópicos e com apenas poucas espécies em regiões temperadas (Bjorhol et al. 2005; Dransfield et al. 2008; Eiserhardt et al. 2011). A família é composta por cerca de 2400 espécies em 183 gêneros e 5 subfamílias (Dransfield et al. 2008). Sua alta riqueza de espécies e diferentes formas de crescimento são um importante elemento do dossel e do sub-bosque florestal (Gentry 1988; Balslev et al. 2011), atuando na estruturação e no funcionamento de vários ecossistemas (Lieberman et al. 1985; Dransfield et al. 2008; Balslev et al. 2011).

Diversos fatores podem atuar na limitação da distribuição de espécies de palmeiras, dentre eles o clima (Hawkins et al. 2003; Svenning & Skov 2007), a topografia e heterogeneidade de habitats (Kerr & Packer 1997), a estrutura da paisagem (Svenning et al. 2008) e interações bióticas (Araújo & Luoto 2007; Kissling et al. 2007). Entretanto, a intensidade com que cada um destes fatores atua depende da escala geográfica (Eiserhardt et al. 2011).

Em uma escala global, o padrão de diversidade da família é direcionado tanto por fatores climáticos atuais e paleoclimáticos (Bjorhol et al. 2005, 2006; Svenning et al. 2008; Blach-Overgaard et al. 2010; Kristiansen et al. 2011; Eiserhardt et al. 2011; Ronca et al. 2011; Kissling et al. 2012) como por restrições espaciais (Blach-Overgaard et al. 2010; Svenning et al. 2008). Não por menos, essas plantas são consideradas como indicadores de climas quentes e úmidos (Walther et al. 2007) e são muito utilizadas em reconstruções paleo-ecológicas (Morley 2000; Ortuño et al. 2011; Kissling et al. 2012; Miller et al. 2012; Blach-Overgaard et al. 2013; Bacon et al. 2013; Giorgis et al. 2015; Bhattacharyya et al. 2015).

As reduzidas taxas fotossintéticas e de crescimento sob condições de baixa temperatura, corroboram a hipótese de que a temperatura é um importante limitante climático para a distribuição e diversidade de espécies de palmeiras (Tripp & Dexter 2006; Gatti et al. 2008). Ainda assim, alguns estudos apontam que as variáveis climáticas relacionadas à água, tais como evapotranspiração, precipitação anual e número de dias chuvosos surgem como os mais fortes preditores climáticos de padrões de diversidade de

palmeiras em escalas espaciais amplas (Bjorhol et al. 2005; Blach-Overgaard et al. 2010; Eiserhardt et al. 2011). A baixa tolerância à seca, comum em muitas espécies de palmeiras, é ilustrada bem pelo declínio dramático de muitas espécies da família na Ilha de Barro Colorado, no Panamá, em resposta à seca crescente do século passado (Condit et al. 1996). No entanto, variações climáticas consideráveis podem ocorrer em escalas menores, especialmente em regiões montanhosas (Svenning et al. 2009; Svenning 2001).

Gradientes de diversidade e distribuição de espécies de palmeiras podem acompanhar gradientes edáficos (Eiserhardt et al. 2011), tanto em escala continental (Blach-Overgaard et al. 2010), quanto em escalas menores (Clark et al. 1995; Vormisto et al. 2000; Svenning 2001). Em escalas geográficas menores, fatores edáficos podem interagir ainda com a topografia, a hidrologia e a estrutura da vegetação, exercendo influência direta ou indireta na distribuição das espécies (Svenning 2001). A estratificação das florestas tropicais gera um gradiente de luz que também tem forte influência sobre a distribuição de palmeiras, onde quanto menor a altura da espécie, mais escuros são os sítios que esta pode explorar (Svenning 2001).

Além disso, mesmo em condições ambientais adequadas, uma determinada espécie pode ser limitada espacialmente por filtros bióticos (Blach-Overgaard et al. 2010; Eiserhardt et al. 2011). Entre as plantas de florestas tropicais, as palmeiras destacam-se por possuírem folhas muito resistentes, o que pode reduzir a pressão dos herbívoros em comparação com as dicotiledôneas e outras monocotiledôneas (Dominy et al. 2008). No entanto, sua distribuição pode ser fortemente limitada por predadores de sementes invertebrados (A'lvarez-Loayza et al. 2011; Dracxler et al. 2011; Andreazzi et al. 2012; Oda et al. 2016, Souza 2016) ou vertebrados (Simmons et al. 2012; Andreazzi et al. 2012), ao reduzir as taxas de recrutamento e limitar o sucesso de seu estabelecimento. A distribuição de palmeiras numa escala fina é moldada especialmente por uma interação complexa entre a estrutura da vegetação, microrganismos patogênicos fúngicos e os herbívoros invertebrados (Alvarez-Loayza et al. 2011).

Visto as condições limitantes das espécies da família, e ressaltando a importância do clima no seu padrão de diversidade e distribuição em uma ampla escala, alterações neste podem trazer consequências irreversíveis para diversos ecossistemas tropicais. Nesse

contexto, as mudanças climáticas representam um importante desafio para a conservação da biodiversidade (Hughes 2000; Sala et al. 2000; Thomas et al. 2004; Walther et al. 2007; Göldel et al. 2015). Estudos mostram que as temperaturas médias globais aumentaram 0,2 °C por década desde de 1970, e a precipitação média global aumentou 2% nos últimos 100 anos (IPCC 2014). De fato, cenários de resfriamento e aquecimento da terra vêm ocorrendo nos últimos 3 bilhões de anos e são responsáveis pelos padrões de diversidade e distribuição das espécies que observamos nos dias atuais (Blach-Overgaard et al. 2010, 2013; Eiserhardt et al. 2011; Kissling et al. 2012; De Lima et al. 2014). Registros fósseis mostram que a baixa diversidade atual de palmeiras no continente Africano (Dransfield et al. 2008) pode ser resultado de severas extinções promovidas pelas mudanças climáticas durante o Terciário, somadas à imigração limitada em um continente isolado (Pan et al. 2006). Enquanto isso, outras regiões, como a América do Sul tropical, parecem ter sido continuamente adequadas para palmeiras há pelo menos 70 milhões de anos (Morley 2000), com efeitos potenciais sobre os padrões atuais de diversidade de espécies por meio de elevadas taxas de diversificação da família (Svenning et al. 2008; Kissling et al. 2012).

Apesar de terem sido observadas alterações tão aceleradas quanto as atuais (Hof et al. 2011), talvez espécies e ecossistemas não consigam se adaptar ou dispersar a tempo (Sala et al. 2000; Davis & Shaw 2001; Thomas et al. 2004; Eiserhardt et al. 2013; Göldel et al. 2015), especialmente porque no passado não existiam tantas barreiras de dispersão geradas pela atividade humana como existem atualmente (Hof et al. 2011; Meier et al. 2012).

Um grande número de estudos mostra que o aquecimento global antropogênico do século XX já vem afetando os ecossistemas terrestres (Hughes 2000; Walther et al. 2000; Parmesan & Yohe 2003; Root et al. 2003; Thomas et al. 2004; Parmesan 2006; IPCC 2014; Walther et al. 2007). Como resposta às mudanças no clima, algumas espécies tendem a gerar respostas plásticas (Jump et al. 2008; Shapcott et al. 2012) ou alterar a sua faixa de distribuição (Grabherr et al. 1994; Parmesan & Yohe 2003; Root et al. 2003; Kelly & Goulden 2008; Trivedi et al. 2008; Chen et al. 2011), no entanto, outras acabam se extinguindo (Thomas et al. 2004).

A presença de novos registros botânicos de uma espécie, em locais antes não habitados por esta pode ser um bom indicativo do movimento de uma espécie. Por exemplo, a expansão latitudinal da palmeira nativa *Sabal minor* (Jacq.) Pers da América do Norte, indicada pelo registro de novos indivíduos ao norte de sua distribuição original, segundo os autores se deu provavelmente devido a ocorrência de invernos menos severos nos últimos anos na região (Tripp & Dexter 2006). A expansão de *Trachycarpus fortunei* (Hook.) H. Wendl, palmeira asiática muito utilizada em paisagismo em todo o mundo, também vem sendo documentada em regiões da Europa e América do Norte por motivos semelhantes (Walther 2000). Estudos botânicos de coleta e registro de espécies são importantes para acompanhar esse movimento espaço-temporal, no entanto deve-se ter cautela com a qualidade dos dados obtidos, especialmente para espécies com pouco conhecimento de sua distribuição original.

Outra forma de prever esses movimentos é através de modelos bioclimáticos, que indicam o aumento ou a redução de áreas de adequabilidade ambiental para as espécies, utilizando modelos climáticos de projeções futuras. A expansão de *Trachycarpus fortunei*, citada anteriormente, foi confirmada pelo aumento de áreas adequadas para a sua ocorrência nos últimos anos, devido ao aumento da temperatura (Walther et al. 2007). O Dendê (*Elaeis guineensis* Jacq.) é outra espécie exótica que teria suas áreas de adequabilidade ambiental aumentada em até 31,3 milhões de hectares até 2100 (Shabani et al. 2012, 2014), segundo os cenários de mudanças climáticas. Outras palmeiras de importância econômica da América do Sul ocidental também têm grande potencial de expansão como *Aphandra natalia* (Balslev & A.J.Hend.) Barfod, *Attalea phalerata* Mart. ex Spreng, *Euterpe oleracea* Mart., *Iriartea deltoidea* Ruiz & Pav., *Mauritia flexuosa* L.f., *Oenocarpus bataua* (Mart.) Burret., *Phytelephas aequatorialis* Spruce, *Phytelephas macrocarpa* Ruiz & Pav. e *Phytelephas seemannii* O.F.Cook (Vedel-Sørensen et al. 2013), mesmo em sua distribuição nativa como é o caso de *E. oleracea* na Amazônia (Vaz et al. 2016).

No entanto, diversos outros estudos mostram a redução de habitats favoráveis para espécies de palmeiras em seu habitat natural. No continente africano são previstas a perda de mais de 70% de área propícia para a ocorrência de palmeiras, promovidos por uma combinação de vulnerabilidade climática e alto crescimento populacional humano (Bach-

Overgaard et al. 2015). Por exemplo, o declínio dramático nas populações de *Hyphaene petersiana* Klotzsch ex Mart., espécie chave africana, são esperadas caso as previsões de reduzida precipitação anual se confirmem (Blach-Overgaard et al. 2009). No entanto, em estudo que acompanhou os efeitos das mudanças climáticas nas últimas décadas na Amazônia ocidental, mais especificamente em Yasuní, Equador, não foi encontrado impacto significativo na estrutura e composição de palmeiras devido a ausência de evidências recentes de variações climaticas nessa região (Olivares et al. 2017).

Quanto a movimentos em gradientes altitudinais, foi observado um leve movimento para faixas superiores em *Hedyscepe canterburyana* (C. Moore & F. Muell) H. Wendl & Drude, representado pelas maiores taxas de crescimento e densidade populacional em altitudes superiores (Simmons et al. 2012). No entanto, para algumas espécies não há oportunidades de migração para faixas superiores, como é o caso de *Lepidorrhachis mooreana* (F.Muell.) O.F.Cook, espécie de palmeira isolada, que já ocupa a faixa de elevação mais alta (Shapcott et al. 2012).

Nesse cenário, populações pequenas e/ou isoladas de palmeiras apresentam grande vulnerabilidade e correm grande risco de extinção (Shapcott et al. 2012, Krause et al. 2015). Geralmente, essas espécies apresentam um nicho germinativo estreito e pequenas mudanças ambientais podem trazer consequências irreversíveis para a espécie. O mesmo é esperado para *Syagrus weddelliana* (H.Wendl.) Becc., espécie de palmeira com nicho germinativo restrito, de lento crescimento e elevadas taxas de predação das suas sementes, que fazem dela uma espécie vulnerável às mudanças climáticas (Braz et al. 2014; Oda et al. 2016).

Mesmo dentro de estudos macro ecológicos, podemos observar que umas espécies são mais vulneráveis do que outras. Estas diferenças na intensidade dos efeitos estariam relacionadas com os traços funcionais das espécies, interações ecológicas, restrições de nicho, conservação do habitat, densidade populacional humana, dentre outros. Dentre os atributos funcionais estudados, o tamanho médio do fruto é o único associado à mudança climática glacial-interglacial quaternária (Göldel et al. 2015) e a forte relação com a sazonalidade atual e a mudança de temperatura paleoclimática corroboram a ideia de que clados de palmeira com tamanhos de frutos grandes tendem a sobreviver melhor em áreas

com riscos sazonais como secas (Westoby 1998). Isso justifica-se pelo fato de que sementes com maior massa possuem maior sucesso reprodutivo (Lloret et al. 1999) e melhor estabelecimento de plântulas sob condições estressantes (Wright 1992).

Algumas medidas morfofisiológicas também podem ser usadas como medida de vulnerabilidade. Palmeiras de maior porte seriam mais afetadas pelo alto VPD (déficit de pressão de vapor) na estação seca do que as árvores menores (ver hipótese de limitação hidráulica de Ryan & Yoder 1997). No entanto, palmeiras maiores geralmente apresentam raízes mais profundas (Irvine et al. 2002) e maiores reservas de água (Holbrook & Sinclair 1992). Além disso, existe evidência de que as palmeiras de grande porte, como é o caso de *Iriartea deltoidea* Ruiz & Pav., apresentam maior fechamento estomático na estação seca comparado à estação chuvosa, o que pode torná-la mais eficiente do que outras espécies numa condição de precipitação anual reduzida e episódios de seca previstos para a sua região de ocorrência (Renninger et al. 2010). Sendo assim, a forma de vida pode ser considerada uma importante medida de vulnerabilidade, no entanto pouca informação sobre outros atributos fisiológicos específicos de palmeira foi encontrada.

Modificações fenológicas também são esperadas em resposta às mudanças climáticas (Walter et al. 2002; Parmesan 2006), já que variações climáticas anuais são suficientes para influenciar o comportamento reprodutivo das palmeiras (De Steven 1987). Outra evidência é o comportamento assincrônico entre populações de espécies de palmeiras em diferentes faixas de um gradiente altitudinal (Castro et al. 2007; Simmons et al. 2012), que corrobora a existência de uma interação com o clima para o início de floração e frutificação. Em faixas altitudinais superiores, são observados um retardamento da floração e uma menor duração da frutificação de *Euterpe edulis* Mart. (Castro et al. 2007) e um progressivo aumento na produção de flor/frutos de *Hedyscepe canterburyana* (C. Moore & F.Muell.) H. Wendl. (Simmons et al. 2012). Esta maior produtividade, já documentada para outras espécies (Crimmins et al. 2009), pode ser um efeito compensatório, que poderia ser indício de um movimento da planta para altitudes superiores (Simmons et al. 2012).

Não necessariamente os efeitos são de influência direta do clima, muitos impactos sobre as espécies são indiretos e de difícil previsão. Isso porque nem sempre as condições climáticas mais adequadas para uma espécie serão também adequadas para outras que

interagem com ela. Isso é especialmente importante quando se trata de espécies chaves e de grande interação com a fauna, onde efeitos diretos sobre seus polinizadores, predadores e dispersores de sementes podem gerar efeitos em cascata e afetar toda a dinâmica do ecossistema.

Como foi visto anteriormente, uma das alternativas para a manutenção de algumas espécies frente às mudanças no clima é a alteração de faixa de ocorrência, seja ela no gradiente atitudinal ou latitudinal. Um estudo realizado na Amazônia com diversas famílias, incluindo Arecaceae, mostrou um aumento significativo da sobrevivência em faixas superiores do gradiente, promovido por uma menor taxa de predação por invertebrados (Hillyer & Silman 2010). No entanto, em estudo com *Euterpe edulis* envolvendo transplante recíproco em gradiente altitudinal da Mata Atlântica, foi observada uma maior predação de sementes por roedores nos limites superiores de sua ocorrência (Souza 2016). Ainda envolvendo alteração de faixa altitudinal, a remoção e predação de frutos por roedores reduz significativamente o recrutamento de *Hedyscepe canterburyana* em gradientes altitudinais superiores (Simmons et al. 2012).

Um estudo realizado com abelhas nativas mostra que os serviços de polinização de *Euterpe oleracea* Mart. seriam prejudicados pelas mudanças climáticas, pois previsões mostram a redução de habitats adequados na Amazônia de seus polinizadores (Giannini et al. 2002). Consequentemente, com a redução dos serviços prestados pelos polinizadores, *E. oleracea* poderá ter dificuldades para se manter nesse ecossistema alterado. Estes estudos indicam que as interações interespecíficas podem ter efeitos indiretos nas respostas das palmeiras às mudanças climáticas globais. Sendo assim, estudos de interação e a inserção dos mesmos em modelos preditivos são de grande importância para um melhor entendimento dos processos bióticos limitantes associados às mudanças climáticas (Krause et al. 2015).

Além disso, as mudanças climáticas podem ser potencializadas por outros impactos antrópicos, como por exemplo, o grande número de habitats fragmentados, que impedem o movimento das espécies, necessário na busca de novos hábitats adequados (Blach-Overgaard et al. 2015; Thomas et al. 2012) e isso é especialmente importante no caso das palmeiras que apresentam baixa capacidade de dispersão (Blach-Overgaard et al. 2010).

Sendo assim, a estrutura da paisagem é outro fator que pode ajudar a classificar a vulnerabilidade de espécies de palmeiras, por exemplo, palmeiras de habitat aberto são menos vulneráveis a extinção do que aquelas de florestas, tanto pela supressão vegetal propriamente dita de seu habitat, quanto pela efetividade de dispersão (Bach-Overgaard et al. 2015).

A fragmentação muitas vezes favorece ainda a caça e a exploração de produtos florestais madeireiros e não madeireiros, que também geram efeito negativo significativo sobre as espécies. Em remanescentes da Mata atlântica a fragmentação eliminou aves de grande porte, exercendo uma pressão seletiva sobre *Euterpe edulis*, favorecendo sementes menores em função do aumento da dispersão por aves de menor porte (Galetti et al. 2013). No entanto, frutos menores, com menor vigor, apresentam menor sucesso frente às mudanças esperadas de escassez hídrica podendo ter grandes consequências no estabelecimento de novas populações (Westoby 1998; Galetti et al. 2013; Göldel et al. 2015).

A exploração de recursos não madeireiros geralmente é vista como menos impactante e muitas vezes sustentável, no entanto seus impactos demográficos são difíceis de estimar e reverberam no recrutamento juvenil, que por sua vez pode ser insuficiente para manter as populações a longo prazo. A superexploração de recursos foliares de palmeiras pode levar a depressão por endogamia como é o caso da palmeirinha do Ernesto (*Chamaedorea ernesti-augusti* H. Wendl.) da América Central (Cibrián-Jaramillo et al. 2009). Outro exemplo de exploração para uso alimentício é o palmito Juçara (*Euterpe edulis* Mart.), cuja exploração desordenada fez com que entrasse para a lista vermelha da flora ameaçada (CNCFlora. 2013). Para conter a exploração do palmito, alternativas de exploração de espécies amazônicas como a pupunha (*Bactris gasipaes* Kunth.) e o açaí (*Euterpe oleracea* Mart.) foram utilizadas. No entanto, a introdução deste último na Mata Atlântica, se tornou uma ameaça ainda maior para o já ameaçado *E. edulis* (Tiberio et al. 2015).

Umas das maiores ameaças atuais à biodiversidade são as espécies invasoras, no entanto não existe um consenso sobre o impacto das mudanças no clima sobre o potencial invasor das espécies (Bradley et al. 2009, 2010). Em geral estudos apontam que as

mudanças climáticas podem facilitar a invasão de espécies exóticas em novas áreas, particularmente para espécies de áreas quentes nativas introduzidas em áreas atualmente marginais de temperatura. Isso é, podemos esperar que espécies subtropicais invadam áreas temperadas mais quentes, e espécies temperadas invadindo zonas boreais mais quentes. No entanto, deve-se levar em conta a imprevisibilidade do clima; existem trabalhos também que dizem haver uma diminuição do risco de invasão, gerando oportunidades de restauração em milhões de hectares (Bradley et al. 2009).

Muitas espécies de palmeiras apresentam elevado potencial de invasão e seu uso comercial e paisagístico intensificam essa ameaça. A família aparece como uma das mais importantes fontes de invasoras nos trópicos (Mengardo et al. 2012; Rejmánek 2014), abastecidas especialmente pela Ásia, com oito espécies de palmeiras distribuídas em todo o globo (Rejmánek 2014). Seu potencial de invasão pode se dar especialmente porque 80 dos 183 gêneros da família das palmeiras têm sido relatados como dispersos por aves em suas áreas nativas (Zona & Henderson 1989; Dransfield et al. 2008). Para espécies dispersas à curta distância, pouco conhecimento se tem sobre seu potencial invasor, pois só podem ser reconhecidas como invasoras após períodos mais longos (Bennet et al. 2013).

A expansão prevista do dendê (*Elaeis guineenses* Jacq.) (Shabani et al. 2012, 2014), que ganhou força nos últimos anos como alternativa de biocombustível, já vem impactando as florestas tropicais do Sudeste Asiático (Koh et al. 2011; Shabani et al. 2014). Suas plantações para a geração de um combustível "ambientalmente amigável" emitem diretamente mais óxidos de nitrogênio e compostos orgânicos voláteis do que a floresta tropical, agravando ainda mais os efeitos sobre o clima da Terra (Hewitt et al. 2009; Danielsen et al. 2009).

Em trabalho experimental utilizando transplante recíproco na Nova Zelândia, a palmeira exótica *Archontophoenix cunninghamiana* Wendl. & Drude teve um desempenho melhor do que a nativa estreitamente relacionada *Rhopalostylis sapida* H.Wendl. & Drude (Sheppard et al. 2014). Com a mudança climática estas espécies exóticas podem ter sua abundância aumentada e afetar negativamente as espécies nativas residentes através da competição (Sheppard 2013). Além da competição direta com espécies nativas, seu impacto sobre a perda da biodiversidade local pode se dar também pela possibilidade de gerar

híbridos (Wolf et al. 2001). Atualmente a utilização do açaí (*Euterpe oleracea*) na indústria alimentícia tem ameaçado o juçara (*Euterpe edulis*), espécie congêneres de grande importância na Mata Atlântica. Estudos mostraram o potencial de invasão *de E. oleracea* e seu sucesso no estabelecimento através da interação com os mesmos dispersores do *E. edulis* (Tiberio et al. 2015). Além disso, foram detectadas evidências da geração de híbridos naturais, através da polinização cruzada e que estes híbridos podem atingir o estádio reprodutivo (Bovi et al. 1987). Para piorar, o híbrido é economicamente mais vantajoso e muitos produtores vêm adotando seu plantio, já que o mesmo é facilmente encontrado em mercados de mudas (Tiberio et al. 2015).

Nesse cenário de impactos antrópicos associados diretamente ou não com às mudanças climáticas, as áreas protegidas aparecem como uma ferramenta de conservação para proteger espécies e seus habitats, no entanto é necessário avaliar a sua efetividade frente as mudanças no clima. Na África, são esperados que até 2080, até 87% de todas as espécies perderão a aptidão climática dentro das atuais Áreas Protegidas (Bach-Overgaard et al. 2015). Isso acontece porque estas áreas são sistemas estáticos e, como tais, são limitados em permanecerem como refúgios seguros para futuras assembleias de espécies no futuro. Ainda assim, as unidades de conservação atuais continuam sendo valiosas para a conservação e não devem ser desconsideradas (Thomas et al 2012).

Finalizamos trazendo que diversos fatores bióticos e abióticos podem atuar nos padrões de composição, diversidade e distribuição das espécies de palmeiras. O clima teve influência ao longo de toda a história evolutiva da família Arecaceae, resultando na distribuição das espécies que observamos nos dias atuais. Sendo assim, as mudanças climáticas do Antropoceno devem ser melhor entendidas para que possamos entender o comportamento das espécies e buscar estratégias conservacionistas. Além disso, quando somado outros impactos antrópicos, tais como a superexploração, elevada densidade populacional humana e a degradação de seus habitats originais, esse cenário se torna ainda mais preocupante. Podemos dizer que, dentre as palmeiras mais vulneráveis, estão aquelas de distribuição restrita e/ou nicho germinativo estreito; espécies com dispersão limitada (curtas distâncias); espécies com hábitat florestal; espécies de sub-bosque, espécies com tamanho de fruto pequeno, além do grau de exploração e estágio de degradação do seu habitat. Apesar de palmeiras serem indicadoras de clima quente e húmido, é esperado de

forma geral que uma redução de hábitat favorável para espécies de palmeiras nativas, seja relacionada especialmente à degradação do habitat. No entanto, é prevista uma expansão de espécies exóticas invasoras ou de uso comercial, promovida em sua maioria pela seleção antrópica. Estudos espécie-específicos considerando a especificidade de nicho, a efetividade do dispersor e características morfo-fisiológicas são importantes para uma melhor classificação de vulnerabilidade das palmeiras.

Referências

Alvarez-Loayza P., White Jr J.F., Torres M.S., Balslev H., Kristiansen T., Svenning J.C, Gil N. (2011). Light converts endosymbiotic fungus to pathogen, influencing seedling survival and niche-space filling of a common tropical tree, *Iriartea deltoidea*. PLoS ONE 6: e16386. Doi:10.1371/journal.pone.0016386

Andreazzi C.S., Pimenta C.S., Pires A.S., Fernandez F.A.S., Oliveira-Santos L.G.R., Menezes, J.F.S. (2012). Increased productivity and reduced seed predation favor a large-seeded palm in small Atlantic Forest fragments. Biotropica 44: 237-245.

Araújo M.B., Luoto M. (2007). The importance of biotic interactions for modelling species distributions under climate change. Global Ecology and Biogeography 16: 743-753.

Bacon C.D., Mora A., Wagner W.L., Jaramillo C.A. (2013). Testing geological models of evolution of the Isthmus of Panama in a phylogenetic framework. Botanical Journal of the Linnean Society 171(1): 287-300.

Balslev H., Kahn F., Millan B., Svenning J.C., Kristiansen T., Borchsenius F., Pedersen D., Eiserhardt W. (2011). Species Diversity and Growth Forms in Tropical American Palm Communities. The Botanical Review 77: 381-425.

Bennett J.R., Vellend M., Lilley P.L., Cornwell W.K., Arcese P. (2013) Abundance, rarity and invasion debt among exotic species in a patchy ecosystem. Biological Invasions 15: 707-716.

Bhattacharyya A., Sandeep K., Misra S., Shanka R., Warrier A.K., Weijian Z., Xuefeng L. (2015). Vegetational and climatic variations during the past 3100 years in southern India: evidence from pollen, magnetic susceptibility and particle size data. Environmental Earth Sciences 74(4): 3559–3572. Doi:10.1007/s12665-015-4415-6

Bjorholm S., Svenning J.C., Baker W.J., Skov F., Balslev H. (2006). Historical legacies in the geographical diversity patterns of New World palm (Arecaceae) subfamilies. Botanical Journal of the Linnean Society 151: 113-125.

Bjorholm S., Svenning J.C., Skov F., Balslev H. (2005). Environmental and spatial controls of palm (Arecaceae) species richness across the Americas. Global Ecology and Biogeography 14: 423-429.

Blach-Overgaard A., Balslev H., Dransfield J., Normand S., Svenning J-C. (2015). Global-change vulnerability of a key plant resource, the African palms. Scientific Reports 5: 12611. Doi: 10.1038/srep12611

Blach-Overgaard A., Kissling W.D., Dransfield J., Balslev H., Svenning, J.-C. (2013). Multimillion-year climatic effects on palm species diversity in Africa. Ecology 94: 2426-2435.

Blach-Overgaard A., Svenning J.C., Balslev H. (2009). Climate change sensitivity of the African ivory nut palm, *Hyphaene petersiana* Klotzsch ex Mart. (Arecaceae) – a keystone species in SE Africa. IOP Conf. Series: Earth and Environmental Science 8: 012014. Doi:10.1088/1755-1315/8/1/012014

Blach-Overgaard A., Svenning J.C., Dransfield J., Greve M., Balslev H. (2010). Determinants of palm species distributions across Africa: the relative roles of climate, non-climatic environmental factors, and spatial constraints. Ecography 33: 380-391.

Bovi M.L.A., Godoy Junior G., Saes L.A. (1987). Híbridos interespecíficos de palmiteiro (*Euterpe oleracea* x *Euterpe edulis*). Bragantia 46(2): 343-363. Doi:10.1590/S0006-87051987000200015.

Bradley B., Oppenheimer M., Wilcove D.S. (2009). Climate change and plant invasions: restoration opportunities ahead? Global Change Biology 15: 1511-1521.

Bradley B.A., Blumenthal D.M., Wilcove D.S., Ziska L.H. (2010). Predicting plant invasions in an era of global change. Trends in Ecology & Evolution 25(5): 310-318.

Braz M.I.G., Portela R.C.Q., Cosme L.H.M., Marques V.G.C., Mattos E.A. (2014). Germination niche breadth differs in two co-occurring palms of the Atlantic Rainforest. Natural Conservation 12(2): 124-128. Doi: 10.1016/j.ncon.2014.09.003

Castro E.R., Galetti M., Morellato L.P.C. (2007). Reproductive phenology of *Euterpe edulis* (Arecaceae) along a gradient in the Atlantic rainforest of Brazil. Australian Journal of Botany 55: 725-735.

Chen I.-C.., Hill J.K., Ohlemüller R., Roy D.B., Thomas C.D. (2011). Rapid range shifts of species associated with high levels of climate warming. Science 333: 1024-1026.

Cibrian-Jaramillo A., Bacon C.D., Garwood N.C., Bateman R.M., Thomas M.M., Russell S., Bailey C.D., Hahn W.J., Bridgewater S.G., De Salle R. (2009). Population genetics of the understory fishtail palm *Chamaedorea ernesti-augusti* in Belize: high genetic connectivity with local differentiation. BMC Genetics 10: 65.

Clark D.A., Clark D.B., Sandoval R., Castro M.V. (1995). Edaphic and human effects on landscape-scale distributions of tropical rain-forest palms. Ecology 76: 2581-2594.

CNCFlora. (2013). Livro Vermelho da Flora do Brasil. Martinelli, G.; Moraes, M.A. (Org.), Instituto de Pesquisas Jardim Botânico do Rio de Janeiro. 1100p.

Condit R., Hubbell S.P., Foster R.B. (1996). Changes in tree species abundance in a Neotropical forest: impact of climate change. Journal of Tropical Ecology 12: 231-256.

Crimmins T.M., Crimmins M.A., Bertelsen C.D. (2009). Flowering range changes across an elevation gradient in response to warming summer temperatures. Global Change Biology 15(5): 1141-1152. Doi: 10.1111/j.1365-2486.2008.01831.x

Danielsen F., Beukema H., Burgess N.D., Parish F., BrÜhl C.A., Donald P.F., Murdiyarso D., Phalan B., Reijnders L., Struebig M., Fitzherbert E.B. (2009). Biofuel plantations on forested lands: Double jeopardy for biodiversity and climate. Conservation Biology 23(2): 348-358.

Davis M.B., Shaw R.G. (2001). Range shifts and adaptive responses to quaternary climate change. Science 292: 673-679.

De Lima N.E., Lima-Ribeiro M.S., Tinoco C.F., Terribile L.C., Collevatti R.G. (2014). Phylogeography and ecological niche modelling, coupled with the fossil pollen record, unravel the demographic history of a Neotropical swamp palm through the Quaternary. Journal of Biogeography 41(4): 673-686.

De Steven D.D., Windsor D.M., Putz F.E., De Leon B. (1987). Vegetative and reproductive phenologies of a palm assemblage in Panama. Biotropica 19(4): 342-356. Doi: 10.2307/2388632

Dominy N.J., Grubb P.J., Jackson R.V., Lucas P.W., Metcalfe D.M., Svenning J.-C.,Turner I.M. (2008). In tropical lowland rain forests monocots have tougher leaves than dicots, and include a new kind of tough leaf. Annals of Botany 101: 1363-1377. Doi 10.1093/aob/mcn046

Dracxler C.M., Pires A.S., Fernandez F.A.S. (2011). Invertebrate seed predators are not all the same: seed predation by Bruchine and Scolytine beetles affects palm recruitment in different ways. Biotropica 43: 8-11.

Dransfield J., Uhl N.W., Asmussen C.B., Baker W.J., Harley M.M., Lewis C.E. (2008). Genera Palmarum. Richmond, UK: Royal Botanic Gardens, Kew.

Eiserhardt W.L., Svenning J.-C., Baker W.J., Couvreur T.L., Balslev H. (2013). Dispersal and niche evolution jointly shape the geographic turnover of phylogenetic clades across continents. Scientific Reports 3 (1164). Doi: 10.1038/srep01164

Eiserhardt W.L., Svenning J-C., Kissling W.D., Balslev H. (2011). Geographical ecology of the palms (Arecaceae): determinants of diversity and distributions across spatial scales. Annals of Botany 108(8):1391-4161. Doi: 10.1093/aob/mcr146

Galetti M., Guevara R., Côrtes M.C., Fadini R., Von Matter S., Leite A.B., Labecca F., Ribeiro T., Carvalho C.S., Collevatti R.G., Pires M.M., Guimarães P.R., Brancalion P.H., Ribeiro M.C., Jordano P. (2013). Functional extinction of birds drives rapid evolutionary changes in seed size. Science 340: 1086-1090. Doi: 10.1126/science.1233774

Gatti M.G., Campanello P.I., Montti L.F., Goldstein G. (2008). Frost resistance in the tropical palm *Euterpe edulis* and its pattern of distribution in the Atlantic Forest of Argentina. Forest Ecology and Management 256: 633-640.

Gentry A.H. (1988). Changes in plant community diversity and floristic composition on environmental and geographical gradients. Annals of the Missouri Botanical Garden 75: 1-34

Giannini T.C., Acosta A.L., Garófalo C.A., Saraiva A.M., Alves-dos-Santos I., Imperatriz-Fonseca V.L. (2012). Pollination services at risk: bee habitats will decrease owing to

climate change in Brazil. Ecological Modelling 244: 127-131. Doi: 10.1016/j.ecolmodel.2012.06.035

Giorgis M.A., Lopez M.L., Rivero D., Cingolan A.M. (2015). Cambios climáticos en las sierras de Córdoba (Argentina) durante el holoceno. Aportes a las reconstrucciones climáticas a través del análisis de silicofitolitos del sitio arqueológico El Alto 3. Boletin de la Sociedad Argentina de Botanica 50 (3): 361-375. ISSN 0373-580

Göldel B., Kissling W.D., Svenning J. (2015). Geographical variation and environmental correlates of functional trait distributions in palms (Arecaceae) across the New World. Botanical Journal of the Linnean Society. Doi: 10.1111/boj.12349

Grabherr G., Gottfried M., Pauli H. (1994). Climate effects on mountain plants. Nature 369: 448

Hawkins B.A., Field R., Cornell H.V., Currie D.J., Guégan J.F., Kaufman D.M., Kerr J.T., Mittelbach G.G., Oberdorff T., O'Brien E.M., Porter E.E., Turner J.R.G. (2003). Energy, water, and broad-scale geographic patterns of species richness. Ecology 84: 3105-3117.

Hewitt C.N., MacKenzie A.R., Di Carlo P., Di Marco C.F., Dorsey J.R., Evans M., Fowler D., Gallagher M.W., Hopkins J.R., Jones C.E., Langford B., Lee J.D., Lewis A.C., Lim S.F., McQuaid J., Misztal P., Moller S.J., Monks P.S., Nemitz E., Oram D.E., Owen S.M., Phillips G.J., Pugh T.A.M., Pyle J.A., Reeves C.E., Ryder J., Siong J., Skiba U., Stewart D.J. (2009). Nitrogen management is essential to prevent tropical oil palm plantations from causing ground-level ozone pollution. Proceedings of the National Academy of Sciences 106 (44): 18447-18451. Doi: 10.1073/pnas.0907541106

Hillyer R., Silman M.R. (2010). Changes in species interactions across a 2.5km elevation gradient: effects on plant migration in response to climate change. Global Change Biology 16: 3205–3214. Doi: 10.1111/j.1365-2486.2010.02268.x

Hof C., Levinsky I., Araújo M.B., Rahbek C. (2011). Rethinking species' ability to cope with rapid climate change. Global Change Biology 17: 2987

Holbrook N.M., Sinclair T.R. (1992). Water balance in the arborescent palm, Sabal palmetto. L. Stem structure, tissue water release properties and leaf epidermal conductance. Plant, Cell and Environtnent 15: 393-399.

Hughes L. (2000). Biological consequences of global warming: is the signal already apparent? Trends in Ecology & Evolution 15: 56-61. Doi: 10.1016/S0169 5347(99)01764-4

International Panel on Climate Changes/IPCC. (2014). Climate change 2014: mitigation of climate change. In: Edenhofer, O. et al. (Ed.). Contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change. Cambridge: Cambridge University Press, 2014c. Disponível em: <https://www.ipcc.ch/pdf/assessment-report/ ar5/w g3/ipcc_wg3_ar5_full.pdf>. Acesso em: 10 jun. 2015.

Jump A.S., Penuelas J., Rico L., Ramallo E., Estiarte M., Martinez J.A., Lloret F. (2008). Simulated climate change provokes rapid genetic change in the Mediterranean shrub Fumana thymifolia. Glob Change Biol 14: 637-643.

Kelly A.E., Goulden M.L. (2008). Rapid shifts in plant distribution with recent climate change. Proceedings of the National Academy of Sciences of the United States of America 105:11823-11826

Kerr J.T., Packer L. (1997). Habitat heterogeneity as a determinant of mammal species richness in high-energy regions. Nature 385: 252-254.

Kissling W.D., Baker W.J., Balslev H., Barfod A.S., Borchsenius F., Dransfield J., Govaerts R., Svenning J-C. (2012). Quaternary and pre Quaternary historical legacies in the global distribution of a major tropical plant lineage. Global Ecology Biogeography 21: 909-921. Doi: 10.1111/j.1466-8238.2011.00728.x

Kissling W.D., Rahbek C., Bohning-Gaese K. (2007). Food plant diversity as broad-scale determinant of avian frugivore richness. Proceedings of Biological Sciences 274: 799-808.

Koh L.P., Miettinen J., Liew S.C., Ghazoul J. (2011). Remotely sensed evidence of tropical peatland conversion to oil palm. Proceedings of the National Academy of Sciences of the United States of America 108(12): 5127-5132.

Krause C.M., Cobb N.S., Pennington D.D. (2015). Range shifts under future scenarios of climate change: Dispersal ability matters for Colorado Plateau endemic plants. Natural Areas Journal 35: 428-438.

Kristiansen T., Svenning J-C., Pedersen D., Eiserhardt W., Grández C., Balslev H. (2011). Local and regional palm (Arecaceae) species richness patterns and their cross-scale determinants in the western Amazon. Journal of Ecology 99: 1001-1015. Doi:10.1111/j.1365-2745.2011.01834.x.

Lieberman M., Lieberman D., Hartshorn G.S., Peralta R. (1985). Small-scale altitudinal variation in lowland wet tropical forest vegetation. Journal of Ecology 73(2): 505-516. Doi:10.2307/2260490

Loret F., Casanovas C., Peñuelas J. (1999). Seedling survival of Mediterranean shrubland species in relation to root:shoot ratio, seed size and water and nitrogen use. Functional Ecology 13: 210-216.

Meier E.S., Lischke H., Schmatz D.R., Zimmermann N.E. (2012). Climate, competition and connectivity affect future migration and ranges of European trees. Global Ecology and Biogeography 21. Doi: 164e178.

Mengardo A.L.T, Figueiredo C.L., Tambosi L.R., Pivello V.R. (2012). Comparing the establishment of an invasive and an endemic palm species in the Atlantic rainforest, Plant Ecology & Diversity 5(3): 345-354. Doi: 10.1080/17550874.2012.735271

Miller L.A., Smith S.Y, Sheldon N.D., Strömberg C.A.E. (2012). Eocene vegetation and ecosystem fl uctuations inferred from a high-resolution phytolith record. Bulletin of the Geological Society of America 124(9-10): 1577-1589.

Morley R.J. (2000). Origin and evolution of tropical rain forests. Chichester, UK: John Wiley & Sons Press.

Oda G.A.M., Braz M.I.G., Portela R.Q. (2016). Does regenerative strategy vary between populations? A test using a narrowly distributed Atlantic Rainforest palm species. Plant Ecology 217(7). Doi:10.1007/s11258-016-0612-y

Olivares I., Svenning J.-C., Van Bodegom P.M., Valencia R., Balslev H. (2017). Stability in a changing world – palm community dynamics in the hyperdiverse western Amazon over 17 years. Global Change Biology 23(3): 1232-1239.

Ortuño T., Ledru M.-P., Cheddadi R., Kuentz A., Favier C., Beck S. (2011). Modern pollen rain, vegetation and climate in Bolivian ecoregions. Review of Palaeobotany and Palynology 165(1-2): 61-74.

Pan A.D., Jacobs B.F., Dransfield J., Baker W.J. (2006). The fossil history of palms (Arecaceae) in Africa and new records from the Late Oligocene (28–27 Mya) of north-western Ethiopia. Botanical Journal of the Linnean Society 151: 69-81.

Parmesan C. (2006). Ecological and evolutionary responses to recent climate change. Annual Review of Ecology, Evolution, and Systematics 37: 637-669

Parmesan C., Yohe G. (2003). A globally coherent fingerprint of climate change impacts across natural systems. Nature 421: 37-42.

Rejmánek M. (2014). Invasive trees and shrubs: where do they come from and what we should expect in the future? Biological Invasions 16: 483-498. Doi: 10.1007/s10530-013-0603-z

Renninger H.J., Phillips N., Salvucci G.D. (2010). Wet-vs. Dry-Season Transpiration in an Amazonian Rain Forest Palm Iriartea deltoidea. Biotropica 42(4): 470-478.

Roncal J., Blach-Overgaard A., Borchsenius F., Balslev H., Svenning J-C. (2011). A dated phylogeny complements macroecological analysis to explain the diversity patterns in Geonoma (Arecaceae). Biotropica 43: 324-334.

Root B.A., Price J.T., Hall K. (2003). Fingerprints of global warming on wild animals and plants. Nature 421: 47–60.

Ryan M.G., Yoder B.J. (1997). Hydraulic Limits to Tree Height and Tree Growth. BioScience 47(4): 235-242.

Sala O.E., Chapin F.S., Armesto J.J., Berlow E., Bloomfield J., Dirzo R., Huber-Sanwald E., Huenneke L.F., Jackson R.B., Kinzig A., Leemans R., Lodge D.M., Mooney H.A., Oesterheld M., Poff N.L., Sykes M.T., Walker B.H., Walker M., Wall D.H. (2000). Global biodiversity scenarios for the year 2100. Science 287: 1770-1774.

Shabani F., Kumar L., Taylor S. (2012). Climate Change Impacts on the Future Distribution of Date Palms: A Modeling Exercise Using CLIMEX. PLoS ONE 7(10): e48021.

Shabani F., Kumar L., Taylor S. (2014). Suitable regions for date palm cultivation in Iran are predicted to increase substantially under future climate change scenarios. Journal of Agricultural Science 152: 543-557. Doi:10.1017/S0021859613000816

Shapcott A., Hutton I., Baker W.J., Auld T.D. (2012). Conservation genetics and ecology of an endemic montane palm on Lord Howe Island and its potential for resilience. Conservation Genetics 13: 257-270. Doi: 10.1007/s10592-011-0282-1

Sheppard C.S. (2013). Potential distribution and invasiveness of recently naturalised alien plants under climate change (PhD thesis). The University of Auckland, Auckland, 236 pp.

Simmons C.L., Auld T.D., Hutton I., Baker W.J., Shapcott A. (2012). Will Climate Change, Genetic and Demographic Variation or Rat Predation Pose the Greatest Risk for Persistence of an Altitudinally Distributed Island Endemic? Biology 1: 736-765.

Souza A.C. (2016). Distribuição e abundância de *Euterpe edulis* ao longo de um gradiente altitudinal na Mata Atlântica (Tese de Doutorado). Universidade Federal do Rio de Janeiro, Rio de Janeiro - RJ.

Svenning J.C., Skov F. (2007). Ice age legacies in the geographical distribution of tree species richness in Europe. Global Ecology and Biogeography 16: 234-245.

Svenning J-C. (2001). On the role of microenvironmental heterogeneity in the ecology and diversification of neotropical rain-forest palms (Arecaceae). Botanical Review 67: 1-53.

Svenning J-C., Borchsenius F., Bjorholm S., Balslev H. (2008). High tropical net diversification drives the New World latitudinal gradient in palm (Arecaceae) species richness. Journal of Biogeography 35: 394-406.

Svenning J-C., Harlev D., Sorensen M., Balslev H. (2009). Topographic and spatial controls of palm species distributions in a montane rain forest, southern Ecuador. Biodiversity and Conservation 18: 219-228.

Thomas C.D., Cameron A., Green R.E., Bakkenes M., Beaumont L.J., Collingham Y.C., Erasmus B.F.N., Siqueira M.F.D., Grainger A., Hannah L. (2004). Extinction risk from climate change. Nature 427 (6970): 145-148. Doi:10.1038/nature02121

Thomas C.D., Gillingham P.K., Bradbury R.B., Roy D.B., Anderson B.J., Baxter J.M., Hill J.K. (2012). Protected areas facilitate species' range expansions. Proceedings of the National Academy of Sciences 109(35): 14063-14068. Doi: 10.1073/pnas.1210251109

Tiberio F.C.S., Sampaio-e-Silva T.A., Matos D.M.S., Antunes A.Z. (2015). The risks of introduction of the Amazonian palm *Euterpe oleracea* in the Atlantic rainforest. Brazilian Journal of Biology. Doi: 10.1590/1519-6984.12114

Tripp E.A., Dexter K.G. (2006). *Sabal minor* (Arecaceae): a new northern record of palms in eastern North America. Castanea 71: 172-177.

Trivedi M.R., Berry P.M., Morecroft M.D., Dawson T.P. (2008). Spatial scale affects bioclimate model projections of climate change impacts on mountain plants. Global Change Biology 14: 1089-1103. Doi: 10.1111/j.1365-2486.2008.01553.x

Vaz U.L., Nabout J.C. (2016). Using ecological niche models to predict the impact of global climate change on the geographical distribution and productivity of *Euterpe oleracea* Mart. (Arecaceae) in the Amazon. Acta Botanica Brasilica 30(2). Doi: 10.1590/0102-33062016abb0036.

Vedel-Sørensen M., Tovaranonte J., Bøcher P.K., Balslev H., Barfod A.S. (2013). Spatial distribution and environmental preferences of 10 economically important forest palms in western South America. Forest Ecology and Management 307(1): 284-292.

Vormisto J., Phillips O.L., Ruokolainen K., Tuomisto H., Vasquez R. (2000). A comparison of fine-scale distribution patterns of four plant groups in an Amazonian rainforest. Ecography 23: 349-359.

Walther G.R. (2000). Climatic forcing on the dispersal of exotic species. Phytocoenologia 30: 409-430.

Walther G.R. (2002). Weakening of climatic constraints with global warming and its consequences for evergreen broadleaved species. Folia Geobotanica 37: 129-139.

Walther G.R., Gritti E.S., Berger S., Hickler T., Tang Z.Y., Sykes M.T. (2007). Palms tracking climate change. Global Ecology and Biogeography 16: 801-809.

Westoby M. (1998). A leaf-height-seed (LHS) plant ecology strategy scheme. Plant and Soil 199: 213-227.

Wolf D.E., Takebayashi N., Rieseberg L.H. (2001). Predicting the risk of extinction through hybridization. Conservation Biology 15(4): 1039-1053.

Wright S.J. (1992). Seasonal drought, soil fertility and the species density of tropicalforest plant communities. Trends in Ecology & Evolution 7(8) 260-3. Doi: 10.1016/0169-5347(92)90171-7.

Zona S., Henderson A. (1989). A review of animal mediated seed dispersal of palms. Selbyana 11: 6-21.

3. CAPÍTULO I:

Damned if I do, damned if I don't: competitive strategies for tracking anthropogenic impacts

3.1. Resumo

A família Arecaceae é distribuída quase exclusivamente nos trópicos e subtrópicos e conduz a estrutura e o funcionamento de vários ecossistemas. As florestas tropicais são fortemente impactadas pela atividade humana e os riscos de extinção para palmeiras vêm aumentando num cenário de mudanças climáticas. Foi realizado um levantamento de características ecológicas utilizando bases bibliográficas, levando em consideração sua relação com impactos antrópicos e disponibilidade dos dados. Além disso, foi criado um ranking de sensibilidade das espécies de palmeira aos impactos antrópicos, utilizando essas características. Espécies de palmeira com maior sensibilidade são aquelas com distribuição restrita, arquitetura menos eficiente e dispersão restrita, em ordem decrescente de importância. Vinte e seis por cento das espécies de palmeiras neotropicais apresentaram um alto grau de sensibilidade aos impactos antrópicos, 72% apresentaram sensibilidade moderada e 2% apresentaram baixa sensibilidade. Os gêneros relativamente mais sensíveis são *Chamaedorea* Willd. (N = 52, 29%), *Syagrus* Mart. (N = 30, 19%) e *Wettinia* Poepp. ex Endl. (N = 14, 11%). As espécies mais sensíveis concentram-se na região da América Central, seguidas pela região do Brasil Central e a Floresta Costeira Atlântica. Os atributos ecológicos mostram que as palmeiras tendem a ter mais estratégias de escape do que estratégias de aclimatização. No entanto, dado o grande número de paisagens fragmentadas, o número de espécies sensíveis pode ser ainda maior. Sendo assim, sugerimos estudos populacionais para as espécies e regiões aqui identificadas como mais sensíveis aos impactos humanos e a identificação de outras características que podem ser relevantes para uso em metodologias de avaliação de risco, orientando os esforços de conservação.

Palavras-chave: atributos ecológicos, avaliação de risco, sensibilidade, Arecaceae

3.2. Abstract

The palm family Arecaceae is distributed almost exclusively in the tropics and subtropics and drives the structure and functioning of several ecosystems. Tropical forests are heavily impacted by human activity and the global extinction risks for palms are increasing under climate change scenario. A survey of ecological characteristics was carried out using bibliographic bases, considering their relationship with anthropic impacts and availability of data. In addition, a sensitivity to anthropic impacts ranking of palm species was created, using these attributes. Palm species showing greater sensitivity are those with (in decreasing order of importance) restricted distribution, less efficient architecture, and restricted dispersion. Twenty six percent of Neotropical palm species had a high degree of sensitivity to climate change, 72% had moderate sensitivity, and 2% had low sensitivity. The relatively most sensitive genera are *Chamaedorea* Willd. (N=52, 29%), *Syagrus* Mart. (N=30, 19%) and *Wettinia* Poepp. ex Endl. (N=14, 11%). The most sensitive species are concentrated in the Central American Region, followed by the Central Brazil Region and the Atlantic coastal forest. Ecological traits show that palm tend to have more escape strategies than acclimatization strategies. However, given the large number of fragmented landscapes, the number of sensitive species may be even greater. We suggest population studies for the species and regions identified here as more sensitive to human impacts. As well as the identification of other traits that may be relevant for use in risk assessment methodologies, guiding conservation efforts.

Keywords: ecological traits, risk assessment, sensitivity, Arecaceae

3.3. Introduction

Tropical regions hold the Earth's most diverse ecosystems (Gentry 1988; Whitmore 1998), structured by many botanical families, and this high species richness promotes a variety of ecological interactions (Terborgh 1986; Zona & Henderson 1989). The Arecaceae family is important in this context, with distribution almost exclusively in the tropics and subtropics (Eiserhardt et al. 2011). Approximately 2600 species in 181 genera are recognized in the family (Baker & Dransfield 2016). The high palm species richness and its different forms of growth are important elements of the forest's strata (Gentry 1988; Balslev et al. 2011), influencing the structure and functioning of several ecosystems (Lieberman et al. 1985; Balslev et al. 2011). Palms are involved in many ecological interactions and their products provide key resources for wildlife (Terborgh 1986; Zona & Henderson 1989) and humans (Macía et al. 2011).

Tropical forests are heavily impacted by human activity, especially by the loss and fragmentation of habitats, the overexploitation of fauna and flora, the introduction of invasive alien species and climate change (Wright 2005; Morris 2010; Pimm et al. 2014). Forest fragmentation promotes the loss of biodiversity by habitat reduction, but also by the abiotic and biotic changes that occur in ecosystems due to the openness in their environment. Fragmentation provides access, and consequently favors the hunting and exploitation of timber and non-timber forest products, which also have a significant effect on palm species. This impact can be direct in the death of the individual, as it happens in the case of the extraction of the heart of palm (Tiberio et al. 2015), or indirect through the extraction of leaves and fruits (Cibrián-Jaramillo et al. 2009).

In addition, forest fragmentation may potentiate the effects of climate changes, one of the main threats to diversity currently (Jetz et al. 2007). The large number of fragmented habitats prevents species movement, increasing potentially negative the effects of climate change, and this is especially important in the case of palms with low dispersal ability (Blach-Overgaard et al. 2010). Climate change may facilitate the invasion of exotic species into new areas, particularly for species of native hot areas introduced into currently marginal areas of temperature (Bradley et al. 2009, 2010). The expansion of tropical palm species to subtropical areas has already been observed as a consequence of the changes in the climate, which can result in alterations in communities' composition. Many palm

species have a high potential for invasion (Mengardo et al. 2012; Rejmánek 2014) and their commercial and landscape use intensifies this threat.

As can be seen, these factors act in a synergetic and complex way, although some species may present different sensitivities in relation to an impact, which would be associated to its intrinsic characteristics. Sensitivity evaluates the degree to which the performance, survival and persistence of a species is affected by an impact (Williams et al. 2008). Some ecological traits are typically available for a broad range of species (McKinney 1997) and can be incorporated simultaneously for different types of anthropogenic impacts into risk assessments studies, as an example we can cite: dispersal ability, habitat specialization and plant life form.

Palms depend on fauna to disperse their propagules for favorable habitats, to reduce density dependent effects and to be able to colonize new areas and to establish new individuals (Zona & Henderson 1989). This ability can be associated with propagule characteristics, plant phenology, disperser behavior and dispersal range (Vittoz & Engler 2007). Species with poor dispersal ability have less capacity to track climate change through scale changes in a climate change scenario (Dirnbock et al. 2010). However, despite the importance of intrinsic characteristics, it is also important to consider landscape structure and dispersion barriers existing within the distribution range.

The loss and fragmentation of habitats is a major problem for species of restricted habitats. Species with restricted ranges or small populations are predicted to have reduced capacity to adapt to environmental change (Brattstrom 1970). The habitat specialization may indicate that species with the ability to occur in a large range of habitats tend to: (1) have more flexibility in terms of available habitats if one range experiences greater anthropogenic impacts than another, and (2) have more capacity to tolerate environmental conditions variations, and it is proportional to the magnitude of the temperature variation they experience in their distribution range (Addo-Bediako et al. 2000).

The majority of palm species lack aerial branching and all leaf and stem growth occurs from a single apical meristem (Henderson 2002), which promotes low resilience to extreme conditions (Liesenfeld 2014). Resilience is the ability of species to survive and

recover from a perturbation and some traits that used to predict extinction risk include, for example, reproductive rates, life history, and life span (McKinney 1997).

The response mechanism of a species may be associated with the degree of sensitivity of the species to the changes or the degree of exposure present in the environment in which it occurs. We sought to identify ecological traits that could be clearly related to predictive variables of anthropic impacts and availability of data in order to create a database that would aid in palm's risk assessment. In addition, these traits can be important to identify ecological strategies after anthropogenic impacts, such as escape, permanence / acclimatization and resilience. A ranking of Neotropical palms sensitivity to anthropogenic impacts was made in order to indicate species and regions that need more conservation efforts.

3.4. Methods

A database was assembled using bibliographic bases, such as: Henderson (1995), botanical monographs and academic articles, with information on morphological and ecological characteristics of Neotropical palms. The botanical synonyms were considered, and the botanical names were standardized using the Kew checklist. The traits considered important for this analysis, their respective justifications and methodologies used to obtain them, are described below:

3.4.1. Ecological traits

Habitat specialization scores were determined through a combination of latitudinal and altitudinal range of the species, since both are associated with environmental variation (Table 1). The assumption was made that a narrower distribution range corresponds to higher niche restriction and that such species consequently are more vulnerable to environmental variations, such as habitat loss, edge effect and climate change. The latitudinal distribution data were obtained in the GBIF, with its range calculated in the Arcgis software and the information on the altitudinal distribution in bibliographic material.

Dispersal ability scores were determined through a combination of disperser specificity, dispersion distance, and number of fruits available for dispersion. Different dispersers use this resource in different ways due to the diversity of palm fruit morphology. The morphological characteristics of the fruits are related to the behavior of the frugivorous groups that disperse them, although this is not always obvious. The large size of some seeds and the presence or absence of pulp or spines define the consumer community and affect dispersal ability (Zona & Henderson 1989). Some palms require large frugivores to disperse large seeds that cannot be swallowed and successfully dispersed by smaller frugivores. Usually these frugivores disperse fruits from several plant species over distances of several kilometers (Galetti et al. 2013). In contrast, some palms that require specific germinative conditions of luminosity and humidity, and thus particular places of seed deposition by the disperser, are dependent on scatter hoarding (Galetti at al. 2006). Taxa with more disperser species, a greater distance of dispersion, and producing a greater number of fruits, scored higher dispersal ability (Table 1). These characteristics were attributed to the behavior of the dispersers, when known, and to the fruit morphology of each species, obtained through the specialized literature.

Stem architecture scores were determined from the form of stem and consequently with the number of meristems of each taxon, that reflects mechanical vulnerability to extreme environmental conditions, diseases and vegetal product extraction. Species with underground stem are more resilient than species with aerial stem (Table 1). Species with underground stem, after storms or fires, for example, are often able to recover completely, without damage their meristem (Liesenfeld 2014). However, when individuals with aerial stem suffer damage to their meristem, those with more than one stipe (clustered stem) present a greater capacity to recover those with only one meristem (solitary stem).

3.4.2. Data analysis

Among the 818 palms species present in the neotropics (Govaerts et al. 2019), 690 species (85%) were included in this evaluation, because only those species that necessarily contained the information of all evaluated traits were included in the analysis.

The species were categorized according to the sensitivity of each trait, to the anthropic impacts, using the following scores: low (1), moderate (2) and high sensitivity (3). The final scores were defined using the resulting sum of the traits and the species were classified as: low (scores ≥ 3 and < 5), moderate (≥ 5 and < 7) and high sensitivity species (≥ 7 and < 9). Below we define each criterion, providing justification for inclusion and details on how each criterion was scored.

Table 1. Summary of the components used to classify each palm species and its traits in each sensitivity criterion category.

Score	Sensitivity	Traits		
		Habitat specialization	Dispersal ability	Stem architecture
1	Low	They occur in more than 20 degrees of latitude rand with an altitude amplitude more than 1,000 meters	Big amount of fruits with pulp and bright colors, dispersed by different groups of large frugivores, which reach long distances	subterranean stem
2	Moderate	They occur between 10- and 20-degrees of latitude and with an altitudinal amplitude ranging from 500 and 1,000 meters	Small amount of little and medium fruits with pulp and bright colors, dispersed by a single frugivore group, mostly small-bodied species, which reaches short distances.	clustered stem and climbing plants
3	High	They occur in less than 10 degrees latitude and in an altitude range of less than 500 meters	Fibrous fruits dispersed by small frugivores and scatter-hoarding or fruits dispersed by a single known species (specialist) or fruits with pulp but in very small amount	solitary stem

Through a combination of each trait scores, some ecological strategies of neotropical palm species were suggested: adaptation / acclimatization, shift range, both strategy, extinction risk and undefined (Table 2).

Table 2. Summary of the components used to classify each palm species in each ecological strategy

Ecological strategy	Description	Score
Adaptation / acclimatization	Species occurring in a large distribution range, and consequently wide environmental variation	Habitat specialization: 1 Dispersal ability: 2 or 3 Stem architecture: 1, 2 or 3
Shift range	Species with high dispersal ability, with many fruits available, dispersed over a range of dispersers and able to reach longer distances	Habitat specialization: 2 or 3 Dispersal ability: 1 Stem architecture: 1, 2 or 3
Both strategy	Species occurring in a large distribution range and with high dispersal ability	Habitat specialization: 1 Dispersal ability: 1 Stem architecture: 1, 2 or 3
Extinction risk	Species occurring in a narrow distribution range and with low dispersal ability	Habitat specialization: 3 Dispersal ability: 3 Stem architecture: 1, 2 or 3
Undefined	When none of the above criteria were met	Habitat specialization: 2 or 3 Dispersal ability: 2 or 3 Stem architecture: 1, 2 or 3

3.4.2. Palm diversity regions

The species were classified according to seven regions of palm diversity (Henderson et al. 1995): Amazon region, Andean region, Atlantic coastal forest, Caribbean region, Central American region, Central Brazilian region, and Mexican region. These subdivisions were chosen because they correspond to centers of endemism or at least centers of diversity. A brief description of each region follows below, and a more detailed description can be seen at Henderson et al. (1995).

Amazon region. This is the largest of the seven regions and includes all of the immense lowland rain forest of the Amazon and Orinoco basins and of the Guianas. Rainfall is high, typically over 1500 mm annually and reaching 6000 mm in some of the western parts. The vegetation types comprise open savanna, cerrado, campina, and lowland, premontane, and montane rain forest.

Andean region. This region extends from Venezuela to Argentina and consists of a narrow, volcanic mountain chain over 800 km in length, with multiple ranges. Rainfall is unevenly distributed in the Andes. In the tropical areas, where palms occur, there are two rainy seasons per year. The highest rainfall is at intermediate elevations (500–1500 m) and decreases with increasing elevation. Variations in topography and climate create dozens of habitat types in the Andes, ranging from desert to rain forest.

Atlantic coastal forest. This region occurs in Brazil and extends from the Rio Grande do Norte state to the Rio Grande do Sul state. Annual rainfall ranges from 1800 mm in the northern part to over 4000 mm in parts of the south. This region contains various habitats including the restinga, campo rupestre, and Araucaria forest.

Caribbean region. This region includes the Greater and Lesser Antilles, and the coastal plains of the United States of America (Florida and Texas), Mexico, Belize, Colombia, and Venezuela. The dominant weather comes from the mountain region where average annual rainfall ranges from 1000 to 2000 mm. In contrast, rain shadow areas can receive as little as 600 mm per year. The vegetation ranges from premontane and montane rain forest in mountainous areas to thorn scrub or desert in rain shadow areas.

Central American region. This is a diverse area in terms of geology, climate, and vegetation type, and extends from southern Mexico to northwestern Ecuador. The annual rainfall varies from 1000 to 12000 mm. Deciduous forests are widespread, but lowland, premontane, and montane forests also occur. Pine-oak forests are common in the northern part of Central America.

Central Brazilian region. This region includes the drier regions of central and northeastern Brazil and adjacent Bolivia, Paraguay, Uruguay, and Argentina. There are various vegetation types, including caatinga, cerrado, pantanal, chaco, llanos, open grassland, and savanna. All these regions have low, strongly seasonal rainfall that does not permit the development of evergreen forests.

Mexican region. This region comprises the drier, inland deserts and mountains of Mexico and the adjacent parts of the United States of America (Texas, New Mexico, Arizona, and California). This area receives between 50 and 400 mm of rain per year, and the vegetation is dominated by plants adapted to very dry areas.

We calculated the proportion of sensitive palm species in each region to provide managers with conservation focal points for the family.

3.5. Results

Our results show that 56% of Neotropical palm species had a high degree of sensitivity to anthropogenic impacts, 41% had moderate sensitivity, and 3% had low sensitivity. The sensitive species to climate change is those with restricted distribution (74%), low resilience after a damage (52%), and low dispersion ability (14%), with the traits in this order explaining greater species sensitivity to anthropogenic impacts.
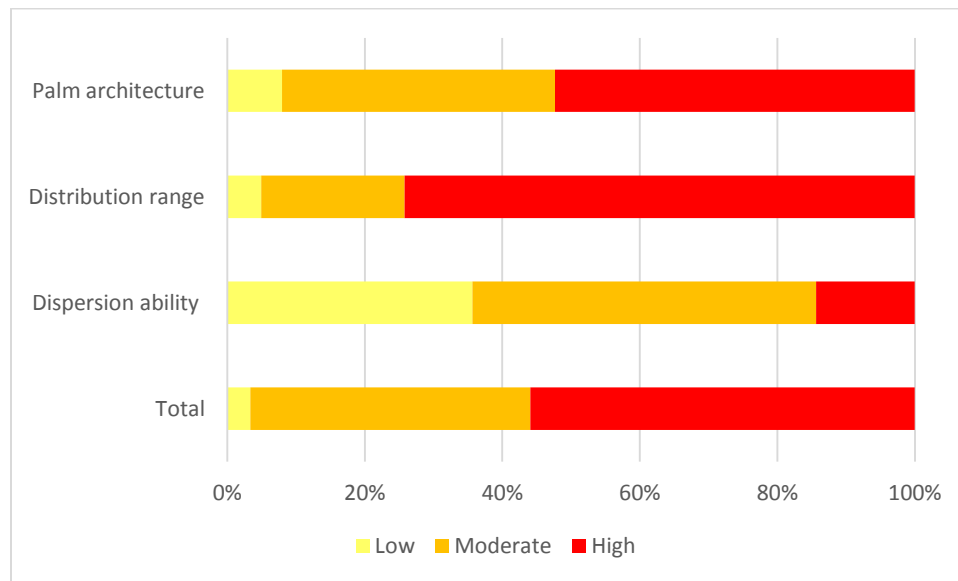
Figure 1. The percentage of Neotropical palm species featuring the individual evaluated traits, showing different degrees of sensitivity to anthropogenic impacts. Yellow, orange, and red correspond to low, moderate, and high sensitivity, respectively.

Based on the characteristics assessed, the most sensitive species to anthropogenic impacts are Aphandra natalia (Balslev & A.J.Hend.) Barfod, Astrocaryum alatum Loomis, Astrocaryum ciliatum F.Kahn & B.Millán, Astrocaryum confertum H.Wendl. ex Burret, Astrocaryum farinosum Barb.Rodr, Astrocaryum ferrugineum F.Kahn & B.Millán , Astrocaryum triandrum Galeano, Attalea brejinhoensis (Glassman) Zona, Attalea dahlgreniana (Bondar) Wess.Boer, Attalea tessmannii Burret, Jubaea chilensis (Molina)

Baill., Parajubaea cocoides Burret, Parajubaea sunkha M.Moraes, Parajubaea torallyi (Mart.) Burret, Phytelephas aequatorialis Spruce, Phytelephas tumacana O.F.Cook, Syagrus botryophora (Mart.) Mart, Syagrus hoehnei Burret, Syagrus longipedunculata Noblick & Lorenzi, Syagrus picrophylla Barb.Rodr., Syagrus smithii (H.E.Moore) Glassman, Syagrus yungasensis M.Moraes, Wettinia castanea H.E.Moore & J.Dransf., Wettinia longipetala A.H.Gentry, Wettinia verruculosa H.E.Moore. These species present less ability in all traits used in the study, that is, reduced capacity of acclimatization, dispersion and resilience after a damage, and consequently would be at great risk of extinction under an anthropic stress scenario.

Considering that species with a broad altitudinal and latituninal distribution present greater niche amplitude and more areas available for species maintenance, the species that would present a strategy of remaining in the altered environment are: Astrocaryum aculeatum Mart., Astrocaryum jauari Mart., Bactris simplicifrons Mart., Chamaedorea allenii L.H.Bailey, Chamaedorea costaricana Oerst., Chamaedorea linearis (Ruiz & Pav.) Mart., Chamaedorea pinnatifrons (Jacq.) Oerst., Desmoncus horridus Mart., Geonoma brevispatha (H.Wendl. ex Drude) A.J.Hend., Geonoma euspatha Burret, Geonoma interrupta (Ruiz & Pav.) Mart., Geonoma lehmannii Dammer ex Burr., Geonoma macrostachys Mart., Geonoma maxima (Poit.) Kunth, Geonoma orbignyana Mart., Geonoma pinnatifrons Willd., Geonoma pohliana Mart., Manicaria saccifera Gaertn., Prestoea ensiformis (Ruiz & Pav.) H.E.Moore.

Whereas there are available dispersers, 231 species have high dispersion ability and consequently, if necessary, would change the distribution range. This strategy pattern was found mainly within the genera: Aiphanes Willd., Brahea Mart., Ceroxylon Bonpl. ex DC., Coccothrinax Sarg., Copernicia Mart. ex Endl., Cryosophila Blume, Dictyocaryum H.Wendl., Gaussia H.Wendl., Hyospathe Mart., Hemithrinax Hook.f., Iriartella H.Wendl., Juania Drude, Leopoldinia Mart., Leucothrinax C.Lewis & Zona, Mauritia L.f., Mauritiella Burret, Oenocarpus Mart., Pholidostachys H.Wendl. ex Benth. & Hook.f., Pseudophoenix H.Wendl. ex Sarg., Roystonea O.F.Cook, Sabal Adans, Schippia Burret, Serenoa Hook.f., Socratea H.Karst., Synechanthus H.Wendl., Thrinax L.f. ex Sw. and Welfia H.Wendl.
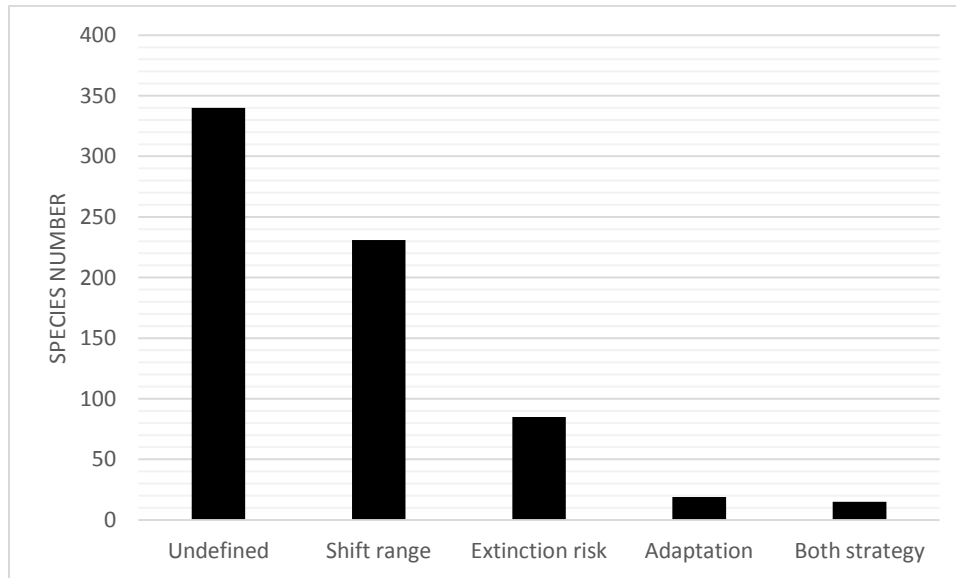
Figure 2. Number of Neotropical palm species in each potential ecological strategy as a result of anthropic impact.

Five genera together represent more than half of the species more sensitive to anthropogenic impacts: *Chamaedorea* Willd. (N=85, 22%), *Syagrus* Mart. (N=39, 10%), Geonoma Willd. (N=30, 8%), Bactris Jacq. ex Scop. (N=23, 6%) and Attalea Kunth (N=22, 6%). However, it is interesting to note that some genera, with few species present all their species with characteristics that make them sensitive to anthropogenic impacts, which are: *Ammandra* O.F.Cook (N=1), *Aphandra* Barfod (N=1), Asterogyne H.Wendl. ex Hook.f. (N=5), Calyptronoma Griseb. (N=3), Chelyocarpus Dammer (N=4), Gaussia H.Wendl (N=5), Hemithrinax Hook.f. (N=3), *Itaya* H.E.Moore (N=1), *Jubaea* Kunth in F.W.H.von Humboldt (N=1), *Parajubaea* Burret (N=3), *Phytelephas* Ruiz & Pav. (N=5), Pseudophoenix H.Wendl. ex Sarg. (N=4) and *Raphia* P.Beauv. (N=1), Schippia Burret (N=1), Zombia L.H.Bailey (N=1).
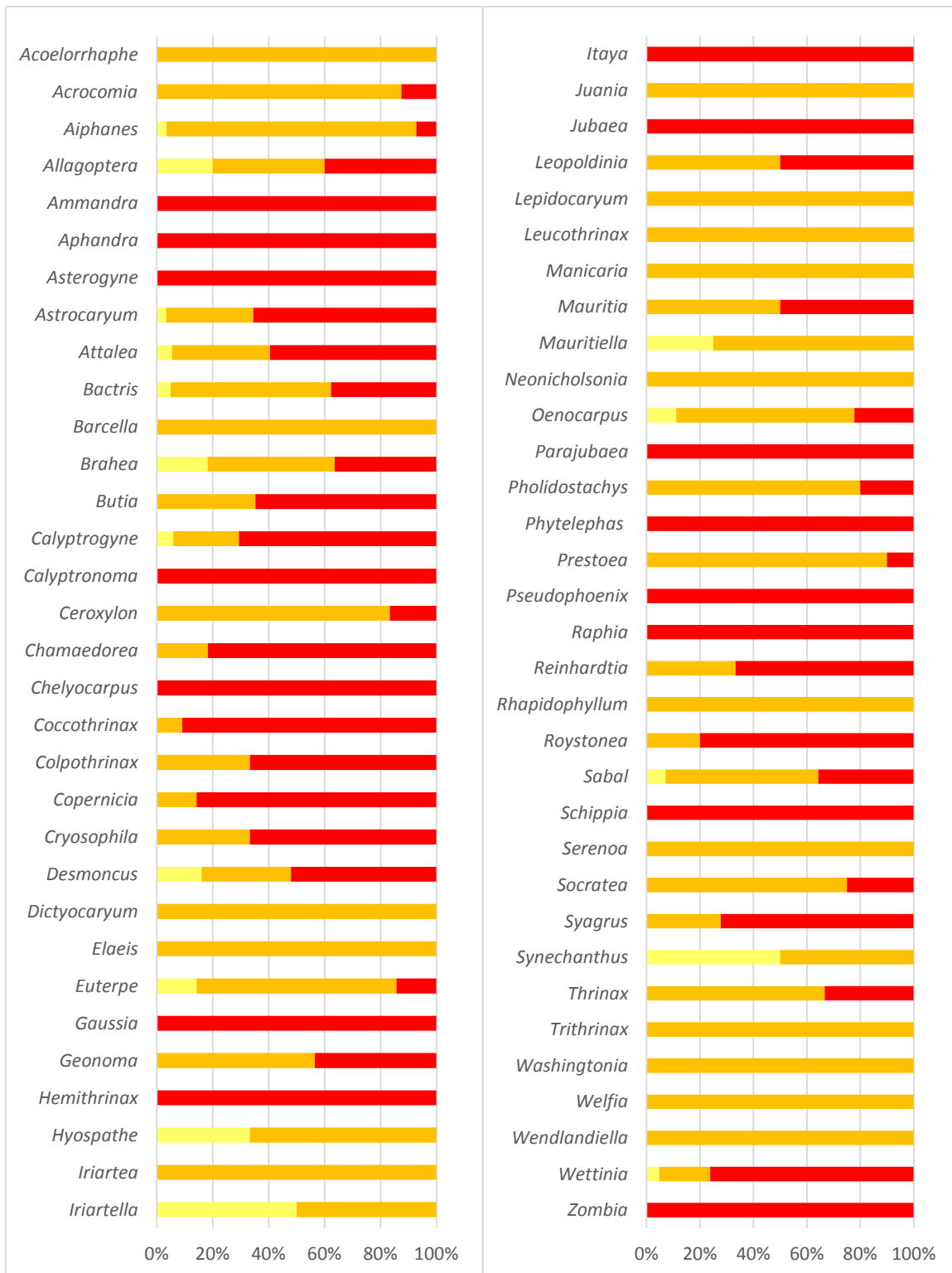
Figure 3. The percentage of Neotropical palm species in each genus showing different degrees of sensitivity to anthropogenic impacts. Yellow, orange, and red correspond to low, moderate, and high sensitivity, respectively.

The majority of species that are highly sensitive to anthropogenic impacts, proportionately in each region, are concentrated in the Central America region (33%), followed by the Central Brazilian region (30%), Atlantic coastal forest (27%), Andean region (22%), Amazon region (19%), and Mexican region (10%).
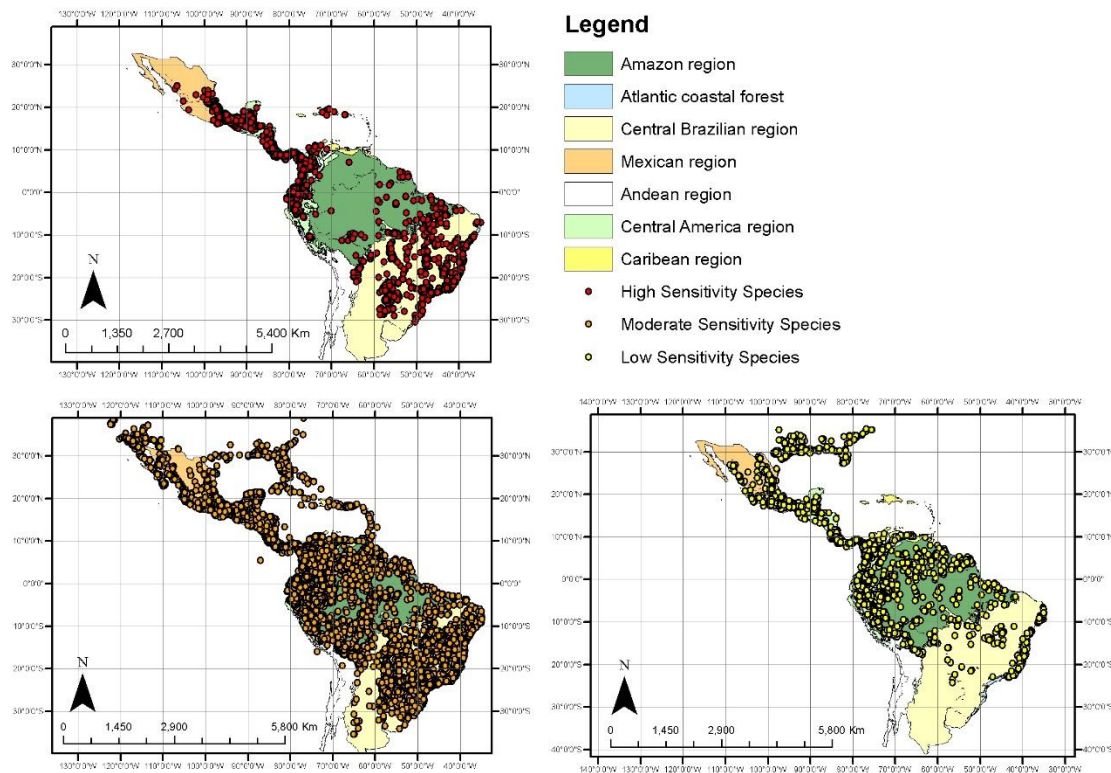
Figure 4. Occurrences records of Neotropical palm species in each region showing different degrees of sensitivity to anthropogenic impacts. Yellow, orange, and red correspond to low, moderate, and high sensitivity, respectively.

3.6. Discussion

The fact that 56% (N=386) of Neotropical palm species show high sensitivity to anthropogenic impacts is an alarming finding, especially considering the functional and structural importance of palm in tropical ecosystems (Gentry 1988; Lieberman et al. 1985; Balslev et al. 2011; Terborgh 1986; Zona & Henderson 1989; Macía et al. 2011). Some of these species that show high sensitivity to anthropogenic impacts present great dominance or hyperdominance in some regions. In the Amazon region, for example, *Astrocaryum*

chambira, *Attalea plowmanii*, *Phytelephas tenuicaulis*, *Attalea butyracea* have great dominance and importance in structuring the local community (Vormisto et al. 2004; Ter Steege et al. 2013). This concerns not only the palm community, but the complete tropical ecosystems that are integrated, once palms interact with a wide range of frugivores that depend on their fruits. The potential species loss associated with anthropogenic impacts bring irreversible changes to tropical forests and to all people who depend on them (Figure 4).

Figure 4. Some examples of anthropic use of Neotropical palm species considered sensitive to anthropogenic impacts, shown from left to right: woman making mats from chambira fibres (*Astrocaryum chambira*) (<http://www.rainforestconservation.org>); leaves from *Attalea butyracea* used during Palm Sunday in Bogotá, Colombia, 1990 (Bernal et al 2010); Selling brooms produced from a palm fibre (*Aphandra natalia*) (<http://www.fao.org/mediabase/forestry/>); Artist work carving Tagua seed (*Phytelephas macrocarpa*), Ivory nut in Ecuador, South America.

Among the species studied here only 11% (N = 78) were evaluated by IUCN Red List. Of the 179 most sensitive palm species, only 40 are included in an IUCN Red List threat category: Least Concern (13), Near Threatened (6), Vulnerable (11), Endangered (9),

Critically Endangered (1). Among the 13 species evaluated here as low sensitivity to anthropogenic impacts, three were considered by the IUCN to be of low concern and the rest were not evaluated. Although some species are not currently at risk today, our study aims to show the list of species most sensitive to the environmental variations promoted in the anthropocene. The IUCN Red List has a well-recognized methodology that takes into account several criteria that involve population viability, land use and its history of exploitation, among others. However, here we use different intrinsic variables, not incorporated by the IUCN, in order to join efforts, providing a list of palm species that should have their evaluation done.

The impact of harvesting and the reduction and degradation of a species' habitat is an evaluation criteria of IUCN Red List. The exploitation of timber and non-timber resources can contribute to a greater vulnerability of the species as a whole. For example, *Chamaedorea ernesti-augusti* H. Wendl of Central America, evaluated in this study as moderately sensitive, is potentially more sensitive if overexploitation of its leaves and inbreeding depression is taken into account (Cibrián-Jaramillo et al. 2009). However, in this study we chose to consider only intrinsic information about palm species, but that had not previously used in this type of analysis for the family.

It is important to emphasize that the comparison was only carried out between palm species. This family has a more reduced dispersion capacity than other plant species (Henderson 2002). In addition, many of these species are dispersed by large frugivores, and a high degree of defaunation would likely result in increased sensitivity (Galetti et al. 2006; Galetti et al. 2013).

The restricted distribution range of most palm species is worth taking into account. Many species are restricted to a single area or even a single population (for example *Crysophila cookii*, Henderson et al. 1995); together with low physiological or mechanical resistance to climate change and limited capacity to disperse to favorable environments, this renders these species more vulnerable to extinction. Small or isolated populations of palms usually have a narrow germination niche (Braz et al. 2014) and are highly vulnerable with a high risk of extinction (Shapcott et al. 2012; Krause et al. 2015) due to the potential of small environmental changes to cause irreversible consequences for the species.

Therefore, considering the probable thermal niche specificity, it is expected that in a scenario of climate change, palm would generally present more escape strategies than acclimatization strategies.

The palm diversity regions noted above also harbor nine global biodiversity hotspots (Myers et al. 2000, modified by the NGO Conservation International in 2005). These are regions of high species richness with a high degree of threat especially caused by habitat loss. Palms are partly responsible for the large diversity of these hotspots, but also suffer from habitat loss (Galetti et al. 2006; Galetti et al. 2013). The Central American Region is one of the most diverse regions of palm in the Neotropics and this study showed that 33% of its species with high sensitivity to anthropogenic impacts. Central Brazilian Region (30%) and Atlantic Coastal Forest (27%) also presented high number of species with high sensitivity. Apparently, there is no relationship with the environmental characteristics of these regions, which are quite different. Thus, the insertion of physiological traits may be interesting for a sensitivity analysis, thus considering the physiological limitations of the species in a changing climate. However, it is known that such traits are difficult to obtain for a macroscale study.

Another issue that must be investigated is the low number of species with high sensitivity to anthropogenic impacts in the Amazon region, when compared to other regions that also have high diversity. This may occur, since the Amazon has many understory species, mostly with grouped stem (Kahan et al. 1988) and species with small / medium fruits dispersed by a large range of dispersers (Levey1987). We recommend that conservation management in this region promote the retention of intact habitats in order to preserve the existing small populations of these species, since it is a region that suffers with the habitat loss.

However, attending to the bottom of the list is as important as looking at the top. Both fragmentation and climate change may facilitate the invasion of exotic species into new areas. This particularly applies to species native to hot regions introduced to areas of currently marginal temperature. We can expect subtropical species to invade warmer temperate areas, and temperate species to invade warmer boreal areas (Bradley et al. 2010). *Sabal minor*, for example, has showi a northward range expansion in response to climate

warming in northeast North Carolina, that currently represents the furthest known northern population of the largely tropical family Arecaceae in eastern North America (Tripp & Dexter 2006; Butler & Tran 2017).

The Arecaceae have a high invasion potential, making up a substantial percentage of invasive species in the tropics (Mengardo et al. 2012; Rejmánek 2014). Of the species evaluated in this study, *Euterpe oleracea*, which show low sensitivity to climatic changes, constitute a sizable threat to Panama forests (Svenning 2002), and according to models, will have its environmental suitability areas expanded in response to climate change (Vaz et al. 2016). Many species with low sensitivity to anthropogenic impacts are used in gardening and landscaping, generally with little oversight or regard for invasive species issues. Palm lovers need to be aware that promoting a fewer sensitive species outside its distribution range may inadvertently damage a sensitive species in its original habitat.

Finally, in this study we defined important ecological traits, useful for indicating strategies of escape, permanence / acclimatization and resilience after anthropic impact. With the robust database attached, it is possible to identify the strategy of 693 neotropical palm species, as well as their sensitivity to anthropic impacts. Ecological traits show that palm tend to have more escape strategies than acclimatization strategies. However, given the large number of fragmented landscapes in the Americas, the number of sensitive species may be even greater. Instead, we show the importance of knowing both top and bottom species of the list. Knowing the most threatened genus are also important because even those with few species, the extinction a genus brings taxonomic, ecological and functional consequences for a larger ecosystem than the extinction of a single species. In addition, we show those regions of palm diversity of the Neotropic that, regardless of their degree of exposure to climate change or loss / degradation of habitat, would have higher species losses, considering only intrinsic species characteristics.

In the face of already occurring climatic changes, which can potentiate other anthropic impacts, political actions for conservation are urgently needed for these species, genera and these regions pointed here. We suggest population studies for the species and regions identified here as more sensitive to human impacts, as well as the identification of

other traits that may be relevant for use in risk assessment methodologies, which may guide conservation efforts.

References

Addo-Bediako A., Chown S.L., Gaston, K.J. (2000) Thermal tolerance, climatic variability and latitude. Proceedings of the Royal Society of London B 267: 739–745.

Blach-Overgaard A., Balslev H., Dransfield J., Normand S., Svenning, J-C. (2015). Global-change vulnerability of a key plant resource, the African palms. Scientific Reports 5, 12611. Doi: 10.1038/srep12611

Baker W.J., Dransfield J. (2016). Beyond Genera Palmarum: progress and prospects in palm systematics. Botanical Journal of the Linnean Society 182: 207-233.

Balslev H., Kahn F., Millan B., Svenning J-C., Kristiansen T., Borchsenius F., Pedersen D., Eiserhardt W. (2011). Species Diversity and Growth Forms in Tropical American Palm Communities. The Botanical Review 77: 381-425.

Bernal R., Galeano G., García N., Olivares I.L., Cocomá C. (2010). Uses and Commercial Prospects for the Wine Palm, Attalea butyracea, in Colombia. Ethnobotany Research & Applications 8:255-268.

Blach-Overgaard A., Svenning J-C., Dransfield J., Greve M., Balslev H. (2010). Determinants of palm species distributions across Africa: the relative roles of climate, non-climatic environmental factors, and spatial constraints. Ecography 33: 380-391.

Bradley B.A., Wilcove D.S., Oppenheimer M. (2009). Climate change increases risk of plant invasion in the Eastern United States. Biol Invasions. Doi 10.1007/s10530-009-9597-y

Bradley B.A., Blumenthal D.M., Wilcove D.S., Ziska L.H. (2010) Predicting plant invasions in an era of global change. Trends in Ecology and Evolution 25: 310-318.

Brattstrom B.H. (1970). Thermal acclimation in Australian amphibians. Comparative Biochemistry and Physiology 35: 69-103.

Braz M.I.G., Portela R.C.Q., Cosme L.H.M., Marques V.G.C., Mattos E.A. (2014). Germination niche breadth differs in two co-occurring palms of the Atlantic Rainforest. Natural Conservation 12(2): 124-128. Doi: 10.1016/j.ncon.2014.09.003.

Butler C.J., Tran H.B. (2017). Dwarf Palmetto (Sabal minor) Population Increase in Southeastern Oklahoma. Castanea 82(2):163-168. Doi: 10.2179/16-114

Ceballos G., Ehrlich P.R., Barnosky A.D., Garcia A., Pringle R.M., Palmer T.M. (2015). Accelerated modern human-induced species losses: entering the sixth mass extinction. Science Advances, 1, e1400253. Doi:10.1126/sciadv.1400253.

Cibrian-Jaramillo A., Bacon C.D., Garwood N.C., Bateman R.M., Thomas M.M., Russell S., Bailey C.D., Hahn W.J., Bridgewater S.G., De Salle R. (2009). Population genetics of the understory fishtail palm Chamaedorea ernesti-augusti in Belize: high genetic connectivity with local differentiation. BMC Genetics 10(65).

Dirnböck T., Essl F., Rabitsch W. (2010). Disproportional risk for habitat loss of high-altitude endemic species under climate change. Global Change Biology, 17: 990-996.

Galetti M., Guevara R., Côrtes M.C., Fadini R., Von Matter S., Leite A.B., Labecca F., Ribeiro T., Carvalho C.S., Collevatti R.G., Pires M.M., Guimarães P.R., Brancalion P. H., Ribeiro M.C., Jordano P. (2013). Functional Extinction of Birds Drives Rapid Evolutionary Changes in Seed Size. Science 340: 1086-1090. Doi: 10.1126/science.1233774

Galetti M., Donatti C.I., Pires A.S., Guimarães Jr. P.R., Jordano P. (2006). Seed survival and dispersal of an endemic Atlantic forest palm: the combined effects of defaunation and forest fragmentation. Botanical Journal of the Linnean Society 151: 141-149.

Gentry A.H. (1988). Changes in plant community diversity and floristic composition on environmental and geographical gradients. Annals of the Missouri Botanical Garden 75: 1-34.

Govaerts R., Dransfield J., Zona S., Hodel D.R., Henderson, A. (2019). World Checklist of Arecaceae. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet; http://wcsp.science.kew.org/ Retrieved

Henderson A.J., Galeano G., Bernal R. (1995). Field Guide to the palms of the Americas. Princeton: Princeton University Press.

Henderson A. (2002). Evolution and Ecology of Palms. New York: The New York Botanical Garden Press.

Jetz W., Wilcove D.S., Dobson A.P. (2007). Projected Impacts of Climate and Land-Use Change on the Global Diversity of Birds. PLoS Biol 5(6): e157. https://doi.org/10.1371/journal.pbio.0050157

Kahan F., Mejia K., Castro A. (1988). Species Richness and Density of Palms in Terra Firme Forests of Amazonia. Biotropica 20(4): 266-269

Krause C.M., Cobb N.S., Pennington D.D. (2015). Range shifts under future scenarios of climate change: Dispersal ability matters for Colorado Plateau endemic plants. Natural Areas Journal 35: 428-438.

Levey D.J. (1987). Seed size and fruit-handling techniques of avian frugivores. American Naturalist 129: 471–485

Lieberman M., Lieberman D., Hartshorn G.S., Peralta R. (1985). Small-Scale Altitudinal Variation in Lowland Wet Tropical Forest Vegetation. Journal of Ecology 73(2): 505-516. Doi:10.2307/2260490.

Liesenfeld M.V.A. (2014). Efeitos do fogo de superfície experimental na ecologia de palmeiras (Arecaceae) de sub- bosque em uma floresta na Amazônia ocidental. Tese (Ciências de Florestas Tropicais (CFT)) - Instituto Nacional de Pesquisas da Amazônia, Manaus, Brazil. 209 f.

Macía M.J., Armesilla P.J., Cámara-Leret R., Paniagua-Zambrana N., Villalba S., Balslev H., Pardo-de-Santayana M. (2011). Palm Uses in Northwestern South America: A Quantitative Review. Botanical Review. Doi: 10.1007/s12229-011-9086-8.

McKinney M. L. (1997). Extinction Vulnerability and Selectivity: Combining Ecological and Paleontological Views. Annual Review of Ecology, Evolution, and Systematics 28: 495-516.

Mengardo A.L.T, Figueiredo C.L., Tambosi L.R., Pivello V.R. (2012). Comparing the establishment of an invasive and an endemic palm species in the Atlantic rainforest, Plant Ecology & Diversity 5 (3): 345-354. Doi: 10.1080/17550874.2012.735271.

Morris R.J. (2010). Anthropogenic impacts on tropical forest biodiversity: a network structure and ecosystem functioning perspective. Philosophical Transactions: Biological Sciences 365: 3709-3718. Doi:10.1098/rstb.2010.0273

Myers N., Mittermeier R.A., Mittermeier C.G., Fonseca G.A.B., Kent J. (2000). Biodiversity hotspots for conservation priorities. Nature 403: 853-858.

Pimm S.L, Jenkins C.N., Abell R., Brooks T.M., Gittleman J.L., Joppa L.N., Raven P.H., Roberts C.M., Sexton J.O. (2014). The biodiversity of species and their rates of extinction, distribution, and protection. Science 344: 1246752.

Rejmánek M. (2014). Invasive trees and shrubs: where do they come from and what we should expect in the future? Biological Invasions 16: 483-498. Doi: 10.1007/s10530-013-0603-z

Shapcott A., Hutton I., Baker W.J., Auld T.D. (2012). Conservation genetics and ecology of an endemic montane palm on Lord Howe Island and its potential for resilience. Conservation Genetics 13: 257-270. Doi: 10.1007/s10592-011-0282-1

Svenning J-C. (2002). Non-Native Ornamental Palms Invade a Secondary Tropical Forest in Panama. Palms 46(2): 81-86.

Ter Steege H., Pitman N.C.A., Sabatier D., Baraloto C., Salomão R.P., Guevara J.E., Phillips O.L., Castilho C.V., Magnusson W.E., Molino J-F., Monteagudo A., Vargas P.N., Montero J.C., Feldpausch T.R., Coronado E.N.H., Killeen T.J., Mostacedo B., Vasquez R., Assis R.L., Terborgh J., Wittmann F., Andrade A., Laurance W.F., Laurance S.G.W, Marimon B.S., Marimon B.H., Vieira I.C.G., Amaral I.L., Brienen R., Castellanos H., López D.C., Duivenvoorden J.F., Mogollón H.F., Matos F.D.A., Dávila N., García-Villacorta R., Diaz P.R.S., Costa F., Emilio T., Levis C., Schietti J., Souza P., Alonso A., Dallmeier F., Montoya A.J.D, Piedade M.T.F., Araujo-Murakami A., Arroyo L., Gribel R., Fine P.V.A., Peres C.A., Toledo M., Baker T.R., Cerón C., Engel J., Henkel T.W., Maas P., Petronelli P., Stropp J., Zartman C.E., Daly D., Neill D., Silveira M., Paredes M.R., Chave J., Lima-Filho D.A., Jørgensen P.M., Fuentes A., Schöngart J., Valverde F.C., Di Fiore A., Jimenez E.M., Mora M.C.P., Phillips J.F., Rivas G., Van Andel T.R., Von Hildebrand P., Hoffman B., Zent E.L., Malhi Y., Prieto A., Rudas A., Ruschell A.R., Silva N., Vos V., Zent S., Oliveira A.A., Schutz A.C., Gonzales T., Nascimento M.T., Ramirez-Angulo H., Sierra R., Tirado M., Medina M.N.U., Van Der Heijden G., Vela C.I.A., Torre E.V, Vriesendorp C., Wang O., Young K.R., Baider C., Balslev H., Ferreira C., Mesones I., Torres-Lezama A., Giraldo L.E.U., Zagt R., Alexiades M.N., Hernandez L., Huamantupa-Chuquimaco I., Milliken W., Cuenca W.P., Pauletto D., Sandoval E.V., Gamarra L.V., Dexter K.G., Feeley K., Lopez-Gonzalez G., Silman M.R. (2013). Hyperdominance in the Amazonian Tree Flora. Science 342: 1243092.

Terborgh J. (1986). Keystone plant resources in the tropical forest. In M. Soule (Ed.), Conservation biology: science of scarcity and diversity (pp. 330–344). Sunderland, MA: Sinauer.

Thomas C.D., Cameron A., Green R.E., Bakkenes M., Beaumont L.J., Collingham Y.C., Erasmus B.F.N., Siqueira M.F.D., Grainger A., Hannah L. (2004). Extinction risk from climate change. Nature 427 (6970): 145-148. Doi: 10.1038/nature02121

Tiberio F.C.S., Sampaio-e-Silva T.A., Matos D.M.S., Antunes A.Z. (2015). The risks of introduction of the Amazonian palm *Euterpe oleracea* in the Atlantic rainforest. Brazilian Journal of Biology. Doi: 10.1590/1519-6984.12114

Tripp E.A., Dexter K.G. (2006). *Sabal minor* (Arecaceae): a new northern record of palms in eastern North America. Castanea 71: 172-177.

Vaz U.L., Nabout J.C. 2016. Using ecological niche models to predict the impact of global climate change on the geographical distribution and productivity of *Euterpe oleracea* Mart. (Arecaceae) in the Amazon. Acta Botanica Brasilica 30(2). Doi: 10.1590/0102-33062016abb0036.

Vittoz P., Engler R. (2007). Seed dispersal distances: a typology based on dispersal modes and plant traits. Bot. Helv. 117: 109–124

Vormisto J., Svenning J.-C., Hall P., Balslev H. (2004). Diversity and dominance in palm (Arecaceae) communities in terra firme forests in the western Amazon basin. J. Ecol. 92:577-588. http://dx.doi.org/10.1111/j.1600-0587.2000.tb00291.x

Wheatley C.J., Beale C.M., Bradbury R.B., Pearce-Higgins J.W., Critchlow R., Thomas C. D. (2017). Climate change vulnerability for species—Assessing the assessments. Global Change Biology 23: 3704-3715. Doi: 10.1111/gcb.13759

Whitmore T.C. (1998). An introduction to tropical rain forests. (2nd ed.). Great Britain: Oxford University Press.

Williams S.E., Shoo L.P., Isaac J.L., Hoffmann A.A., Langham G. (2008). Towards an Integrated Framework for Assessing the Vulnerability of Species to Climate Change. PLoS Biology 6 (12): e325. Doi: 10.1371/journal.pbio.0060325

Wright S.J. (2005). Tropical forests in a changing environment. Trends in Ecology & Evolution 20 (10). Doi: 10.1016/j.tree.2005.07.009

Zona S., Henderson A. (1989). A review of animal mediated seed dispersal of palms. Selbyana 11: 6-21.

Appendix: Database with the sensitivity to anthropic impacts of the ecological traits of 623 species of Neotropical palm, as well as their degree of threat at IUCN: Not Evaluated (NE), Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU) and Endangered (EN). Methodology that defined sensitivity classifications can be found in Table 1. For regions definition see Henderson (1995).

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Final score	Sensitivity	Ecological strategy	Ameaça IUCN
Acoelorrhaphe										
Acoelorrhaphe wrightii (Griseb. & H.Wendl.) H.Wendl. ex Becc.	Caribbean region	Moderate	High	Moderate	High	Low	5.5	Moderate	Shift range	NE
Acrocomia										
Acrocomia aculeata (Jacq.) Lodd. ex R.Keith	Central Brazilian Region, Central American Region and Caribbean region	High	Low	Low	Low	Low	5	Moderate	Both strategy	NE
Acrocomia crispa (Kunth) C.F.Baker ex Becc.	Caribbean region	Moderate	High	Moderate	High	Low	5.5	Moderate	Shift range	NE
Acrocomia emensis (Toledo) Lorenzi	Central Brazilian Region and Atlantic Costal Forest	Low	NA	High	High	Low	5	Moderate	Shift range	NE
Acrocomia glaucescens Lorenzi	Central Brazilian Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Acrocomia hassleri (Barb.Rodr.) W.J.Hahn	Central Brazilian Region	Low	NA	Moderate	Moderate	High	6	Moderate	Undefined	NE
Acrocomia intumescens Drude	Central Brazilian Region	High	NA	Moderate	Moderate	Low	6	Moderate	Shift range	NE
Acrocomia media O.F.Cook	Caribbean region	High	NA	High	High	Low	7	High	Shift range	NE
Acrocomia totai Mart.	Central Brazilian Region	High	NA	Low	Low	Low	5	Moderate	Both strategy	NE
Aiphanes										
Aiphanes acanthophylla Burret	Caribbean region	High	NA	High	High	Low	7	High	Shift range	NE
Aiphanes acaulis Galeano & R.Bernal	Andean Region	Low	Moderate	High	High	Low	4.5	Low	Shift range	NE
Aiphanes bicornis Cerón & R.Bernal	Andean Region	High	NA	High	High	Low	7	High	Shift range	NE
Aiphanes buenaventurae R.Bernal & Borchs	Central American Region	Moderate	High	High	High	Low	6	Moderate	Shift range	NE
Aiphanes chiribogensis Borchs. & Balslev	Andean Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	VU
Aiphanes deltoidea Burret	Amazon Region	Moderate	Low	High	Moderate	Low	5	Moderate	Shift range	NE
Aiphanes duquei Burret	Andean Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	VU

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Aiphanes eggersii Burret	Andean Region	Moderate	High	High	High	Low	6	Moderate	Shift range	NE
Aiphanes erinacea (H.Karst.) H.Wendl	Andean Region	Moderate	Low	High	Moderate	Low	5	Moderate	Shift range	NE
Aiphanes gelatinosa H.E.Moore	Andean Region	Moderate	Low	High	Moderate	Low	5	Moderate	Shift range	NE
Aiphanes graminifolia Galeano & R.Bernal	Amazon Region	Moderate	NA	High	High	Low	6	Moderate	Shift range	NE
Aiphanes grandis Borchs. & Balslev	Andean Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	EN
Aiphanes hirsuta Burret	Andean Region and Central American Region	Moderate	Low	High	Moderate	Low	5	Moderate	Shift range	LC
Aiphanes horrida (Jacq.) Burret	Andean Region and Central American Region	High	Low	Low	Low	Low	5	Moderate	Both strategy	NE
Aiphanes leiostachys Burret	Andean Region	Moderate	High	High	High	Low	6	Moderate	Shift range	EN
Aiphanes lindeniana (H.Wendl.) H.Wendl.	Andean Region	Moderate	Moderate	High	High	Low	5.5	Moderate	Shift range	VU
Aiphanes linearis Burret	Andean Region	Moderate	Moderate	High	High	Low	5.5	Moderate	Shift range	LC
Aiphanes macroloba Burret	Andean Region	Moderate	Moderate	High	High	Low	5.5	Moderate	Shift range	NE
Aiphanes mínima (Gaertn.) Burret	Caribbean region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Aiphanes multiplex R.Bernal & Borchs	Andean Region	Moderate	NA	High	High	Low	6	Moderate	Shift range	NE
Aiphanes parvifolia Burret	Andean Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Aiphanes pilaris R.Bernal	Andean Region	Moderate	NA	High	High	Low	6	Moderate	Shift range	NE
Aiphanes simplex Burret	Andean Region	Moderate	Low	High	Moderate	Low	5	Moderate	Shift range	NE
Aiphanes spicata Borchs. & R.Bernal	Andean Region	Low	High	High	High	Low	5	Moderate	Shift range	NE
Aiphanes tricuspidata Borchs.	Andean Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Aiphanes ulei (Dammer) Burret	Andean Region and Amazon Region	High	Moderate	Moderate	Moderate	Low	6	Moderate	Shift range	LC
Aiphanes verrucosa Borchs. & Balslev	Andean Region	Moderate	High	High	High	Low	6	Moderate	Shift range	EN
Aiphanes weberbaueri Burret	Andean Region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Allagoptera										

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Allagoptera arenaria (Gomes) Kuntze	Atlantic Costal Forest	Low	High	Moderate	High	High	6.5	Moderate	Extinction risk	NE
Allagoptera brevicalyx M.Moraes	Atlantic Costal Forest	Low	High	High	High	High	7	High	Extinction risk	NE
Allagoptera campestris (Mart.) Kuntze	Central Brazilian Region	Low	Moderate	Low	Moderate	Moderate	4.5	Low	Undefined	NE
Allagoptera caudescens (Mart.) Kuntze	Atlantic Costal Forest	High	High	Moderate	High	Moderate	7.5	High	Undefined	NE
Allagoptera leucocalyx (Drude) Kuntze	Central Brazilian Region	Low	High	Low	Moderate	Moderate	5	Moderate	Undefined	NE
Ammandra										
Ammandra decasperma O.F.Cook	Central American Region	Moderate	High	High	High	High	8	High	Extinction risk	NE
Aphandra										
Aphandra natalia (Balslev & A.J.Hend.) Barfod	Amazon Region	High	High	High	High	High	9	High	Extinction risk	NE
Asterogyne										
Asterogyne guianensis Granv. & A.J.Hend.	Amazon Region	High	High	High	High	Moderate	8	High	Undefined	NE
Asterogyne martiana (H.Wendl.) H.Wendl. ex Drude	Central American Region	High	High	Moderate	High	Moderate	7.5	High	Undefined	NE
Asterogyne ramosa (H.E.Moore) Wess.Boer	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	LC
Asterogyne spicata (H.E.Moore) Wess.Boer	Central American Region	High	High	High	High	Moderate	8	High	Undefined	VU
Asterogyne yaracuyense A.J.Hend. & Steyerm.	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	CR
Astrocaryum										
Astrocaryum acaule G.Mey	Amazon Region	Low	High	Low	Moderate	High	6	Moderate	Undefined	NE
Astrocaryum aculeatissimum (Schott) Burret	Atlantic Costal Forest	Moderate	High	High	High	High	8	High	Extinction risk	LC
Astrocaryum aculeatum Mart.	Amazon Region	High	NA	Low	Low	High	7	High	Adaptation	NE
Astrocaryum alatum Loomis	Central American Region	High	High	High	High	High	9	High	Extinction risk	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Astrocaryum campestre Mart.	Central Brazilian Region	Low	High	Moderate	High	High	6.5	Moderate	Extinction risk	NE
Astrocaryum carnosum F.Kahn & B.Millán	Amazon Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Astrocaryum chambira Burret	Amazon Region	High	High	Moderate	High	High	8.5	High	Extinction risk	NE
Astrocaryum ciliatum F.Kahn & B.Millán	Amazon Region	High	NA	High	High	High	9	High	Extinction risk	NE
Astrocaryum confertum H.Wendl. ex Burret	Central American Region	High	High	High	High	High	9	High	Extinction risk	NE
Astrocaryum echinatum Barb.Rodr	Amazon Region	High	NA	High	High	Low	7	High	Shift range	NE
Astrocaryum faranae F.Kahn & E.Ferreira	Amazon Region	Moderate	NA	High	High	Low	6	Moderate	Shift range	NE
Astrocaryum farinosum Barb.Rodr	Amazon Region	High	NA	High	High	High	9	High	Extinction risk	NE
Astrocaryum ferrugineum F.Kahn & B.Millán	Amazon Region	High	NA	High	High	High	9	High	Extinction risk	NE
Astrocaryum giganteum Barb.Rodr.	Amazon Region	High	NA	High	High	Low	7	High	Shift range	NE
Astrocaryum huaimi Mart.	Amazon Region	Moderate	High	High	High	High	8	High	Extinction risk	NE
Astrocaryum huicungo Dammer ex Burret	Amazon Region	Low	NA	High	High	Low	5	Moderate	Shift range	NE
Astrocaryum jauari Mart.	Amazon Region	Moderate	NA	Low	Low	Moderate	5	Moderate	Adaptation	NE
Astrocaryum javarense (Trail) Drude	Amazon Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Astrocaryum macrocalyx Burret	Amazon Region	Moderate	NA	Moderate	Moderate	Low	5	Moderate	Shift range	NE
Astrocaryum mexicanum Liebm. ex Mart.	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Astrocaryum murumuru Mart.	Amazon Region	Moderate	Moderate	Low	Moderate	Moderate	5.5	Moderate	Undefined	NE
Astrocaryum paramaca Mart.	Amazon Region	Low	High	Moderate	High	Moderate	5.5	Moderate	Undefined	NE
Astrocaryum rodriguesii Trail	Amazon Region	High	NA	High	High	Moderate	8	High	Undefined	NE
Astrocaryum sciophilum (Miq.) Pulle	Amazon Region	Low	High	High	High	High	7	High	Extinction risk	NE
Astrocaryum sociale Barb.Rodr.	Amazon Region	Low	NA	High	High	High	7	High	Extinction risk	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Astrocaryum standleyanum L.H. Bailey	Central American Region	High	High	Moderate	High	High	8.5	High	Extinction risk	NE
Astrocaryum triandrum Galeano	Central American Region	High	High	High	High	High	9	High	Extinction risk	NE
Astrocaryum ulei Burret	Amazon Region	Moderate	NA	High	High	Low	6	Moderate	Shift range	NE
Astrocaryum vulgare Mart.	Amazon Region	Low	High	Low	Moderate	Low	4	Low	Shift range	NE
Attalea										
Attalea allenii H.E.Moore	Central American Region	Low	High	High	High	Low	5	Moderate	Shift range	NE
Attalea amygdalina Kunth in F.W.H.von Humboldt	Central American Region	Low	Moderate	Moderate	Moderate	Low	4	Low	Shift range	NE
Attalea apoda Burret	Central Brazilian Region and Atlantic Costal Forest	High	NA	Moderate	Moderate	High	8	High	Undefined	NE
Attalea attaleoides (Barb.Rodr.) Wess.Boer	Amazon Region	Low	Moderate	High	High	High	6.5	Moderate	Extinction risk	NE
Attalea brasiliensis Glassman	Central Brazilian Region	High	NA	High	High	Moderate	8	High	Undefined	NE
Attalea brejinhoensis (Glassman) Zona	Central Brazilian Region	High	NA	High	High	High	9	High	Extinction risk	NE
Attalea burretiana Bondar	Central Brazilian Region and Atlantic Costal Forest	High	NA	High	High	Moderate	8	High	Undefined	NE
Attalea butyracea (Mutis ex L.f.) Wess.Boer	Central American Region and Amazon Region	High	Moderate	Low	Moderate	High	7.5	High	Undefined	NE
Attalea cephalotus Poepp. ex Mart.	Amazon Region	High	NA	High	High	Low	7	High	Shift range	NE
Attalea cohune Mart.	Central American Region	High	High	Moderate	High	High	8.5	High	Extinction risk	NE
Attalea colenda (O.F.Cook) Balslev & A.J.Hend.	Central American Region	High	Moderate	High	High	High	8.5	High	Extinction risk	NE
Attalea compta Mart.	Central Brazilian Region	High	NA	Moderate	Moderate	Low	6	Moderate	Shift range	NE
Attalea crassispatha (Mart.) Burret.	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Attalea cuatrecasana (Dugand) A.J.Hend.	Central American Region	Low	High	High	High	High	7	High	Extinction risk	NE
Attalea dahlgreniana (Bondar) Wess.Boer	Amazon Region	High	High	High	High	High	9	High	Extinction risk	NE
Attalea dúbia (Mart.)	Atlantic Costal Forest	High	High	High	High	Moderate	8	High	Undefined	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Burret										
Attalea eichleri (Mart.) Burret	Central Brazilian Region	Low	Moderate	Moderate	Moderate	High	6	Moderate	Undefined	NE
Attalea exígua Drude	Central Brazilian Region	Low	Moderate	Moderate	Moderate	High	6	Moderate	Undefined	NE
Attalea funifera Mart.	Atlantic Costal Forest	High	High	High	High	Low	7	High	Shift range	NE
Attalea geraensis Barb.Rodr.	Atlantic Costal Forest and Central Brazilian Region	Low	Moderate	Moderate	Moderate	High	6	Moderate	Undefined	NE
Attalea humilis Mart. ex Spreng.	Atlantic Costal Forest	Low	High	Moderate	High	Moderate	5.5	Moderate	Undefined	NE
Attalea insignis (Mart.) Drude	Amazon Region	Low	Moderate	Moderate	Moderate	High	6	Moderate	Undefined	NE
Attalea maripa (Aubl.) Mart.	Central Brazilian Regionn and Amazon Region	High	High	Low	Moderate	Low	6	Moderate	Shift range	NE
Attalea microcarpa Mart.	Amazon Region	Low	High	Moderate	High	Low	4.5	Low	Shift range	NE
Attalea oliefera Barb.Rodr.	Atlantic Costal Forest	High	High	Moderate	High	Moderate	7.5	High	Undefined	NE
Attalea phalerata Mart. ex Spreng.	Central Brazilian Region	High	Moderate	Low	Moderate	Low	5.5	Moderate	Shift range	NE
Attalea pindobassu Bondar	Central Brazilian Region	High	Moderate	High	High	High	8.5	High	Extinction risk	NE
Attalea plowmanii (Glassman) Zona	Amazon Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Attalea princeps Mart.	Central Brazilian Region	High	NA	High	High	Low	7	High	Shift range	NE
Attalea racemosa Spruce	Amazon Region	High	High	Moderate	High	High	8.5	High	Extinction risk	NE
Attalea rostrata Oerst.	Central American Region	High	NA	Moderate	Moderate	Low	6	Moderate	Shift range	NE
Attalea salvadorensis Glassman	Atlantic Costal Forest and Central Brazilian Region	High	NA	High	High	Low	7	High	Shift range	NE
Attalea seabrensis Glassman	Central Brazilian Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Attalea speciosa Mart.	Central Brazilian Regionn and Amazon Region	High	Moderate	Low	Moderate	High	7.5	High	Undefined	NE
Attalea spectabilis Mart.	Amazon Region	Low	High	High	High	Low	5	Moderate	Shift range	NE
Attalea tessmannii Burret	Amazon Region	High	High	High	High	High	9	High	Extinction risk	NE
Attalea vitrivir Zona	Central Brazilian Region	High	NA	High	High	Low	7	High	Shift range	NE
Bactris										
Bactris acanthocarpa Mart.	Atlantic Costal Forest and Amazon Region	Moderate	Moderate	Low	Moderate	Low	4.5	Low	Shift range	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Bactris acanthocarpoides Barb.Rodr	Amazon Region	Moderate	High	Moderate	High	Low	5.5	Moderate	Shift range	NE
Bactris aubletiana Trail	Amazon Region	Moderate	High	High	High	High	8	High	Extinction risk	NE
Bactris bahiensis Noblick ex A.J.Hend.	Atlantic Costal Forest	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris balanophora Spruce	Amazon Region	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Bactris barronis L.H.Bailey	Central American Region	Moderate	Moderate	High	High	Low	5.5	Moderate	Shift range	NE
Bactris bidentula Spruce	Amazon Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Bactris bifida Mart.	Amazon Region	Moderate	Moderate	Low	Moderate	Moderate	5.5	Moderate	Undefined	NE
Bactris brongniartii Mart.	Amazon Region	Moderate	High	Low	Moderate	Moderate	6	Moderate	Undefined	NE
Bactris campestris Poepp.	Amazon Region	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Bactris caryotifolia Mart.	Atlantic Costal Forest	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris caudata H.Wendl. ex Burret	Central American Region	Moderate	Moderate	High	High	Low	5.5	Moderate	Shift range	NE
Bactris charnleyae de Nevers	Central American Region	Moderate	High	High	High	High	8	High	Extinction risk	NE
Bactris chaveziae A.J.Hend.	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris coloniata L.H.Bailey	Central American Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Bactris coloradonis L.H.Bailey	Central American Region	Moderate	Moderate	Moderate	Moderate	Low	5	Moderate	Shift range	NE
Bactris concinna Mart.	Amazon Region	Moderate	High	Moderate	High	Low	5.5	Moderate	Shift range	NE
Bactris constanciae Barb.Rodr.	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris corossilla H. Karst.	Andean Region	Moderate	High	Low	Moderate	Moderate	6	Moderate	Undefined	NE
Bactris cuspidata Mart.	Amazon Region	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Bactris elegans Schaedtler	Amazon Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Bactris ferruginea Burret	Atlantic Costal Forest	Moderate	High	Moderate	High	Low	5.5	Moderate	Shift range	NE
Bactris fissifrons Mart.	Amazon Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Bactris gasipaes Kunth	Amazon Region	Moderate	Moderate	Low	Moderate	Low	4.5	Low	Shift range	NE
Bactris gastoniana	Amazon Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE

Barb.Rodr.

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Bactris glandulosa Oerst.	Central American Region	Moderate	Moderate	High	High	Low	5.5	Moderate	Shift range	NE
Bactris glassmanii Med.Costa & Noblick ex A.J.Hend.	Atlantic Costal Forest	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris glaucescens Drude	Amazon Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Bactris gracilior Burret	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris guineenses (L.) H.E.Moore	Central American Region	Moderate	High	Moderate	High	Low	5.5	Moderate	Shift range	NE
Bactris halmoorei A.J.Hend.	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris hatschbachii Noblick ex A.J.Hend.	Central Brazilian Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Bactris hirta Mart.	Atlantic Costal Forest and Amazon Region	Moderate	High	Low	Moderate	Moderate	6	Moderate	Undefined	NE
Bactris horridispatha Noblick ex A.J.Hend.	Atlantic Costal Forest	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris killipii Burret	Amazon Region	High	High	Moderate	High	High	8.5	High	Extinction risk	NE
Bactris longiseta H.Wendl. ex Burret	Central American Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Bactris macroacantha Mart.	Amazon Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Bactris major Jacq.	Central American Region	Moderate	Moderate	Low	Moderate	Moderate	5.5	Moderate	Undefined	NE
Bactris maraja Mart.	Central American Region	Moderate	Moderate	Low	Moderate	Moderate	5.5	Moderate	Undefined	NE
Bactris martiana A.J.Hend.	Amazon Region	Moderate	High	Moderate	High	Low	5.5	Moderate	Shift range	NE
Bactris mexicana Mart.	Central American Region	Moderate	Moderate	Moderate	Moderate	Low	5	Moderate	Shift range	NE
Bactris militaris H.E.Moore	Central American Region	Moderate	High	High	High	High	8	High	Extinction risk	NE
Bactris nancibaensis Granv	Amazon Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Bactris obovata Schaedtler	Central American Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Bactris oligocarpa Barb.Rodr.	Amazon Region	Moderate	High	Moderate	High	High	7.5	High	Extinction risk	NE
Bactris panamensis de Nevers & Grayum	Central American Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE

51

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Bactris pickelii Burret	Atlantic Costal Forest	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Bactris pilosa H.Karst.	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris pliniana Granv. & A.J.Hend.	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris rhaphidacantha Wess.Boer	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris riparia Mart.	Amazon Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Bactris setiflora Burret	Andean Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris setosa Mart.	Atlantic Costal Forest	Moderate	High	Low	Moderate	Low	5	Moderate	Shift range	NE
Bactris setulosa H.Karst.	Central American Region	Moderate	Moderate	Low	Moderate	Low	4.5	Low	Shift range	NE
Bactris simplicifrons Mart.	Amazon Region	Moderate	Low	Low	Low	High	6	Moderate	Adaptation	NE
Bactris soeiroana Noblick ex A.J.Hend.	Atlantic Costal Forest	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris sphaerocarpa Trail	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris syagroides Barb.Rodr. & Trail in J.Barbosa Rodrigues	Amazon Region	Moderate	High	High	High	High	8	High	Extinction risk	NE
Bactris timbuiensis H.Q.B.Fern.	Atlantic Costal Forest	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris tomentosa Mart.	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Bactris vulgaris Barb.Rodr.	Atlantic Costal Forest	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Barcella										
Barcella odora (Trail) Drude	Amazon Region	Low	High	High	High	Moderate	6	Moderate	Undefined	NE
Brahea										
Brahea aculeata (Brandegee) H.E.Moore	Mexican Region	High	High	High	High	Low	7	High	Shift range	NE
Brahea armata S.Watson	Mexican Region	High	Moderate	Moderate	Moderate	Low	6	Moderate	Shift range	NE
Brahea brandegeei (Purpus) H.E.Moore	Mexican Region	High	High	High	High	Low	7	High	Shift range	NE
Brahea calcarea Liebm.	Mexican Region	High	Moderate	Moderate	Moderate	Low	6	Moderate	Shift range	NE
Brahea decumbens Rzed.	Mexican Region	Moderate	Moderate	High	High	Low	5.5	Moderate	Shift range	NE
Brahea dulcis (Kunth)	Mexican Region	Moderate	Low	Moderate	Moderate	Low	4.5	Low	Shift range	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Mart.										
Brahea edulis H.Wendl. ex S.Watson	Mexican Region	High	High	High	High	Low	7	High	Shift range	NE
Brahea moorei L.H.Bailey ex H.E.Moore	Mexican Region	Low	Moderate	High	High	Low	4.5	Low	Shift range	NE
Brahea pimo Becc.	Mexican Region	High	High	High	High	Low	7	High	Shift range	NE
Brahea salvadorensis H.Wendl.	Central American Region	Moderate	Moderate	High	High	Low	5.5	Moderate	Shift range	NE
Brahea sarukhanii H.J.Quero	Mexican Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Butia										
Butia archeri (Glassman) Glassman	Central Brazilian Region	Low	High	High	High	Moderate	6	Moderate	Undefined	NE
Butia campicola (Barb.Rodr.) Noblick	Central Brazilian Region	Low	High	High	High	Moderate	6	Moderate	Undefined	NE
Butia capitata (Mart.) Becc.	Central Brazilian Region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Butia catarinensis Noblick & Lorenzi	Atlantic Costal Forest	High	NA	High	High	Moderate	8	High	Undefined	NE
Butia eriospatha (Mart. ex Drude) Becc.	Central Brazilian Region	High	Low	Moderate	Moderate	Low	5.5	Moderate	Shift range	NE
Butia exospadix Noblick	Central Brazilian Region	Low	NA	High	High	Moderate	6	Moderate	Undefined	NE
Butia lallemantii Deble & Marchiori	Central Brazilian Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Butia lepidotispatha Noblick	Central Brazilian Region	High	High	High	High	Moderate	8	High	Undefined	NE
Butia leptospatha (Burret) Noblick	Central Brazilian Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Butia marmorii Noblick	Central Brazilian Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Butia matogrossensis Noblick & Lorenzi	Central Brazilian Region	High	NA	High	High	Moderate	8	High	Undefined	NE
Butia microspadix Burret	Central Brazilian Region	Low	High	High	High	Moderate	6	Moderate	Undefined	NE
Butia odorata (Barb.Rodr.) Noblick	Central Brazilian Region	High	NA	High	High	Low	7	High	Shift range	NE
Butia paraguayensis (Barb.Rodr.) L.H.Bailey	Central Brazilian Region	High	High	Moderate	High	Moderate	7.5	High	Undefined	NE
Butia pubispatha Noblick & Lorenzi	Central Brazilian Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Butia purpurascens Glassman	Central Brazilian Region	High	High	High	High	Low	7	High	Shift range	NE
Butia yatay (Mart.) Becc.	Central Brazilian Region	High	NA	High	High	Low	7	High	Shift range	NE
Calyptrogyne										
Calyptrogyne allenii (L.H.Bailey) de Nevers	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Calyptrogyne anomala de Nevers & A.J.Hend.	Central American Region	Low	High	High	High	Moderate	6	Moderate	Undefined	NE
Calyptrogyne baudensis A.J.Hend.	Central American Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Calyptrogyne coloradensis A.J.Hend.	Central American Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Calyptrogyne condensata (L.H.Bailey) Wess.Boer	Central American Region	Low	High	High	High	Moderate	6	Moderate	Undefined	NE
Calyptrogyne costatifrons (L.H.Bailey) de Nevers	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Calyptrogyne deneversii A.J.Hend.	Central American Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Calyptrogyne fortunensis A.J.Hend.	Central American Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Calyptrogyne ghiesbreghtiana (Linden & H.Wendl.) H.Wendl.	Central American Region	Low	Low	Moderate	Moderate	Moderate	4.5	Low	Undefined	NE
Calyptrogyne herrerae Grayum	Central American Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Calyptrogyne kunaria de Nevers	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Calyptrogyne kunorum de Nevers	Central American Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Calyptrogyne osensis A.J.Hend.	Central American Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Calyptrogyne panamensis A.J.Hend.	Central American Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Calyptrogyne pubescens de Nevers	Central American Region	Low	High	High	High	Moderate	6	Moderate	Undefined	NE
Calyptrogyne sanblasensis A.J.Hend.	Central American Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Calyptrogyne trichostachys Burret	Central American Region	Low	High	High	High	Moderate	6	Moderate	Undefined	NE
Calyptronoma										

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Calyptronoma occidentalis (Sw.) H.E.Moore	Caribbean region	High	High	High	High	Moderate	8	High	Undefined	NE
Calyptronoma plumeriana (Mart.) Lourteig	Caribbean region	High	NA	High	High	Moderate	8	High	Undefined	NE
Calyptronoma rivalis (O.F.Cook) L.H.Bailey	Caribbean region	High	High	High	High	Moderate	8	High	Undefined	NE
Ceroxylon										
Ceroxylon alpinum Bonpl. ex DC.	Andean Region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Ceroxylon amazonicum Galeano	Andean Region	High	High	High	High	Low	7	High	Shift range	NE
Ceroxylon ceriferum (H.Karst.) Pittier	Andean Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Ceroxylon echinulatum Galeano	Andean Region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Ceroxylon parvifrons (Engel) H.Wendl.	Andean Region	High	Low	Low	Low	Low	5	Moderate	Both strategy	NE
Ceroxylon parvum Galeano	Andean Region	High	High	Low	Moderate	Low	6	Moderate	Shift range	NE
Ceroxylon peruvianum Galeano	Andean Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Ceroxylon pityrophyllum (Mart.) Mart. ex H.Wendl	Andean Region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Ceroxylon quindiuense (H.Karst.) H.Wendl	Andean Region	High	Moderate	Moderate	Moderate	Low	6	Moderate	Shift range	NE
Ceroxylon sasaimae Galeano	Andean Region	High	High	High	High	Low	7	High	Shift range	NE
Ceroxylon ventricosum Burret	Andean Region	High	Moderate	Moderate	Moderate	Low	6	Moderate	Shift range	NE
Ceroxylon vogelianum (Engel) H.Wendl.	Andean Region	High	Low	Low	Low	Low	5	Moderate	Both strategy	NE
Chamaedorea										
Chamaedorea adscendens (Dammer) Burret	Central American Region	High	High	Moderate	High	Moderate	7.5	High	Undefined	NE
Chamaedorea allenii L.H.Bailey	Central American Region	High	Low	Low	Low	Moderate	6	Moderate	Adaptation	NE
Chamaedorea alternans H.Wendl.	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Chamaedorea amabilis H.Wendl.	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Chamaedorea anemophila Hodel	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea angustisecta Burret	Andean Region e Amazon Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Chamaedorea arenbergiana H.Wendl.	Central American Region	High	Low	Moderate	Moderate	Moderate	6.5	Moderate	Undefined	NE
Chamaedorea atrovirens Mart.	Mexican Region	High	NA	High	High	Moderate	8	High	Undefined	NE
Chamaedorea benziei Hodel	Central American Region	High	NA	High	High	Moderate	8	High	Undefined	NE
Chamaedorea binderi Hodel	Central American Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Chamaedorea brachyclada H.Wendl.	Central American Region	Low	High	High	High	Moderate	6	Moderate	Undefined	NE
Chamaedorea brachypoda Standl. & Steyerm.	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Chamaedorea carchensis Standl. & Steyerm.	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Chamaedorea castillo-montii Hodel	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea cataractarum Mart.	Central American Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Chamaedorea christinae Hodel	Central American Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Chamaedorea correae Hodel & N.W.Uhl	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea costaricana Oerst.	Central American Region	Moderate	Low	Low	Low	Moderate	5	Moderate	Adaptation	NE
Chamaedorea crucensis Hodel	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea dammeriana Burret	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea deckeriana (Klotzsch) Hemsl.	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea deneversiana Grayum & Hodel	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea elatior Mart.	Central American Region	Low	Moderate	Moderate	Moderate	Moderate	5	Moderate	Undefined	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Chamaedorea elegans Mart.	Central American Region e Mexican Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea ernesti-augusti H.Wendl.	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Chamaedorea falcifera H.E.Moore	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea foveata Hodel	Central American Region e Mexican Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea fractiflexa Hodel & Cast.Mont	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Chamaedorea fragrans (Ruiz & Pav.) Mart.	Andean Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Chamaedorea frondosa Hodel	Central American Region	High	NA	High	High	Moderate	8	High	Undefined	NE
Chamaedorea geonomiformis H.Wendl.	Central American Region	High	Moderate	Moderate	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea glaucifolia H.Wendl.	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Chamaedorea graminifolia H.Wendl.	Central American Region	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Chamaedorea guntheriana Hodel & N.W.Uhl	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea hodelii Grayum	Central American Region	High	NA	High	High	Moderate	8	High	Undefined	NE
Chamaedorea hooperiana Hodel	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Chamaedorea ibarrae Hodel	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea incrustata Hodel	Central American Region	High	NA	High	High	Moderate	8	High	Undefined	NE
Chamaedorea keelerorum Hodel & Cast.Mont	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Chamaedorea klotzschiana H.Wendl.	Central American Region	High	Moderate	Low	Moderate	Moderate	6.5	Moderate	Undefined	NE
Chamaedorea lehmannii Burret	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea liebmannii Mart.	Central American Region	High	Moderate	Moderate	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea linearis (Ruiz & Pav.) Mart.	Andean Region e Central American Region	High	Low	Low	Low	Moderate	6	Moderate	Adaptation	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Chamaedorea lucidifrons L.H.Bailey.	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea macrospadix Oerst.	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea matae Hodel	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea metallica O.F.Cook ex H.E.Moore	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea microphylla H.Wendl.	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea microspadix Burret	Central American Region	Moderate	Low	High	Moderate	Moderate	6	Moderate	Undefined	NE
Chamaedorea moliniana Hodel	Central American Region	High	NA	High	High	Moderate	8	High	Undefined	NE
Chamaedorea nationsiana Hodel & Cast.Mont	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea neurochlamys Burret	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea nubium Standl. & Steyerm.	Central American Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Chamaedorea oblongata Mart.	Central American Region	High	High	Moderate	High	Moderate	7.5	High	Undefined	NE
Chamaedorea oreophila Mart.	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea pachecoana Standl. & Steyerm.	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea palmeriana Hodel & N.W.Uhl	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea parvifolia Burret	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea parvisecta Burret	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea pauciflora Mart.	Amazon Region	High	Moderate	Low	Moderate	Moderate	6.5	Moderate	Undefined	NE
Chamaedorea pedunculata Hodel	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea pinnatifrons (Jacq.) Oerst.	Amazon Region, Mexican Region and Central American Region	High	Low	Low	Low	Moderate	6	Moderate	Adaptation	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Chamaedorea piscifolia Hodel	Central American Region	High	NA	High	High	Moderate	8	High	Undefined	NE
Chamaedorea pittieri L.H.Bailey	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Chamaedorea plumosa Hodel	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Chamaedorea pochutlensis Liebm	Central American Region	Moderate	Low	High	Moderate	Moderate	6	Moderate	Undefined	NE
Chamaedorea ponderosa Hodel	Central American Region	High	NA	High	High	Moderate	8	High	Undefined	NE
Chamaedorea pumila H.Wendl.	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea pygmaea H.Wendl.	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea queroana Hodel	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea radicalis Mart.	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea recurvata Hodel	Central American Region	High	NA	High	High	Moderate	8	High	Undefined	NE
Chamaedorea rhizomatosa Hodel	Mexican Region and Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Chamaedorea ricardoi R.Bernal	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Chamaedorea rígida H.Wendl.	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea robertii Hodel & N.W.Uhl	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Chamaedorea rojasiana Standl. & Steyerm.	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea rosibeliae Hodel	Central American Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Chamaedorea rossteniorum Hodel	Central American Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Chamaedorea sartorii Liebm	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea scheryi L.H.Bailey	Central American Region	Low	Low	High	Moderate	Moderate	5	Moderate	Undefined	NE
Chamaedorea schiedeana Mart.	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea schippii Burret	Central American Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Chamaedorea seifrizii Burret	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Chamaedorea serpens Hodel	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Chamaedorea simplex Burret	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea skutchii Standl. & Steyerm.	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea smithii A.H.Gentry	Andean Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea stenocarpa Standl. & Steyerm.	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Chamaedorea stolonifera H.Wendl. ex Hook.f.	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Chamaedorea stricta Standl. & Steyerm.	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea subjectifolia Hodel	Central American Region	High	NA	High	High	Moderate	8	High	Undefined	NE
Chamaedorea tenerrima Burret	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Chamaedorea tepejilote Liebm.	Central American Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Chamaedorea tuerckheimii (Dammer) Burret	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Chamaedorea undulatifolia Hodel & N.W.Uh	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea verapazensis Hodel & Cast.	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea verecunda Hodel & N.W.Uh	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chamaedorea volcanensis Hodel & N.W.Uh	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Chamaedorea vulgata Standl. & Steyerm.	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Chamaedorea warscewiczii H.Wendl.	Central American Region	High	High	Moderate	High	Moderate	7.5	High	Undefined	NE
Chamaedorea whitelockiana H.Wendl.	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Chamaedorea woodsoniana L.H.Bailey	Central American Region	High	Low	Moderate	Moderate	Moderate	6.5	Moderate	Undefined	NE
Chamaedorea zamorae Hodel	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chelyocarpus										
Chelyocarpus chuco (Mart.) H.E.Moore	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Chelyocarpus dianeurus (Mart.) H.E.Moore	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chelyocarpus repens F.Kahn & K.Mejia	Amazon Region	High	High	High	High	Moderate	8	High	Undefined	NE
Chelyocarpus ulei Dammer	Amazon Region	High	Moderate	Moderate	Moderate	Moderate	7	High	Undefined	NE
Coccothrinax										
Coccothrinax alta (O.F.Cook) Becc.	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Coccothrinax argentata (Jacq.) L.H.Bailey	Caribbean region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Coccothrinax argentea (Lodd. ex Schult. & Schult.f.) Sarg. ex Becc.	Caribbean region	Moderate	High	High	High	Low	6	Moderate	Shift range	NE
Coccothrinax barbadensis (Lodd. ex Mart.) Becc.	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Coccothrinax borhidiana O.Muñiz	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Coccothrinax crinita (Griseb. & H.Wendl. ex C.H.Wright) Becc.	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Coccothrinax ekmanii Burret	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Coccothrinax fagildei Borhidi & O.Muñiz.	Caribbean region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Coccothrinax fragrans Burret, Kongl. Svenska Vetensk.	Caribbean region	High	NA	High	High	Low	7	High	Shift range	NE
Coccothrinax gracilis Burret	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Coccothrinax gundlachii León	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE

61

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Coccothrinax hioramii León	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Coccothrinax inaguensis Read	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Coccothrinax macroglossa (León) O.Muñiz & Borhidi	Caribbean region	High	NA	High	High	Moderate	8	High	Undefined	NE
Coccothrinax miraguama (Kunth) Becc.	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Coccothrinax moaensis (Borhidi & O.Muñiz) O.Muñiz	Caribbean region	High	NA	High	High	Moderate	8	High	Undefined	NE
Coccothrinax montana Burret, Kongl. Svenska Vetensk.	Caribbean region	High	NA	High	High	Moderate	8	High	Undefined	NE
Coccothrinax pauciramosa Burret	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Coccothrinax proctorii Read	Caribbean region	High	NA	High	High	Low	7	High	Shift range	NE
Coccothrinax salvatoris León	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Coccothrinax spissa L.H.Bailey	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Coccothrinax torrida Morici & Verdecia	Caribbean region	High	NA	High	High	Moderate	8	High	Undefined	NE
Colpothrinax										
Colpothrinax aphanopetala R.Evans	Central American Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Colpothrinax cookii Read	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Colpothrinax wrightii Schaedtler	Caribbean region	High	High	High	High	Moderate	8	High	Undefined	NE
Copernicia										
Copernicia alba Morong	Central Brazilian Region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Copernicia baileyana León	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Copernicia berteroana Becc.	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Copernicia brittonorum León	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE

62

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Copernicia cowellii Britton & P.Wilson	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Copernicia ekmanii Burret	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Copernicia fallaensis León	Caribbean region	High	NA	High	High	Low	7	High	Shift range	NE
Copernicia gigas Ekman ex Burret	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Copernicia glabrescens H.Wendl. ex Becc.	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Copernicia hospita Mart.	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Copernicia macroglossa Schaedtler	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Copernicia prunifera (Mill.) H.E.Moore	Central Brazilian Region	High	High	Low	Moderate	Low	6	Moderate	Shift range	NE
Copernicia rigida Britton & P.Wilson	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Copernicia tectorum (Kunth) Mart.	Caribbean region	High	High	High	High	Moderate	8	High	Undefined	NE
Cryosophila										
Cryosophila cookii Bartlett	Central American Region	High	High	High	High	Low	7	High	Shift range	NE
Cryosophila grayumii R.J.Evans	Central American Region	High	High	High	High	Low	7	High	Shift range	NE
Cryosophila guagara P.H.Allen	Central American Region	High	High	High	High	Low	7	High	Shift range	NE
Cryosophila kalbreyeri (Dammer ex Burret) Dahlgren	Central American Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Cryosophila macrocarpa R.J.Evans	Central American Region	High	High	High	High	Low	7	High	Shift range	NE
Cryosophila nana (Kunth) Blume	Central American Region	High	High	High	High	Low	7	High	Shift range	NE
Cryosophila stauracantha (Heynh.) R.J.Evans	Central American Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Cryosophila warscewiczii (H.Wendl.) Bartlett	Central American Region	High	Low	High	Moderate	Low	6	Moderate	Shift range	NE
Cryosophila williamsii P.H.Allen	Central American Region	High	High	High	High	Low	7	High	Shift range	NE
Desmoncus										

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Desmoncus chinantlensis Liebm. ex Mart.	Central American Region and Mexican Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Desmoncus cirrhifer A.H.Gentry & Zardini	Central American Region	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Desmoncus cirrhiferus A.H.Gentry & Zardini	Central American Region	Low	High	High	High	Low	5	Moderate	Shift range	NE
Desmoncus costaricensis (Kuntze) Burre	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Desmoncus giganteus A.J.Hend.	Amazon Region	Low	High	Moderate	High	Low	4.5	Low	Shift range	NE
Desmoncus horridus Mart.	Central Brazilian Region and Amazon Region	Moderate	NA	Low	Low	Moderate	5	Moderate	Adaptation	NE
Desmoncus interjectus A.J.Hend.	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Desmoncus kunarius de Nevers ex A.J.Hend.	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Desmoncus latisectus Burret.	Central Brazilian Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Desmoncus leptoclonos Drude	Central Brazilian Region	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Desmoncus loretanus A.J.Hend.	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Desmoncus madrensis A.J.Hend.	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Desmoncus mitis Mart.	Amazon Region	Low	High	Low	Moderate	Low	4	Low	Shift range	NE
Desmoncus moorei A.J.Hend.	Central American Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Desmoncus myriacanthos Dugand	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Desmoncus obovoideus A.J.Hend.	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Desmoncus orthacanthos Mart.	Central American Region, Amazon Region and Atlantic Costal Forest	Low	Moderate	Low	Moderate	Low	3.5	Low	Shift range	NE
Desmoncus osensis A.J.Hend.	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Desmoncus parvulus L.H.Bailey	Amazon Region	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Desmoncus polyacanthos Mart.	Central Brazilian Region, Amazon Region and Atlantic Costal Forest	Low	High	Low	Moderate	Low	4	Low	Shift range	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Desmoncus prunifer Poepp. ex Mart.	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Desmoncus pumilus Trail.	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Desmoncus setosus Mart.	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Desmoncus stans Grayum & Nevers	Central American Region	Moderate	High	High	High	Low	6	Moderate	Shift range	NE
Desmoncus vacivus L.H.Bailey	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Dictyocaryum										
Dictyocaryum fuscum (H.Karst.) H.Wendl.	Andean Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Dictyocaryum lamarckianum (Mart.) H.Wendl.	Andean Region	High	Moderate	Low	Moderate	Low	5.5	Moderate	Shift range	NE
Dictyocaryum ptarianum (Steyerm.) H.E.Moore & Steyerm.	Amazon Region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Elaeis										
Elaeis oleífera (Kunth) Cortés	Central American Region	High	Low	Low	Low	Low	5	Moderate	Both strategy	NE
Euterpe										
Euterpe broadwayi Becc. ex Broadway	Caribbean region	Moderate	High	High	High	Low	6	Moderate	Shift range	NE
Euterpe catinga Wallace	Amazon Region	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Euterpe edulis Mart.	Central Brazilian Region and Atlantic Costal Forest	High	Low	Low	Low	Low	5	Moderate	Both strategy	NE
Euterpe longibracteata Barb.Rodr.	Amazon Region	Moderate	High	Moderate	High	Low	5.5	Moderate	Shift range	NE
Euterpe luminosa A.J.Hend.	Andean Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Euterpe oleracea Mart.	Amazon Region	Moderate	Low	Low	Low	Low	4	Low	Both strategy	NE
Euterpe precatoria Mart.	Central American Region and Amazon Region	High	Low	Low	Low	Low	5	Moderate	Both strategy	NE
Gaussia										
Gaussia attenuata (O.F.Cook) Becc.	Caribbean region	High	NA	High	High	Low	7	High	Shift range	NE

65

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Gaussia gomezpompae (H.J.Quero) H.J.Quero	Caribbean region	High	NA	High	High	Low	7	High	Shift range	NE
Gaussia maya (O.F.Cook) H.J.Quero & Read	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Gaussia princeps H.Wendl	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Gaussia spirituana Moya & Leiva	Caribbean region	High	NA	High	High	Low	7	High	Shift range	NE
Geonoma										
Geonoma aspidiifolia Spruce	Amazon Region	Moderate	Low	Moderate	Moderate	Moderate	5.5	Moderate	Undefined	NE
Geonoma baculífera (Poit.) Kunth	Amazon Region	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Geonoma bernalii A.J.Hend.	Andean Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Geonoma braunii (F.W.Stauffer) A.J.Hend.	Andean Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Geonoma brenesii Grayum	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Geonoma brevispatha (H.Wendl. ex Drude) A.J.Hend.	Central Brazilian Region	Moderate	Low	Low	Low	Moderate	5	Moderate	Adaptation	NE
Geonoma brongniartii Mart.	Amazon Region	High	High	Low	Moderate	Moderate	7	High	Undefined	NE
Geonoma calyptrogynoidea Burret	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Geonoma camana Trail	Amazon Region	High	Moderate	Moderate	Moderate	Moderate	7	High	Undefined	NE
Geonoma chlamydostachys Galeano	Andean Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Geonoma chococola Wess.Boer	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Geonoma concinna Burret	Central American Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Geonoma concinnoidea A.J.Hend.	Central American Region	Moderate	NA	High	High	Moderate	7	High	Undefined	NE
Geonoma congesta H.Wendl. ex Spruce	Central American Region	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Geonoma cuneata H.Wendl. ex Spruce	Central American Region	High	Moderate	Low	Moderate	Moderate	6.5	Moderate	Undefined	NE

66

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Geonoma deneversii A.J.Hend.	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Geonoma deversa (Poit.) Kunth	Central American Region and Amazon Region	Moderate	Moderate	Low	Moderate	Moderate	5.5	Moderate	Undefined	NE
Geonoma dindoensis A.J.Hend	Central American Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Geonoma divisa H.E.Moore	Central American Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Geonoma elegans Mart.	Atlantic Costal Forest	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Geonoma epetiolata H.E.Moore	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Geonoma euspatha Burret	Amazon Region and Andean Region	Moderate	Low	Low	Low	Moderate	5	Moderate	Adaptation	NE
Geonoma ferruginea H.Wendl. ex Spruce	Central American Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Geonoma fosteri A.J.Hend.	Andean Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Geonoma frontinensis Burret	Andean Region	Moderate	Low	Moderate	Moderate	Moderate	5.5	Moderate	Undefined	NE
Geonoma galeanoae A.J.Hend.	Andean Region	High	High	High	High	Moderate	8	High	Undefined	NE
Geonoma gentryi A.J.Hend.	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Geonoma hollinensis A.J.Hend.	Andean Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Geonoma hugonis Grayum & Nevers	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Geonoma interrupta (Ruiz & Pav.) Mart.	Central American Region	Moderate	Low	Low	Low	Moderate	5	Moderate	Adaptation	NE
Geonoma lanata A.J.Hend.	Andean Region	Moderate	Low	High	Moderate	Moderate	6	Moderate	Undefined	NE
Geonoma laxiflora Mart.	Amazon Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Geonoma lehmannii Dammer ex Burr.	Andean Region	Moderate	NA	Low	Low	Moderate	5	Moderate	Adaptation	NE
Geonoma leptospadix Trail	Amazon Region	Moderate	Low	Moderate	Moderate	Moderate	5.5	Moderate	Undefined	NE
Geonoma longepedunculata Burret	Amazon Region	High	High	High	High	Moderate	8	High	Undefined	NE
Geonoma longevagina H.Wendl. ex Spruce	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Geonoma macrostachys	Amazon Region	Moderate	Low	Low	Low	Moderate	5	Moderate	Adaptation	NE

67

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Mart.										
Geonoma maxima (Poit.) Kunth	Andean Region	Moderate	Low	Low	Low	Moderate	5	Moderate	Adaptation	NE
Geonoma monospatha de Nevers	Central American Region	Moderate	Low	High	Moderate	Moderate	6	Moderate	Undefined	NE
Geonoma mooreana de Nevers & Grayum	Central American Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Geonoma multisecta (Burret) Burret	Amazon Region and Andean Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Geonoma occidentalis (A.J.Hend.) A.J.Hend.	Amazon Region	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Geonoma oldemanii Granv.	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Geonoma oligoclona Trail	Amazon Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Geonoma operculata A.J.Hend.	Andean Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Geonoma orbignyana Mart.	Andean Region	Moderate	Low	Low	Low	Moderate	5	Moderate	Adaptation	NE
Geonoma paradoxa Burret	Andean Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Geonoma pauciflora Mart.	Atlantic Costal Forest	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Geonoma peruviana A.J.Hend.	Andean Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Geonoma pinnatifrons Willd.	Caribbean region, Mexican Region and Central American Region	Moderate	NA	Low	Low	Moderate	5	Moderate	Adaptation	NE
Geonoma poeppigiana Mart.	Amazon Region	High	High	Moderate	High	Moderate	7.5	High	Undefined	NE
Geonoma pohliana Mart.	Atlantic Costal Forest	Moderate	Low	Low	Low	Moderate	5	Moderate	Adaptation	NE
Geonoma poiteauana Kunth	Amazon Region	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Geonoma sanmartinensis A.J.Hend	Andean Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Geonoma santanderensis Galeano & R.Bernal	Andean Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Geonoma schizocarpa A.J.Hend.	Amazon Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Geonoma schottiana Mart.	Atlantic Costal Forest and Central Brazilian Region	Moderate	Low	Moderate	Moderate	Moderate	5.5	Moderate	Undefined	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Geonoma scoparia Grayum & Nevers	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Geonoma simplicifrons Willd.	Amazon Region	Moderate	Moderate	Low	Moderate	Moderate	5.5	Moderate	Undefined	NE
Geonoma spinescens H.Wendl. ex Burret	Amazon Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Geonoma stricta (Poit.) Kunth	Amazon Region	Moderate	Moderate	Low	Moderate	Moderate	5.5	Moderate	Undefined	NE
Geonoma talamancana Grayum	Central American Region	Moderate	Low	High	Moderate	Moderate	6	Moderate	Undefined	NE
Geonoma tenuissima H.E.Moore	Andean Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Geonoma triandra (Burret) Wess.Boer	Central American Region	Moderate	Low	High	Moderate	Moderate	6	Moderate	Undefined	NE
Geonoma triglochin Burret	Amazon Region and Andean Region	High	Moderate	Moderate	Moderate	Moderate	7	High	Undefined	NE
Geonoma trigona (Ruiz & Pav.)	Andean Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Geonoma umbraculiformis Wess.Boer	Central American Region	High	High	High	High	Moderate	8	High	Undefined	NE
Geonoma undata Klotzsch	Central American Region and Andean Region	High	Moderate	Low	Moderate	Moderate	6.5	Moderate	Undefined	NE
Geonoma venosa A.J.Hend.	Andean Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Hemithrinax										
Hemithrinax compacta (Griseb. & H.Wendl.) M.Gómez	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Hemithrinax ekmaniana Burret	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Hemithrinax rivularis León	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Hyospathe										
Hyospathe elegans Mart.	Central American Region and Amazon Region	Moderate	Low	Low	Low	Low	4	Low	Both strategy	NE
Hyospathe macrorhachis Burret	Andean Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Hyospathe wendlandiana Dammer ex Burret	Central American Region	Moderate	NA	High	High	Low	6	Moderate	Shift range	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Iriartea										
Iriartea deltoidea Ruiz & Pav.	Central American Region, Amazon Region and Andean Region	High	Low	Low	Low	Low	5	Moderate	Both strategy	NE
Iriartella										
Iriartella setigera (Mart.) H.Wendl.	Amazon Region	Moderate	Moderate	Low	Moderate	Low	4.5	Low	Shift range	NE
Iriartella stenocarpa Burret	Amazon Region	Moderate	High	Moderate	High	Low	5.5	Moderate	Shift range	NE
Itaya										
Itaya amicorum H.E.Moore	Amazon Region	High	High	High	High	Moderate	8	High	Undefined	NE
Juania										
Juania australis (Mart.) Drude ex Hook.f.	Andean Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Jubaea										
Jubaea chilensis (Molina) Baill.	Andean Region	High	High	High	High	High	9	High	Extinction risk	NE
Leopoldinia										
Leopoldinia piassaba Wallace	Amazon Region	High	High	High	High	Low	7	High	Shift range	NE
Leopoldinia pulchra Mart.	Amazon Region	Moderate	High	Low	Moderate	Low	5	Moderate	Shift range	NE
Lepidocaryum										
Lepidocaryum tênue Mart	Amazon Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Leucothrinax										
Leucothrinax morrisii (H.Wendl.) C.Lewis & Zona	Caribbean region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Manicaria										
Manicaria martiana Burret	Amazon Region	Moderate	High	High	High	Low	6	Moderate	Shift range	NE
Manicaria saccifera Gaertn.	Central American Region and Amazon Region	Moderate	Low	Low	Low	High	6	Moderate	Adaptation	NE
Mauritia										

70

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Mauritia carana Wallace	Amazon Region	High	High	High	High	Low	7	High	Shift range	NE
Mauritia flexuosa L.f.	Amazon Region	High	Moderate	Low	Moderate	Low	5.5	Moderate	Shift range	NE
Mauritiella										
Mauritiella aculeata (Kunth) Burret	Amazon Region	Moderate	High	Low	Moderate	Low	5	Moderate	Shift range	NE
Mauritiella armata (Mart.) Burret	Central Brazilian Region and Amazon Region	Moderate	Low	Low	Low	Low	4	Low	Both strategy	NE
Mauritiella macroclada (Burret) Burret	Andean Region e Central American Region	Moderate	Moderate	High	High	Low	5.5	Moderate	Shift range	NE
Mauritiella pumila (Wallace) Burret	Andean Region e Central American Region	Moderate	NA	High	High	Low	6	Moderate	Shift range	NE
Neonicholsonia										
Neonicholsonia watsonii Dammer	Central American Region	Low	Moderate	High	High	Moderate	5.5	Moderate	Undefined	NE
Oenocarpus										
Oenocarpus bacaba Mart.	Amazon Region	High	High	Low	Moderate	Low	6	Moderate	Shift range	NE
Oenocarpus balickii F.Kahn	Amazon Region	High	Low	Moderate	Moderate	Low	5.5	Moderate	Shift range	NE
Oenocarpus bataua Mart.	Central American Region, Andean Region and Central Brazilian Region	High	Moderate	Low	Moderate	Low	5.5	Moderate	Shift range	NE
Oenocarpus circumtextus Mart.	Amazon Region	High	NA	High	High	Low	7	High	Shift range	NE
Oenocarpus distichus Mart.	Central American Region, Amazon Region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Oenocarpus makeru R.Bernal, Galeano & A.J.Hend.	Amazon Region	High	High	High	High	Low	7	High	Shift range	NE
Oenocarpus mapora H.Karst.	Central American Region, Amazon Region	Moderate	Moderate	Low	Moderate	Low	4.5	Low	Shift range	NE
Oenocarpus minor Mart.	Amazon Region	Moderate	High	Low	Moderate	Low	5	Moderate	Shift range	NE
Oenocarpus simplex R.Bernal Galeano & A.J.Hend.	Amazon Region	Moderate	High	High	High	Low	6	Moderate	Shift range	NE
Parajubaea										
Parajubaea cocoides Burret	Andean Region	High	High	High	High	High	9	High	Extinction risk	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Parajubaea sunkha M.Moraes	Central American Region	High	High	High	High	High	9	High	Extinction risk	NE
Parajubaea torallyi (Mart.) Burret	Central American Region	High	High	High	High	High	9	High	Extinction risk	NE
Pholidostachys										
Pholidostachys dactyloides H.E.Moore	Central American Region and Andean Region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Pholidostachys kalbreyeri H.Wendl. ex Burret	Central American Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Pholidostachys panamensis A.J.Hend.	Central American Region	High	Moderate	High	High	High	8.5	High	Extinction risk	NE
Pholidostachys pulchra H.Wendl. ex Hemsl.	Central American Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Pholidostachys synanthera (Mart.) H.E.Moore	Central American Region	High	High	Low	Moderate	Low	6	Moderate	Shift range	NE
Phytelephas										
Phytelephas aequatorialis Spruce	Andean Region	High	High	High	High	High	9	High	Extinction risk	NE
Phytelephas macrocarpa Ruiz & Pav.	Amazon Region	High	High	Low	Moderate	High	8	High	Undefined	NE
Phytelephas schottii H.Wendl.	Central American Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Phytelephas tenuicaulis (Barfod) A.J.Hend.	Amazon Region	Moderate	High	Moderate	High	High	7.5	High	Extinction risk	NE
Phytelephas tumacana O.F.Cook	Andean Region	High	High	High	High	High	9	High	Extinction risk	NE
Prestoea										
Prestoea acuminata (Willd.) H.E.Moore	Caribbean region, Andean Region and Central American Region	Moderate	Moderate	Low	Moderate	Moderate	5.5	Moderate	Undefined	NE
Prestoea carderi (W.Bull) Hook.f.	Andean Region	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Prestoea decurrens H.E.Moore	Central American Region	Moderate	Moderate	Moderate	Moderate	Moderate	6	Moderate	Undefined	NE
Prestoea ensiformis (Ruiz & Pav.) H.E.Moore	Andean Region and Central American Region	Moderate	Low	Low	Low	Moderate	5	Moderate	Adaptation	NE
Prestoea longepetiolata (Oerst.) H.E.Moore	Central American Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Prestoea pubens H.E.Moore	Central American Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Prestoea pubigera (Griseb. & H.Wendl.) Hook.f.	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Prestoea schultzeana (Burret) H.E.Moore	Andean Region	Moderate	Moderate	Low	Moderate	Moderate	5.5	Moderate	Undefined	NE
Prestoea simplicifolia Galeano	Andean Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Prestoea tenuiramosa (Dammer) H.E.Moore	Amazon Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Pseudophoenix										
Pseudophoenix ekmanii Burret	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Pseudophoenix lediniana Read	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Pseudophoenix sargentii H.Wendl. ex Sarg.	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Pseudophoenix vinifera (Mart.) Becc.	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Raphia										
Raphia taedigera (Mart.) Mart.	Amazon Region and Central American Region	Moderate	High	Moderate	High	High	7.5	High	Extinction risk	NE
Reinhardtia										
Reinhardtia elegans Liebm.	Central American Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Reinhardtia gracilis (H.Wendl.) Burret	Central American Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Reinhardtia koschnyana (H.Wendl. & Dammer) Burret	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Reinhardtia latisecta Zanoni & M.M.Mejía	Central American Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Reinhardtia paiewonskiana Read	Caribbean region	High	High	High	High	Moderate	8	High	Undefined	NE
Reinhardtia simplex (H.Wendl.) Burret	Central American Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Rhapidophyllum										
Rhapidophyllum hystrix	Caribbean region	Moderate	High	Moderate	High	Low	5.5	Moderate	Shift range	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
(Fraser ex Thouin) H.Wendl. & Drude										
Roystonea										
Roystonea altissima (Mill.) H.E.Moore	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Roystonea borinquena O.F.Cook	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Roystonea dunlapiana P.H.Allen	Caribbean region	High	NA	High	High	Low	7	High	Shift range	NE
Roystonea lenis León	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Roystonea maisiana (L.H.Bailey) Zona	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Roystonea oleracea oleracea (Jacq.) O.F.Cook	Caribbean region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Roystonea princeps (Becc.) Burret	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Roystonea regia (Kunth) O.F.Cook	Caribbean region	High	NA	Low	Low	Low	5	Moderate	Both strategy	NE
Roystonea stellata León	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Roystonea violacea León	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Sabal										
Sabal bermudana L.H.Bailey	Caribbean region	High	NA	High	High	Low	7	High	Shift range	NE
Sabal causiarum (O.F.Cook) Becc.	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Sabal domingensis Becc.	Caribbean region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Sabal etonia Swingle ex Nash	Caribbean region	Low	NA	High	High	Low	5	Moderate	Shift range	NE
Sabal gretherae H.J. Quero	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Sabal maritima (Kunth) Burret	Caribbean region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Sabal mauritiiformis (H.Karst.) Griseb. & H.Wendl.	Caribbean region, Central American Region e Mexican Region	High	Moderate	Low	Moderate	Low	5.5	Moderate	Shift range	NE
Sabal mexicana Mart.	Central American Region e Mexican Region	High	NA	Moderate	Moderate	Low	6	Moderate	Shift range	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Sabal minor (Jacq.) Pers.	Caribbean region	Low	NA	Moderate	Moderate	Low	4	Low	Shift range	NE
Sabal palmetto (Walter) Lodd. ex Schult. & Schult.f.	Caribbean region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Sabal pumos (Kunth) Burret	Central American Region e Mexican Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Sabal rosei (O.F.Cook) Becc.	Central American Region e Mexican Region	High	High	High	High	Low	7	High	Shift range	NE
Sabal uresana Trel.	Mexican Region	High	Low	High	Moderate	Low	6	Moderate	Shift range	NE
Sabal yapa C.Wright ex Becc.	Caribbean region and Central American Region	High	High	High	High	Low	7	High	Shift range	NE
Schippia										
Schippia concolor Burret	Central American Region	High	High	High	High	Low	7	High	Shift range	NE
Serenoa										
Serenoa repens (W.Bartram) Small	Caribbean region	Low	High	High	High	Low	5	Moderate	Shift range	NE
Socratea										
Socratea exorrhiza (Mart.) H.Wendl.	Amazon Region and Central American Region	High	Moderate	Low	Moderate	Low	5.5	Moderate	Shift range	NE
Socratea hecatonandra (Dugand) R.Bernal	Central American Region	High	High	High	High	Low	7	High	Shift range	NE
Socratea rostrata Burret	Andean Region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Socratea salazarii H.E.Moore	Amazon Region e Andean Region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Syagrus										
Syagrus allagopteroides Noblick & Lorenzi	Central Brazilian Region and Atlantic Costal Forest	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus amara (Jacq.) Mart.	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Syagrus angustifolia Noblick & Lorenzi	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus botryophora (Mart.) Mart.	Atlantic Costal Forest	High	High	High	High	High	9	High	Extinction risk	NE
Syagrus caerulescens Noblick & Lorenzi	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus campestris (Mart.) H.Wendl.	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Syagrus campylospatha (Barb.Rodr.) Becc.	Central Brazilian Region	Moderate	High	High	High	High	8	High	Extinction risk	NE
Syagrus cardenasii Glassman	Andean Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus cearensis Noblick	Central Brazilian Region and Atlantic Costal Forest	Moderate	Moderate	High	High	High	7.5	High	Extinction risk	NE
Syagrus cerqueirana Noblick & Lorenzi	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus cocoides Mart.	Central Brazilian Region	High	High	Moderate	High	High	8.5	High	Extinction risk	NE
Syagrus comosa (Mart.) Mart.	Central Brazilian Region	High	High	Moderate	High	Moderate	7.5	High	Undefined	NE
Syagrus coronata (Mart.) Becc.	Central Brazilian Region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Syagrus deflexa Noblick & Lorenzi	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus duartei Glassman	Central Brazilian Region	Low	High	High	High	Moderate	6	Moderate	Undefined	NE
Syagrus evansiana Noblick	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus flexuosa (Mart.) Becc.	Central Brazilian Region	Moderate	High	Low	Moderate	Moderate	6	Moderate	Undefined	NE
Syagrus glaucescens Glaz. ex Becc.	Central Brazilian Region	High	High	High	High	Moderate	8	High	Undefined	NE
Syagrus glazioviana (Dammer) Becc	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus gouveiana Noblick & Lorenzi	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus graminifolia (Drude) Becc.	Central Brazilian Region	Low	High	Moderate	High	High	6.5	Moderate	Extinction risk	NE
Syagrus harleyi Glassman	Central Brazilian Region	Low	Moderate	High	High	Moderate	5.5	Moderate	Undefined	NE
Syagrus hoehnei Burret	Atlantic Costal Forest	High	High	High	High	High	9	High	Extinction risk	NE
Syagrus inajai (Spruce) Becc.	Amazon Region	High	High	Moderate	High	Low	6.5	Moderate	Shift range	NE
Syagrus itacambirana Noblick & Lorenzi	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus kellyana Noblick & Lorenzi	Central Brazilian Region	High	NA	High	High	Moderate	8	High	Undefined	NE
Syagrus lilliputiana (Barb.Rodr.) Becc.	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus loefgrenii	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Glassman										
Syagrus longipedunculata Noblick & Lorenzi	Central Brazilian Region	High	NA	High	High	High	9	High	Extinction risk	NE
Syagrus lorenzoniorum Noblick & Lorenzi	Atlantic Costal Forest	High	NA	High	High	Moderate	8	High	Undefined	NE
Syagrus macrocarpa Barb.Rodr.	Central Brazilian Region	High	Moderate	High	High	High	8.5	High	Extinction risk	NE
Syagrus mendanhensis Glassman	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus microphylla Burret	Central Brazilian Region	Low	High	High	High	Moderate	6	Moderate	Undefined	NE
Syagrus minor Noblick & Lorenzi	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus oleracea (Mart.) Becc.	Central Brazilian Region	High	High	Moderate	High	Moderate	7.5	High	Undefined	NE
Syagrus orinocensis (Spruce) Burret	Amazon Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Syagrus petraea (Mart.) Becc.	Central Brazilian Region	Low	High	Moderate	High	High	6.5	Moderate	Extinction risk	NE
Syagrus picrophylla Barb.Rodr.	Atlantic Costal Forest	High	High	High	High	High	9	High	Extinction risk	NE
Syagrus pleioclada Burret	Central Brazilian Region	Low	Moderate	High	High	High	6.5	Moderate	Extinction risk	NE
Syagrus pleiocladoides Noblick & Lorenzi	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus procumbens Noblick & Lorenzi	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus pseudococos (Raddi) Glassman	Atlantic Costal Forest	High	Moderate	High	High	High	8.5	High	Extinction risk	NE
Syagrus romanzoffiana (Cham.) Glassman	Atlantic Costal Forest and Central Brazilian Region	High	NA	Moderate	Moderate	Low	6	Moderate	Shift range	NE
Syagrus rupicola Noblick & Lorenzi	Central Brazilian Region	Moderate	NA	High	High	High	8	High	Extinction risk	NE
Syagrus ruschiana (Bondar) Glassman	Atlantic Costal Forest	Moderate	High	High	High	Low	6	Moderate	Shift range	NE
Syagrus sancona (Kunth) H.Karst.	Andean Region	High	High	Low	Moderate	Low	6	Moderate	Shift range	NE
Syagrus schizophylla (Mart.) Glassman	Atlantic Costal Forest	Moderate	High	Moderate	High	Low	5.5	Moderate	Shift range	NE
Syagrus smithii (H.E.Moore) Glassman	Amazon Region	High	High	High	High	High	9	High	Extinction risk	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Syagrus stratincola Wess.Boer	Amazon Region	Moderate	High	High	High	High	8	High	Extinction risk	NE
Syagrus vagans (Bondar) A.D.Hawkes	Central Brazilian Region	Moderate	Moderate	High	High	Moderate	6.5	Moderate	Undefined	NE
Syagrus vermicularis Noblick	Central Brazilian Region and Amazon Region	High	High	High	High	Low	7	High	Shift range	NE
Syagrus weddelliana (H.Wendl.) Becc.	Atlantic Costal Forest	High	Moderate	High	High	High	8.5	High	Extinction risk	NE
Syagrus werdermannii Burret	Central Brazilian Region	Moderate	High	High	High	Moderate	7	High	Undefined	NE
Syagrus yungasensis M.Moraes	Andean Region	High	High	High	High	High	9	High	Extinction risk	NE
Synechanthus										
Synechanthus fibrosus (H.Wendl.) H.Wendl.	Central American Region	High	Low	High	Moderate	Low	6	Moderate	Shift range	NE
Synechanthus warscewiczianus H.Wendl.	Central American Region	Moderate	Low	Moderate	Moderate	Low	4.5	Low	Shift range	NE
Thrinax										
Thrinax excelsa Lodd. ex Mart.	Caribbean region	High	High	High	High	Low	7	High	Shift range	NE
Thrinax parviflora Sw.	Caribbean region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Thrinax radiata Lodd. ex Schult. & Schult.f.	Caribbean region	High	High	Low	Moderate	Low	6	Moderate	Shift range	NE
Trithrinax										
Trithrinax brasiliensis Mart.	Central Brazilian Region	Moderate	High	Low	Moderate	Moderate	6	Moderate	Undefined	NE
Trithrinax campestris (Burmeist.) Drude & Griseb.	Central Brazilian Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Trithrinax schizophylla Drude	Central Brazilian Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Washingtonia										
Washingtonia filifera (Rafarin) H.Wendl. ex de Bary	Mexican Region	High	NA		Low	Low	Low	5	Moderate	Both strategy	NE
Washingtonia robusta H.Wendl.	Mexican Region	High	NA		Low	Low	Low	5	Moderate	Both strategy	NE

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Welfia										
Welfia regia H.Wendl.	Central American Region	High	Low	Moderate	Moderate	Low	5.5	Moderate	Shift range	NE
Wendlandiella										
Wendlandiella gracilis Dammer	Amazon Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Wettinia										
Wettinia aequalis (O.F.Cook & Doyle) R.Bernal	Andean Region and Central American Region	High	High	Moderate	High	Moderate	7.5	High	Undefined	NE
Wettinia aequatorialis R.Bernal	Andean Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Wettinia anômala (Burret) R.Bernal	Andean Region	High	High	High	High	Moderate	8	High	Undefined	NE
Wettinia augusta Poepp. & Endl.	Amazon Region	Moderate	High	Moderate	High	High	7.5	High	Extinction risk	NE
Wettinia castanea H.E.Moore & J.Dransf.	Andean Region	High	High	High	High	High	9	High	Extinction risk	NE
Wettinia disticha (R.Bernal) R.Bernal	Andean Region	High	High	High	High	Moderate	8	High	Undefined	NE
Wettinia drudei (O.F.Cook & Doyle) A.J.Hend.	Amazon Region	Moderate	High	Moderate	High	Moderate	6.5	Moderate	Undefined	NE
Wettinia fascicularis (Burret) H.E.Moore & J.Dransf.	Andean Region	High	Moderate	High	High	High	8.5	High	Extinction risk	NE
Wettinia hirsuta Burret	Andean Region	High	Moderate	High	High	High	8.5	High	Extinction risk	NE
Wettinia kalbreyeri (Burret) R.Bernal	Andean Region	Moderate	Low	Moderate	Moderate	Low	4.5	Low	Shift range	NE
Wettinia lanata R.Bernal	Andean Region	High	High	High	High	Moderate	8	High	Undefined	NE
Wettinia longipetala A.H.Gentry	Andean Region	High	High	High	High	High	9	High	Extinction risk	NE
Wettinia maynensis Spruce	Andean Region	High	Low	Moderate	Moderate	Moderate	6.5	Moderate	Undefined	NE
Wettinia microcarpa (Burret) R.Bernal	Andean Region	High	High	High	High	Moderate	8	High	Undefined	NE

79

Genus and species	Region	Hydraulic architecture	Altitudinal range	Latitudinal range	Distribution total	Dispersion ability	Score total	Sensitivity	Ecological strategy	IUCN
Wettinia minima R.Bernal	Andean Region	High	High	High	High	Moderate	8	High	Undefined	NE
Wettinia oxycarpa Galeano & R.Bernal	Andean Region	High	Moderate	High	High	Moderate	7.5	High	Undefined	NE
Wettinia panamensis R.Bernal	Central American Region	High	Low	High	Moderate	Moderate	7	High	Undefined	NE
Wettinia praemorsa (Willd.) Wess.Boer	Andean Region	Moderate	Low	High	Moderate	Low	5	Moderate	Shift range	NE
Wettinia quinaria (O.F.Cook & Doyle) Burret	Andean Region	High	Moderate	Moderate	Moderate	High	8	High	Undefined	NE
Wettinia radiata (O.F.Cook & Doyle) Burret	Central American Region	High	Moderate	High	High	Low	6.5	Moderate	Shift range	NE
Wettinia verruculosa H.E.Moore	Andean Region	High	High	High	High	High	9	High	Extinction risk	NE
Zombia										
Zombia antillarum (Descourt.) L.H.Bailey	Caribbean region	Moderate	High	High	High	Moderate	7	High	Undefined	NE

4. CAPÍTULO II:

Are leaf traits driven by climatic factors? A test with neotropical palms

4.1. Resumo

Dado que os riscos de extinção global são altos e crescentes como consequência das mudanças climáticas, vários métodos padronizados de avaliação de risco têm sido propostos, no entanto, poucos levam em consideração as características foliares das espécies. A folha é comumente utilizada como indicadora de variações ambientais e pode ser um bom objeto de estudo em um cenário de mudanças climáticas. Neste estudo buscamos entender a relação de atributos foliares com o clima, espaço e microhabitats, a fim de avaliar seu uso em métodos de avaliação de risco e análises de sensibilidade as mudanças climáticas. Para isso, foram determinadas a área foliar específica (SLA) e a espessura foliar de 79 espécies de palmeiras neotropicais. A correlação desses atributos com o clima (temperatura e índice de umidade) e com o espaço geográfico (latitude) foi verificada para todas as espécies conjuntamente e para subgrupos definidos de acordo com o microhabitat: espécies de sub-bosque florestal, espécies intermediárias, espécies de dossel florestal e espécies de ambientes abertos. Nossos resultados mostram que as características foliares aqui avaliadas não foram espacialmente distribuídas, ou seja, espécies com estratégias fisiológicas semelhantes não estão associadas necessariamente a mesma faixa latitudinal. Este resultado destaca a importância do uso de metodologias de sensibilidade e exposição de forma complementar para uma análise mais precisa. Apesar dos atributos foliares analisados apresentarem forte pressão filogenética, foi observada enfluencia de variáveis climáticas na distribuição destes atributos. Foi observado uma redução do SLA e um aumento da espessura foliar associado ao aumento da exposição do ambiente, isso é, ambientes com maior intensidade luminosa apresetaram espécies com folhas mais espessas e com menor área foliar. Espécies de sub-bosque apresentam características foliares mais vulneráveis às mudanças climáticas, porém, estão menos expostas a condições climáticas extremas.

Palavras-chave: área foliar específica, espessura de folhas, avaliação de risco, índice de umidade, temperatura

4.2. Abstract

Given that global extinction risks are high and increasing as consequence of climate change several standardized methods of risk assessment have been proposed, however, few take into account species' leaf traits. The leaf is commonly used as indicators of environmental variations and can be a good study object in a climate change scenario. In this study we sought to understand the relationship of leaf attributes with climate, space and microhabitats, in order to evaluate their use in methods of risk assessment and sensitivity analyzes of climate change. For this, specific leaf area (SLA) and leaf thickness of 79 neotropical palm species were determined. The correlation of these traits with climate (temperature and moisture index) and space (latitude) was verified for the whole group of species and for subgroups of microhabitats: forest understory species, forest midstory species, forest canopy species and species of open habitats. Our results show that the leaf traits evaluated here were not spatially distributed, that is, species with similar physiological strategies are not necessarily associated with the same latitudinal range. This result highlights the importance of using sensitivity and exposure methodologies in a complementary way for a more accurate analysis. Despite the leaf traits analyzed here, presented strong phylogenetic pressure, effects of the climate variables on the distribution of these traits were observed. A reduction in SLA and an increase in leaf thickness were observed associated with increased exposure of the environment, that is, environments with higher light intensity, presented species with thicker leaves and smaller leaf area. Understory species have leaf characteristics that are more vulnerable to climate change, however, are less exposed to extreme climatic conditions.

Keywords: specific leaf area, leaf thickness, risk assessment, moisture index, temperature

4.3. Introduction

Climate change poses a major threat to global biodiversity, therefore one of the greatest challenges today is to understand its effects and species responses to these changes (Hughes 2000; Sala et al. 2000; Thomas et al. 2004; Walther et al. 2007; Göldel et al. 2015). These responses include movement to track the most appropriate abiotic conditions, resulting in shift range (Hickling et al. 2006; Parmesan 2006), plastic or acclimatory responses to altered conditions in existing populations (Nicotra et al. 2010), evolutionary adaptation to new conditions (Valladares et al. 2014; Kim & Donohue 2013), and extinction (Ceballos et al. 2015; Pimm et al. 2014; Thomas et al. 2004). Such responses are not unique and are generally associated with the intrinsic characteristics of the species, the magnitude of exposure to climate change and the spatial structure of the landscapes in which the species occur (Wheatley et al. 2017).

Climate change vulnerability assessment methodologies follow broad trait- and trend-based approaches and aim to prioritize adaptive strategies to combat the impacts of climate change, including conservation actions for those species most susceptible to extinction (Pacifici et al. 2015; Wheatley et al. 2017). The response mechanism of a species may be associated with the degree of sensitivity of the species to the changes or the degree of exposure present in the environment in which it occurs. The sensitivity of a species is determined by intrinsic factors including physiological, ecological, and genetic diversity (Williams et al. 2008). Specific functional traits, such as those related to plant species responses (Guitay & Noble 1997; Diaz & Cabido 2001), are relevant in terms of their resilience to the impacts of climate change. Traits to be considered for analysis should be in accordance with the ecological issues in which they are involved (Petchey & Gaston 2006), and for that, it is important to understand their relationship with the climate and geographic space. Even so, this relationship may vary from one taxonomic group to another, or even vary at different functional group and habitats (Poorter et al. 2009).

Understanding how plant species differ in relation to functional traits for resource acquisition and utilization, and whether the relationship between these traits varies according to environmental differences, is one way of constructing a more predictive ecology in the context of global climate change. The leaf is the anatomically most variable organ of a plant, and its varieties are commonly used as indicators of environmental conditions (Danquah 2010). In a

region with intense sunlight and high temperatures, the plants avoid excessive heating of their leaves, such as increased leaf thickness and reducing the absorption of solar radiation through foliar adaptations such as reflective trichomes and leaf waxes, vertical foliar winding, small leaves and stomata on the abaxial face (Lambers et al. 2008). In environments with water deficiency, plants tolerant to this condition may present morphological alterations, such as leaf area reduction and increased number of stomata per area (Batista et al. 2010; Lambers et al. 2008). Thus, as a response to climate change, plants will go through changes in morphology, anatomy and physiology to adapt to different environmental conditions (Nicotra et al. 2010).

The specific leaf area (SLA) reflects the relationship between light interception per leaf area invested in a biomass unit, where leaves with lower SLA values allow an increase in resistance to water loss during the dry season (Ribeiro et al. 2016). Variation in leaf thickness is related to a trade-off between the rate of photosynthesis and the loss of water by transpiration (Michaletz et al. 2016). Thicker leaves can buffer the increased temperature variation and thus withstand increasing temperature (Michaletz et al. 2016; Soudzilovskaia et al. 2013). Thus, it is expected that species with higher SLA (Ribeiro et al. 2016; Nicotra el al. 2010) and lower thickness (Michaletz et al. 2016; Soudzilovskaia et al. 2013) will be more sensitive to climatic changes, in regions where episodes of temperature increase and drought regimes are predicted.

In this study, the relation of leaf traits with climatic and spatial variables was investigated in order to identify the importance of these traits in the evaluation of neotropical palms sensitivity to climatic changes. The following questions were asked: (1) Is there a geographical pattern in leaf traits? (2) Is there a relation between the leaf thickness of palms and the atmospheric temperature? (3) Is there a relationship between the specific leaf area and the mosture index? (4) The relationship between leaf traits and climatic variables can change between microenvironments?

4.4. Methods

For this study, 79 palm species were selected, distributed in 29 genus and 14 subtribes, chosen according to the number of exsiccates available in the Herbarium at the Kew Royal Botanic Gardens. The total sampled represents approximately 10% of the total number of

neotropical palm species (Govaerts et al. 2019), but they are distributed in eight biomes and represent the entire neotropical region.
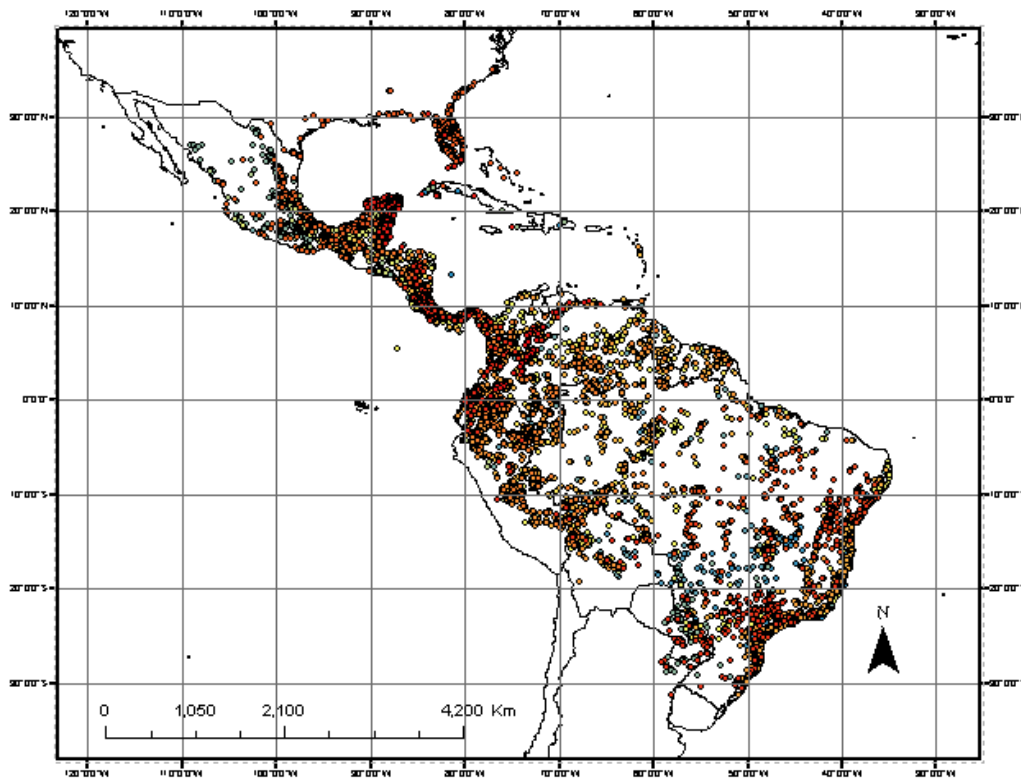
Figure 1. Occurrence record of 79 of neotropical palm species obtained in Global Biodiversity Information Facility – GBIF, for which the information of leaf foliar traits was collected.

Three samples of approximately 3 cm^2 each of dry leaves deposited in the herbarium were collected for each species. The dry weight of each sample was obtained on a precision scale and the samples were hydrated for at least 60 hours to obtain measurements of area and leaf thickness. The leaf area was evaluated using ImageJ software and used as a numerator to obtain the specific leaf area (SLA = leaf area / leaf dry mass).

We sought to verify the traits range variation among related species. The variation of SLA and leaf thickness between the different subfamilies was measured through a one-way ANOVA, with FDR pairwise test. Phylogeny was used to test if any potential patterns in leaf traits are not due to phylogenetic relationship, that is, the tendency of the species closest phylogenetically to be

more similar than the distant ones. The species-level Arecaceae tree was derived from Faurby et al. (2016) and tested against Pagels λ (Pagel, 1999) and Bloomberg's K (Blomberg, 2003) using the function phylosig in phytools package. K compares the variance among species to the overall variance within a tree. Significant values of K reflect that close relatives are more similar than expected under the Brownian model. λ is a scaling parameter for the correlations between species, relative to the correlation expected under Brownian evolution. We calculated the phylogenetic signal for the 1000 probable trees. When species are equivalent to Brownian evolution it is expected that λ = 1, indicating a strong phylogenetic signal. λ = 0 indicates that there is no phylogenetic signal in the trait, i.e. that the trait has evolved independently of phylogeny and thus close relatives are not more similar on average than distant relatives (Kamilar and Cooper 2013).

The correlation between the traits and the geographic space occupied by the samples was verified, using coordinates obtained from the exsicata. The species were classified into three groups related to their microhabitat: open area species, understory midstory and canopy forest species. For the classification between open and forested areas, the coordinates of the collections were plotted on the ecoregions (Olson et al., 2001), and were divided on open areas: Tropical and subtropical grasslands, Temperate Grasslands, Flooded Grasslands and Savannas, Montane Grasslands and Shrublands, Deserts and Xeric Shrublands and Mangroves/Costal Region; and enclosed areas: Tropical and Subtropical Moist Broadleaf Forests, Tropical and Subtropical Dry Broadleaf Forests and Tropical and Subtropical Coniferous Forests. For the classification of the forest stratification, we used the height information of the individuals obtained in the exsiccates and then classified using the Raunkiær system (1934). Therefore, we divided it into understory (Hemicryptophytes, Nanophanerophytes and Microphanerophytes), midstory (Mesophanerophytes and Liana) and forest canopy (Megaphanerophytes). We chose this classification because the influence of the climate on the selected traits can act with different intensity according to their micro-habitat (Poorter et al., 2009). The variation of SLA and leaf thickness between the different microhabitats was measured through a one-way ANOVA, with FDR pairwise test.

The correlation between the traits and the current climate of species occurrence: SLA with the moisture index (ratio between the annual precipitation and the annual evapotranspiration) and

leaf thickness with the maximum average temperature, were made for each micro-habitat group separately. The climatic variables were obtained from the CHELSA database (Karger et al., 2017) that provides current climatic data (1979-2013 series). The temperatures were extracted directly from the occurrence records of each species and moisture index (MI) was calculated as the ratio of precipitation to potential evapotranspiration, where humidity increases with the increase of moisture index.

4.5. Results

The leaf thickness of the 237 samples of 79 palms analyzed ranged from 0.06 to 0.58 cm and SLA range from 39.60 to 364.16 $cm^2 \ g^{-1}$.

The leaf thickness (F= 44.83, Df = 13, p<0.001) and SLA (F= 103, Df = 13, p<0.001) was different among the palm subtribes. Phylogenetic signal was found for SLA (Figure 2) and leaf thickness (Figure 3) within the 79 species. All 1000 compared trees gave significant signalling levels at a 95% confidence level. For all species $\lambda = 0$, presenting a p-value < 0.001. For SLA, K ranged within 0.082 and 0.961 with significant levels varying between 0.001 and 0.229. For leaf thickness K ranged within 0.023 and 0.512 with significant levels varying between 0.001 and 0.519. This indicated that there is phylogenetic signal within or between species.
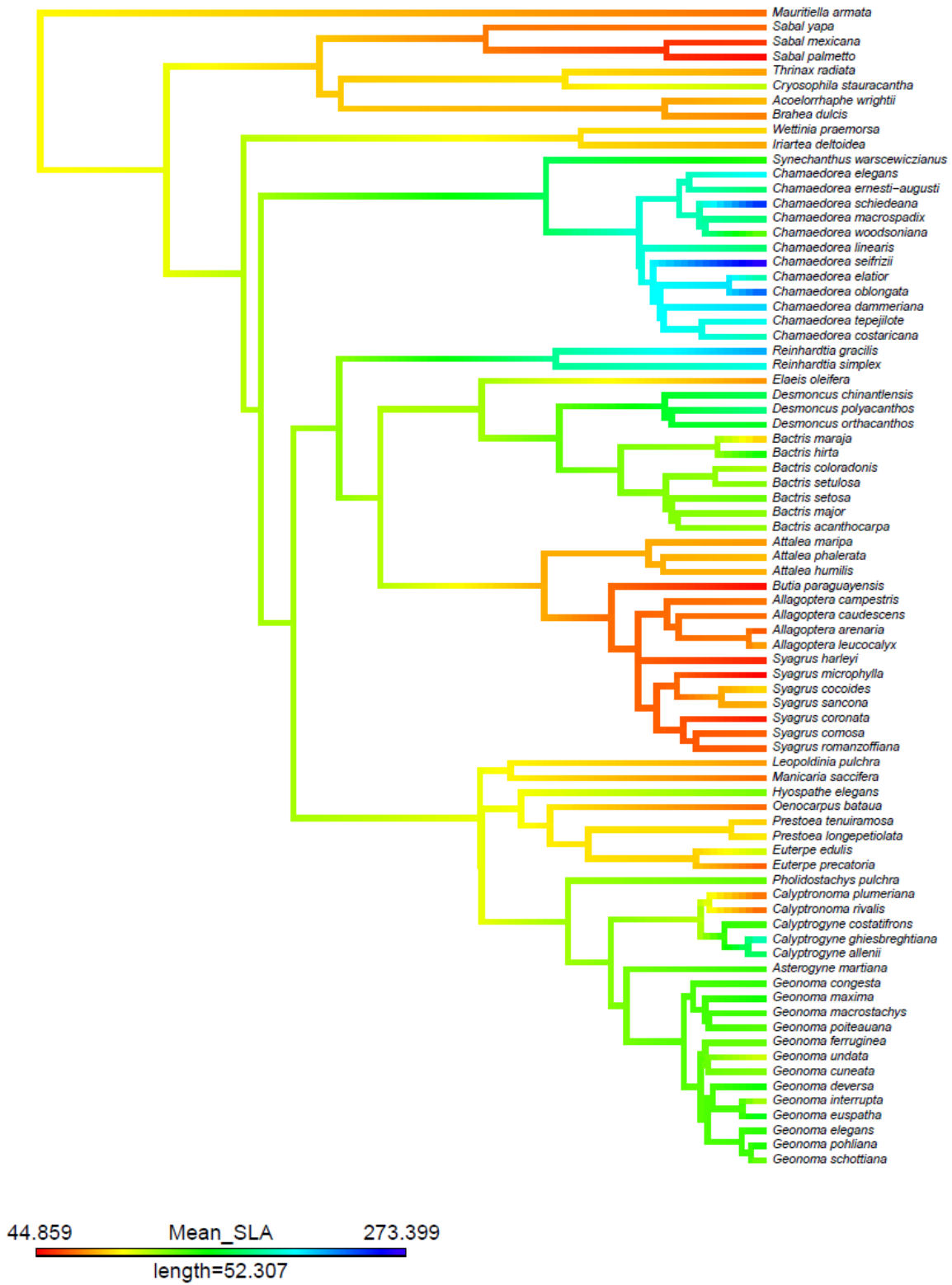
Figure 2. Phylogenetic distribution of specific leaf area (cm^2 g^{-1}) in 79 Neotropical palm (Arecaceae) species.
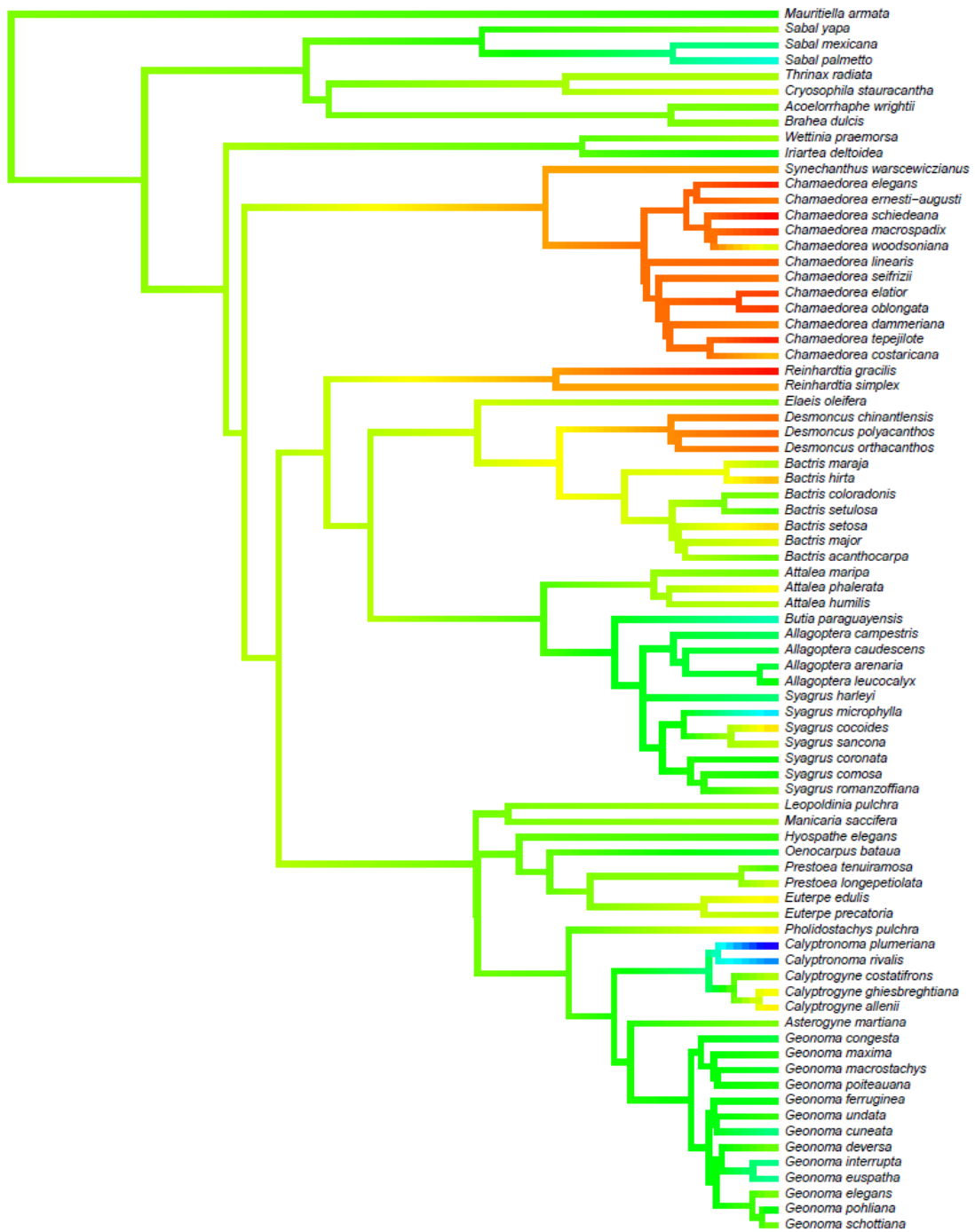
Figure 3. Phylogenetic distribution of leaf thickness (cm) in 79 Neotropical palm (Arecaceae) species.

The leaf thickness (F= 11.92, Df = 6, p<0.001) (Figure 4a) and SLA (F= 17.05, Df = 6, p<0.001) (Figure 4b) was different among the lifeforms.
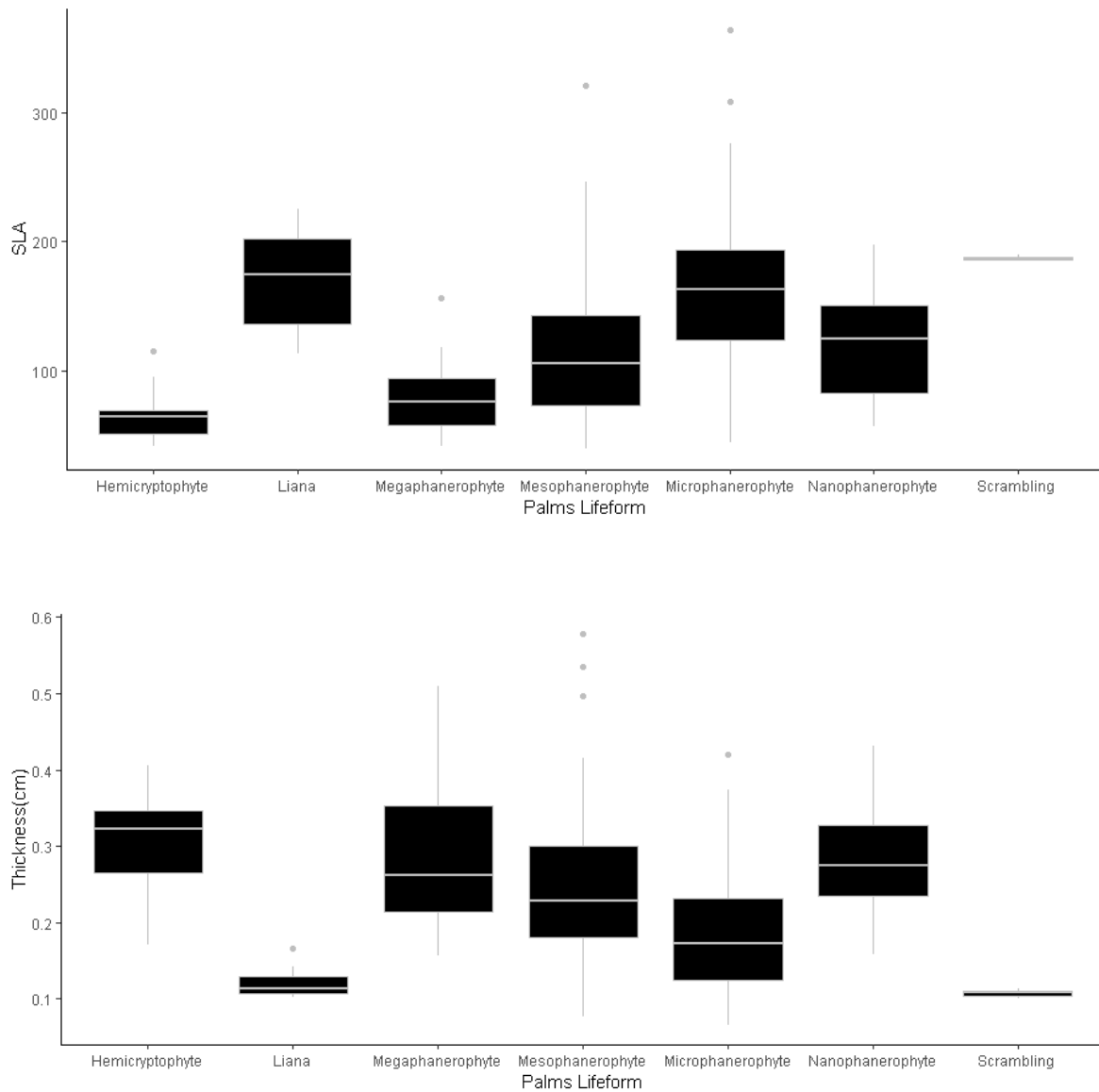
Figure 4. Range of specific leaf area (cm^2 g^{-1}) and leaf thickness (cm) in different Arecaceae lifeform.

When the entire data group was used, without the microhabitat division, no relationships were found between traits and latitude (SLA: r= 0.1467, p= 0.1971; thickness leaf: r= -0.0354, p=

0.757). A positive and significant relationship was found for SLA and moisture index ($r = 0.249$, $p < 0.0001$), however no correlation was found for leaf thickness and temperature ($r = -0.0183$, $p = 0.779$).
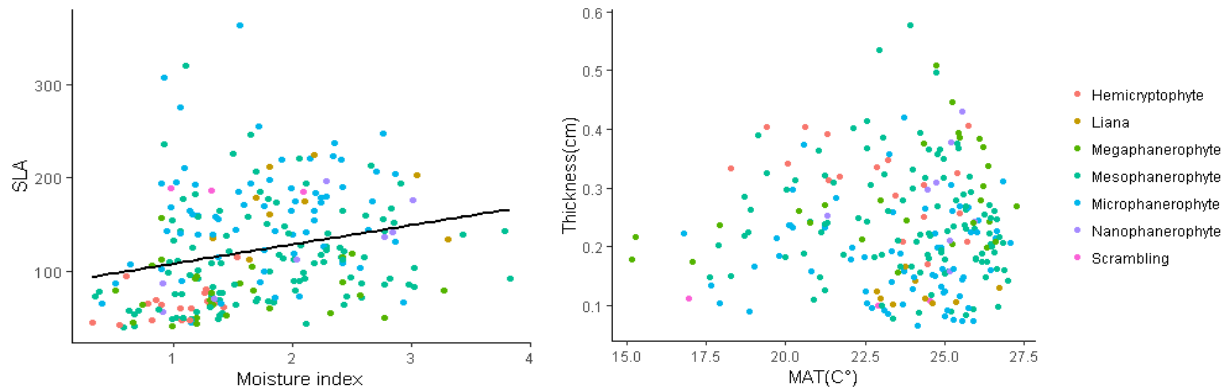
Figure 5. Relationships between SLA ($cm^2\ g^{-1}$) and moisture index and leaf thickness (cm) and temperature for all lifeform and microhabitat.

SLA ($Df = 3$, $F = 24$, $p < 0.0001$) and leaf thickness ($Df = 3$, $F = 9.341$, $p < 0.0001$) differed between microhabitats. Open habitat species and species located in forest canopy showed greater leaf thickness and lower SLA than understory species (Figure 6).
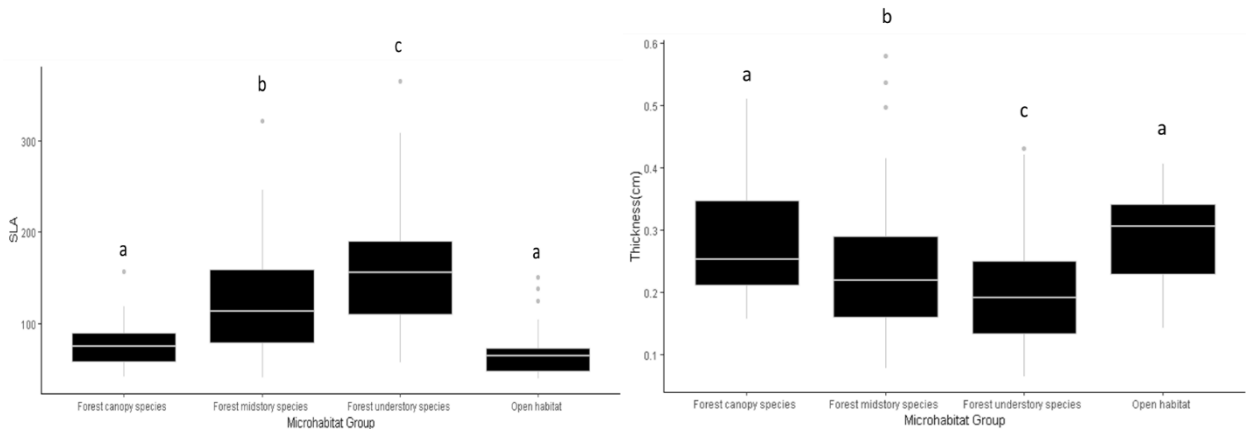
Figure 6. Boxplots with SLA (cm^2 g^{-1}) and leaf thickness (cm) values for each Microhabitat Group. Same letters indicate no statistical difference.

The results show that in species of open habitats (N= 29) there is a positive and significant correlation between SLA and the moisture index (r= 0.6552, p= 0.0002873) and an absence of correlation between leaf thickness and temperature (r= - 0.06633, p=0.7475). For forest canopy species (N= 23) there is no correlation between SLA and moisture index (r = 0.0421, p= 0.8487) and a significant positive correlation between leaf thickness and temperature (r = 0.4003, p = 0.052). For forest midstory species (N= 108), no correlation was found between SLA and moisture index (r = 0.1453, p = 0.1316) and leaf thickness and temperature (r = -0.0765, p = 0.429). For forest understory species (N= 77), no correlation was found between SLA and moisture index (r = 0.1909, p = 0.0941) and leaf thickness and temperature (r = 0.0960, p = 0.4031).
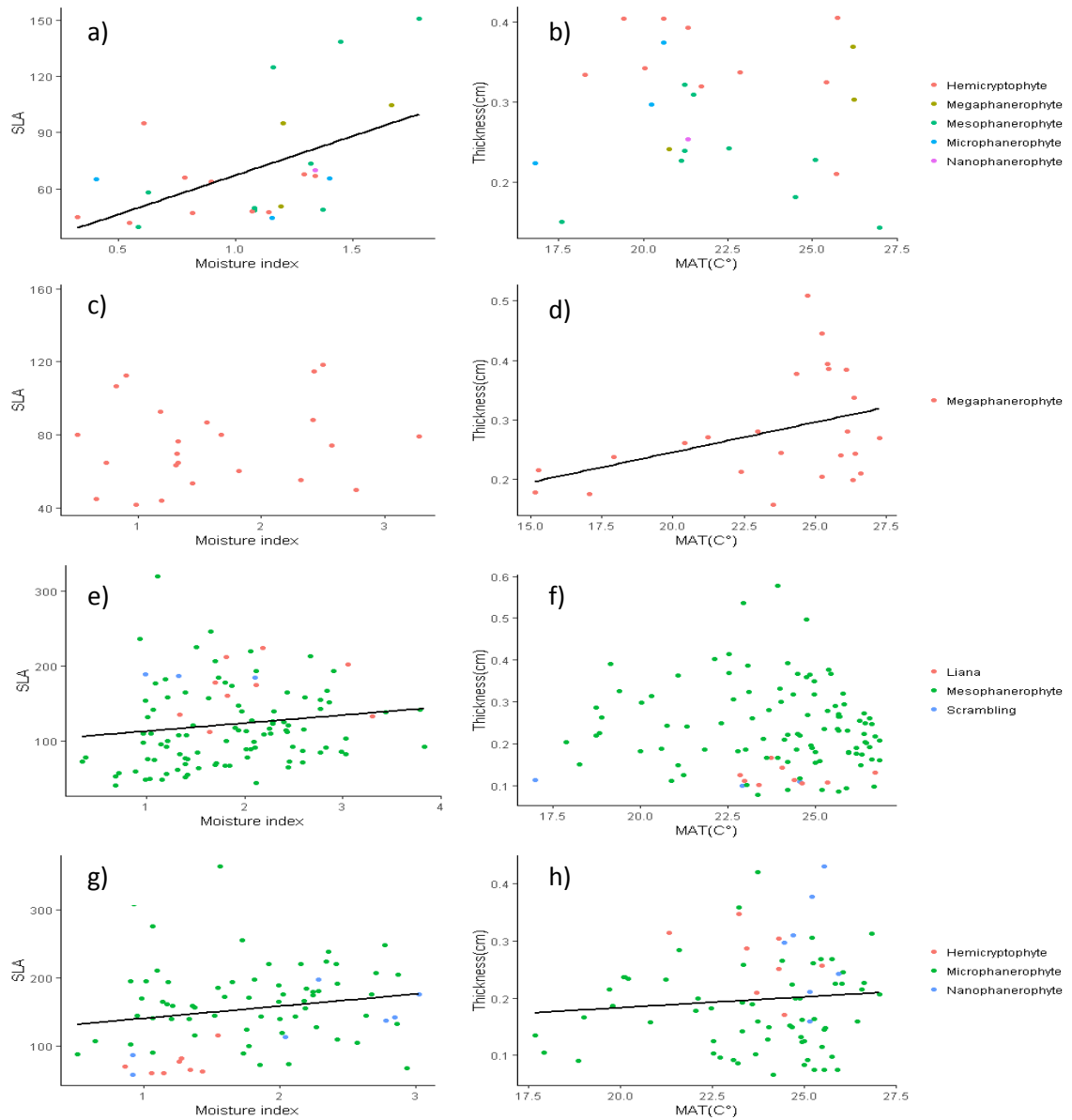
Figure 7. Relationships between specific leaf area (a, c, e and g) (cm^2 g^{-1}) and leaf thickness (cm) (b, d, f and h) and climatic variables (mean annual temperature – MAT and mosture index – MI) for neotropical palms that occur in different microhabitats: open habitats (a, b), canopy forest (c, d), midstory forest (e, f) and understory forest (g, h). Points are from the 237 samples of 79 palms species.

4.6. Discussion

Our results show that palm's leaf thickness and specific leaf area are driven by phylogenetic pressures. This means that more related species share similar characteristics (Blomberg et al. 2003, Losos 2016), indicating the evolutionary stability of these traits (Olalla-Tárraga et al. 2017). Seeing the similarity of these traits between related species, this result gives us the opportunity to extend the discussion for other palms species not studied here.

Leaf traits evaluated here were not spatially distributed, that is, they did not present a relation with the maximum latitudinal of the species, this result emphasizes the independence of sensitivity and exposure approaches and highlights the importance of using both methodologies in a complementary way for a more accurate analysis. The absence of correlation shows that species with different physiological strategies are spatially distributed regardless of their latitudinal distribution range. Some studies of climate change consider only exposure or trend-based methodology (Wheatley et al. 2017), this is, the spatial arrangement of climatic factors associated with a geographic coordinate, regardless of the species characteristics that occurs there. It is an important measure but does not consider the intrinsic and ecological factors of the species associated to these coordinates, since each species has an adaptive capacity or escape strategy involved.

Arecaceae are composed of a diversity of forms ranging from shrub, climbing and canopy species, and consequently are spatially arranged in a forest stratification, which get different light intensity. Moreover, the topographic and the altitudinal variation existing in some biomes promotes microclimatic variations that may have a strong influence on the distribution of palm species (Vormisto et al. 2004; Svenning 1999). Leaf traits are directly associated to light intensity. For example, higher SLA values are expected in regions with higher light competitiveness: consequently, influences the composition of the species in the different forest strata and microhabitats (Poorter et al. 2009). All this diversity of forms and microhabitats may have masked the results when evaluating the species together. Here it was seen that the greater the exposure of the attribute to the climate, the greater its correlation with it, so it was not observed this relation in forest understory species. This is especially important for palms with narrow regenerative niche, where microscale features appear to be more limiting in species establishment than macroscale characteristics (Oda et al., submitted).

The relationship between specific leaf area and leaf thickness with climatic variables has been demonstrated previously in other studies (Niinemets 2001). SLA declines along decreasing moisture gradients and / or nutrient availability (Cunningham et al. 1999, Fonseca et al. 2000). This relationship directly proportional to humidity also justifies the higher values of SLA found in understory palms. In addition, studies show intraspecific variation of the SLA value associated with individual height, with SLA decreasing as canopy height increases. These pattern occour because when trees become taller, increased water stress due to gravity and resistance may limit leaf expansion and photosynthesis for greater height investment (Koch et al. 2004)

Plants with thick leaves become a vegetative component increasingly important in climates with higher average temperatures and higher solar radiation. Increases in thickness allow the exposure of a larger fraction of leaf biomass to high light, where the rate of return on investment is higher (Niinemets 2001). Thus, although understory species present more sensitive characteristics to climatic changes, the individuals in turn, located in these microclimates, are less exposed to extreme climatic conditions.

In addition to climate relations, specific leaf area and leaf thickness are associated with fitness measures such as photosynthetic capacity, long leaf survival, nutrient retention and protection against desiccation (Mooney & Dunn, 1970). These traits can be used for sensitivity measure associated with climate change, however, the environmental scale and the exposure of these leaf traits to the climate should be considered, since when less exposed, smaller is your correlation with the climate. Since forest fragmentation increases edge effects (Murcia 1995), and at the same time exposes understory species to this altered climate, we can not say that these would be in a condition of low concern.

References

Batista L.A., Guimarães R.J., Pereira F.J., Carvalho G.R., Castro, E.M. (2010). Anatomia foliar e potencial hídrico na tolerância de cultivares de café ao estresse hídrico. Revista Ciência Agronômica 41(3): 475- 481.

Bjorholm S., Svenning J-C., Baker W. J., Skov F., Balslev H. (2006). Historical legacies in the geographical diversity patterns of New World palm (Arecaceae) subfamilies. Botanical Journal of the Linnean Society, 151, 113-125.

Bjorholm S., Svenning J-C., Skov F., Balslev H. (2005). Environmental and spatial controls of palm (Arecaceae) species richness across the Americas. Global Ecology and Biogeography, 14: 423-429.

Blomberg S.P., Garland T., Ives A.R. (2003). Testing for phylogenetic signal in comparative data: behavioral traits are more labile. Evolution 57: 717–745.

Blach-Overgaard A., Balslev H., Dransfield J., Normand S., Svenning J-C. (2015). Global-change vulnerability of a key plant resource, the African palms. Scientific Reports, 5, 12611. Doi: 10.1038/srep12611

Blach-Overgaard A., Svenning J-C., Balslev H. (2009). Climate change sensitivity of the African ivory nut palm, Hyphaene petersiana Klotzsch ex Mart. (Arecaceae) – a keystone species in SE Africa. IOP Conf. Series: Earth and Environmental Science, 8. Doi:10.1088/1755-1315/8/1/012014

Blach-Overgaard A., Svenning J-C., Dransfield J., Greve M., Balslev H. (2010). Determinants of palm species distributions across Africa: the relative roles of climate, non-climatic environmental factors, and spatial constraints. Ecography 33: 380-391.

Ceballos G., Ehrlich P.R., Barnosky A.D., Garcia A., Pringle R.M., Palmer T.M. (2015). Accelerated modern human-induced species losses: entering the sixth mass extinction. Science Advances, 1, e1400253. Doi:10.1126/sciadv.1400253.

Cunningham S.A., Summerhayes B., Westoby M. (1999) Evolutionary divergences in leaf structure and chemistry, comparing rainfall and soil nutrient gradients. Ecological Monographs 69: 569–588.

Danquah J.A. (2010). Phonotypic plasticity of leaf legth to an environmental gradient in Khaya ivorensis (Meliaceae) population in Ghana. African Journal of Environmental Science and Technology 4(12): 860-865.

Diaz S., Cabido M. (1997). Plant Functional Types and Ecosystem Function in Relation to Global Change. Journal of Vegetation Science 8(4).

Eiserhardt W.L., Svenning J-C., Kissling W.D., Balslev H. (2011). Geographical ecology of the palms (Arecaceae): determinants of diversity and distributions across spatial scales. Annals of Botany, 108 (8): 1391-4161. Doi: 10.1093/aob/mcr146

Faurby S., Eiserhardt W.L., Baker W.J., Svenning J.C. (2016). An all-evidence species-level supertree for the palms (Arecaceae). Molecular Phylogenetics and Evolution 100: 57-69.

Fonseca C.R., Overton J.M., Collins B., Westoby M. (2000) Shifts in trait-combinations along rainfall and phosphorus gradients. Journal of Ecology 88: 964–977.

Gentry A.H. (1988). Changes in plant community diversity and floristic composition on environmental and geographical gradients. Annals of the Missouri Botanical Garden, 75: 1-34.

Göldel B., Kissling W.D., Svenning J. (2015). Geographical variation and environmental correlates of functional trait distributions in palms (Arecaceae) across the New World. Botanical Journal of the Linnean Society. DOI: 10.1111/boj.12349

Govaerts R., Dransfield J., Zona S., Hodel D.R., Henderson, A. (2019). World Checklist of Arecaceae. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet; http://wcsp.science.kew.org/ Retrieved

Guitay H., Noble I.R. (1997). What are functional types and how can we seek them? In: Smith T.M., Shugart H.H., Woodward F.I. (eds.), Plant functional types: their relevance to ecosystem properties and global change. Cambridge: Cambridge University Press.

Hickling R., Roy D.B., Hill J.K., Fox R., Thomas C.D. (2006). The distributions of a wide range of taxonomic groups are expanding polewards. Global Change Biology 12: 450–455.

Hughes L. (2000). Biological consequences of global warming: is the signal already apparent? Trends in Ecology & Evolution 15: 56-61. Doi: 10.1016/S0169 5347(99)01764-4

Kamilar J.M., Cooper N. (2013). Phylogenetic signal in primate behaviour, ecology and life history. Phil. Trans. R. Soc. B http://doi.org/10.1098/rstb.2012.0341

Karger D.N., Conrad O., Böhner J., Kawohl T., Kreft H., Soria-Auza R.W., Zimmermann N.E., Linder H.P., Kessler M. (2017). Climatologies at high resolution for the earth's land surface areas. Scientific Data, 4: 170122 (20 pp.). Doi: 10.1038/sdata.2017.122

Kim E., Donohue K. (2013). Local adaptation and plasticity of Erysimum capitatum to altitude: its implications for responses to climate change. Journal of Ecology 101:796–805.

Kissling W.D., Baker W.J., Balslev H., Barfod A.S., Borchsenius F., Dransfield J., Govaerts R., Svenning J-C. (2012). Quaternary and pre Quaternary historical legacies in the global distribution of a major tropical plant lineage. Global Ecology Biogeography, 21, 909-921. Doi: 10.1111/j.1466-8238.2011.00728.x

Koch G., Sillett S., M Jennings G., Davis S. (2004). The limit to tree height. Nature, 428, 851-854. Doi: 10.1038/nature02417

Kristiansen T., Svenning J-C., Pedersen D., Eiserhardt W., Grández C., Balslev H. (2011). Local and regional palm (Arecaceae) species richness patterns and their cross-scale determinants in the western Amazon. Journal of Ecology 99: 1001-1015. Doi:10.1111/j.1365-2745.2011.01834.x

Losos, J. B. (2008). Phylogenetic niche conservatism, phylogenetic signal and the relationship between phylogenetic relatedness and ecological similarity among species. Ecology letters 11: 995–1003.

Michaletz S.T., Weiser M.D., McDowell N.G., Zhou J., Kaspari M., Helliker B.R., Enquist B. (2016). The energetic and carbon economic origins of leaf thermoregulation. Nature Plants 2: 16129

Mooney H.A., Dunn E.L. (1970). Convergent evolution of Mediterranean-climate evergreen sclerophyll shrubs. Evolution 24: 292–303. Doi:10.1111/j.1558-5646.1970.tb01762.x

Morris R.J. (2010). Anthropogenic impacts on tropical forest biodiversity: a network structure and ecosystem functioning perspective. Philosophical Transactions: Biological Sciences 365: 3709-3718. Doi:10.1098/rstb.2010.0273

Murcia C. (1995). Edge effects in fragmented forests: implications for conservation. Trends in Ecology and Evolution 10: 58-62.

Nicotra A.B., Atkin O.K., Bonser S.P., Davidson A.M., Finnegan E.J., Mathesius U., Poot P., Purugganan M.D., Richards C.L., Valladares F., van Kleunen M. (2010). Plant phenotypic plasticity in a changing climate. Trends in Plant Science 15(12): 684-692

Niinemets Ü. (2001). Global-scale climatic controls of leaf dry mass per area, density, and thickness in trees and shrubs. Ecology 82:453-469.

Oda et al., Portela, R.Q., Siqueira M.F. Micro or macroscale? Which one has the most influence in the establishment of an endemic Atlantic Forest palm? Submitted for Ecology and Evolution in December 23, 2018.

Olalla-Tárraga M.Á., González-Suárez M., Bernardo-Madrid R., Revilla E., Villalobos F. (2016). Contrasting evidence of phylogenetic trophic niche conservatism in mammals worldwide. Journal of Biogeography 44 (1): 99-110

Olson D.M., Dinerstein E., Wikramanayake E.D., Burgess N.D., Powell G.V.N., Underwood E.C., D'Amico J.A., Itoua I., Strand H.E., Morrison J.C., Loucks C.J., Allnutt T.F., Ricketts T.H., Kura Y., Lamoreux J.F., Wettengel W.W., Hedao P., Kassem K.R. (2001). Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 51(11): 933-938.

Pacifici M., Foden W.B., Visconti P., Watson J.E.M., Butchart S.H.M., Kovacs K.M., Scheffers B.R., Hole D.G., Martin T.G., Akçakaya H.R., Corlett R.T., Huntley B., Bickford D, Carr J.A., Hoffmann A.A., Midgley G.F., Pearce-Kelly P., Pearson R.G., Williams S.E., Willis S.G., Young B., Rondinini C. (2015). Assessing species vulnerability to climate change. Nature Climate Change, 5. Doi: 10.1038/NCLIMATE2448.

Pagel M. (1999): Inferring the historical patterns of biological evolution. Nature 401:877-884

Parmesan C. (2006). Ecological and Evolutionary Responses to Recent Climate Change. Annual Review of Ecology, Evolution, and Systematics 37: 637-669

Petchey O.L., Gaston K.J. (2006). Functional diversity: back to basics and looking forward. Ecology Letter 9(6).

Pimm S.L, Jenkins C.N., Abell R., Brooks T.M., Gittleman J.L., Joppa L.N., Raven P.H., Roberts C.M., Sexton J.O. (2014). The biodiversity of species and their rates of extinction, distribution, and protection. Science 344: 1246752.

Poorter H., Niinemets U., Poorter L., Wright J.I., Villar R. (2009). Causes and consequences of variation in leaf mass per area (LMA): a meta-analysis. New Phytologist 183(4): 1222-1222

Raunkiær C.C. (1934). The Life Forms of Plants and Statistical Plant Geography, Oxford, Oxford University Press.

Ribeiro P.C., Souza M.L., Muller L.A., Ellis V.A., Heuertz M., Lemos-Filho J.P., Lovato M.B. (2016). Climatic drivers of leaf traits and genetic divergence in the tree Annona crassiflora: a broad spatial survey in the Brazilian savannas. Glob. Chang. Biol. 22 (11): 3789–3803

Roncal J., Blach-Overgaard A., Borchsenius F., Balslev H., Svenning J-C. (2011). A dated phylogeny complements macroecological analysis to explain the diversity patterns in Geonoma (Arecaceae). Biotropica 43: 324-334.

Sala O.E., Chapin F.S., Armesto J.J., Berlow E., Bloomfield J., Dirzo R., Huber-Sanwald E., Huenneke L.F., Jackson R.B., Kinzig A., Leemans R., Lodge D.M., Mooney H.A., Oesterheld M., Poff N.L., Sykes M.T., Walker B.H., Walker M., Wall D.H. (2000). Global biodiversity scenarios for the year 2100. Science 287: 1770-1774.

Soudzilovskaia N.A., Elumeeva T.G., Onipchenko V.G., Shidakov I.I., Salpagarova F.S., Khubiev A.B., Tekeev D.K., Cornelissen J.H.C. (2013). Functional traits predict relationship between plant abundance dynamic and long-term climate warming. Proc. Natl. Acad. Sci. 110 (45): 18180–18184

Svenning J.C. (1999). Microhabitat specialization in a species-rich palm community in Amazonian Ecuador. Journal of Ecology 87: 55-65.

Svenning J-C., Borchsenius F., Bjorholm S., Balslev H. (2008). High tropical net diversification drives the New World latitudinal gradient in palm (Arecaceae) species richness. Journal of Biogeography 35: 394-406.

Thomas C.D., Cameron A., Green R.E., Bakkenes M., Beaumont L.J., Collingham Y.C., Erasmus B.F.N., Siqueira M.F.D., Grainger A., Hannah L. (2004). Extinction risk from climate change. Nature, 427 (6970): 145-148. Doi: 10.1038/nature02121

Valladares F., Matesanz S., Guilhaumon F., Araújo M.B., Balaguer L., Benito-Garzón M., Cornwell W., Gianoli E., van Kleunen M., Naya D.E., Nicotra A.B., Poorter H., Zavala M.A. (2014) The effects of phenotypic plasticity and local adaptation on forecasts of species range shifts under climate change. Ecol Lett 17:1351–64.

Vormisto J., Tuomisto H., Oksanen J. (2004). Palm distribution patterns in Amazonian rainforests: What is the role of topographic variation? Journal of Vegetation Science 15: 485-494.

Walther G.R., Gritti E.S., Berger S., Hickler T., Tang Z.Y., Sykes M.T. (2007). Palms tracking climate change. Global Ecology and Biogeography 16: 801-809.

Wheatley C.J., Beale C.M., Bradbury R.B., Pearce-Higgins J.W., Critchlow R., Thomas C.D. (2017). Climate change vulnerability for species—Assessing the assessments. Global Change Biology 23: 3704-3715. Doi: 10.1111/gcb.13759

Whitmore T.C. (1998). An introduction to tropical rain forests. (2nd ed.). Great Britain: Oxford University Press

Williams S.E., Shoo L.P., Isaac J.L., Hoffmann A.A., Langham G. (2008). Towards an Integrated Framework for Assessing the Vulnerability of Species to Climate Change. PLoS Biology 6 (12): e325. Doi: 10.1371/journal.pbio.0060325

Wright S.J. (2005). Tropical forests in a changing environment. Trends in Ecology & Evolution 20 (10). Doi: 10.1016/j.tree.2005.07.009

5. CAPÍTULO III:

Neotropical palms response to climate change: An approach based on leaf trait characteristics

5.1. Resumo

As mudanças climáticas representam uma grande ameaça à biodiversidade global, portanto, um dos maiores desafios hoje é entender seus efeitos e respostas de espécies a essas mudanças. Estudos de características morfofuncionais das espécies e suas adaptações à heterogeneidade ambiental favorecem uma maior compreensão dos ecossistemas frente a esses impactos. Nesse sentido, foram usadas características foliares para predizer respostas ao impacto das mudanças climáticas nas palmeiras neotropicais. Para isso, foram gerados modelos de Nicho Ecológico para 79 espécies utilizando dados climáticos de séries históricas e futuras em dois cenários, otimistas e pessimistas. Além disso, amostras dessas mesmas espécies foram coletadas para área foliar específica e espessura foliar. Os modelos mostraram aumento na adequação ambiental das palmeiras para todos os Neotrópicos, com aumento de riqueza especialmente nas regiões áridas. Espécies com folhas de alta espessura, que ocorrem em áreas abertas, terão um aumento na adequação ambiental em cenários de mudanças climáticas. Esta relação não foi encontrada para áreas florestais, nem para área foliar específica. Indicamos o uso da espessura foliar em metodologias padronizadas de avaliação de risco e vulnerabilidade às mudanças climáticas e incentivamos a busca por outros atributos de fácil obtenção e com relação direta com o clima.

Palavras-chave: espessura foliar, avaliação de risco, Modelo de Nicho Ecológico, adequabilidade ambiental

5.2. Abstract

The climatic changes pose a major threat to global biodiversity, therefore one of the greatest challenges today is to understand its effects and species responses to these changes. Studies of morphofunctional characteristics of the species and their adaptations to environmental heterogeneity aid a greater understanding ecosystem in face of these impacts. In this sense, the relationship of leaf traits to predict responses to the impact of climatic changes on neotropical palms was verified. For this, Ecological Niche models were generated for 79 species using climatic data of historical and future series in two scenarios, optimistic and pessimistic. In addition, samples of these same species were collected for specific leaf area and leaf thickness analysis. The models showed increase in environmental suitability of palms for all the Neotropics, with increase of richness especially in arid regions. Species with high thickness leaf, that occurs in open areas will have an increase in environmental suitability in a climate change scenario. This relationship was not found for forest areas, nor for specific leaf area. We indicated the use of leaf thickness in in standardized methodologies of risk assessment and climate change vulnerability and we encourage the search for other traits that are easy to obtain and with direct relation with the climate.

Keywords: leaf thickness, risk assessment, Ecological Niche Model, environmental suitability

5.3. Introduction

Ecological Niche Models (ENM) and Species Distribution Models (SDM) are widely used to estimate the limits of species' niche or distribution of the species in time (i.e. past, present and future) and space (e.g. native and exotic distribution) (Peterson & Soberón 2012). These models are based on the relationship between the species' geographical distribution and environmental variables (Peterson et al. 2011; Pearman et al. 2008).

Each species has a specific climatic niche, in which they can developed more efficiently (Thuiller et al. 2005). Climatic variables such as temperature and rainfall are determinant for the physiological functions of plants, and consequently influence the richness, composition and distribution of species (Eiserhardt et al. 2011). The predicted climatic changes pose a major threat to global biodiversity, therefore one of the greatest challenges today is to understand its effects and species responses to these changes (Hughes 2000; Sala et al. 2000; Thomas et al. 2004; Göldel et al. 2015).

Macroecology shares similar objectives to studies of functional traits, both seek general pattern for the field of community ecology, by comparing data from many species and sites, emphasizing functional relations between variables (McGill et al. 2006). Studies of adaptive mechanisms of species (Cornelissen et al. 2003; Webb et al. 2010) are important to define the competitive ability and the coexistence of species (Begon & Wall 1987; Callaway et al. 2003), their invasion capacity (Sexton et al. 2001; Richards et al. 2006), and their resistance to disturbances (Reusch et al. 2005; Gamfeldt & Kallstrom, 2007).

Studies that relate morphofunctional characteristics of the species and their adaptations to environmental heterogeneity, present and future, are frequent increasingly because they allow a greater understanding on the organization and the functioning of forest ecosystems in face of the climate change impacts (McGill et al. 2006; Guitay & Noble 1997; Diaz & Cabido 2001). The choice of functional traits to be considered for analysis should be in accordance with the ecological issues in which they are involved (Petchey & Gaston 2006). Specific functional traits, such as those related to plant species responses (Guitay & Noble 1997; Diaz & Cabido 2001), are relevant in terms of their resilience to the impacts of climate change.

The specific leaf area (SLA) reflects the relationship between light captured per leaf area invested in a biomass unit, where leaves with lower SLA values allow an increase in resistance to

water loss during the dry season (Ribeiro et al. 2016). Variation in leaf thickness is related to a trade-off between the rate of photosynthesis and the loss of water by transpiration (Michaletz et al. 2016). Thicker leaves can buffer the increased temperature variation and thus withstand increasing temperature (Michaletz et al. 2016; Soudzilovskaia et al. 2013). Thus, it is expected that species with higher SLA (Ribeiro et al. 2016; Nicotra el al. 2010) and lower thickness (Michaletz et al. 2016; Soudzilovskaia et al. 2013) will be more sensitive to climatic changes, in regions where episodes of temperature increase and drought regimes are predicted.

The Arecaceae family is a good model to investigate climate changes consequences (Blach-Overgaard et al. 2009; Blach-Overgaard et al. 2015; Walther et al. 2007) due to its marked distribution in the tropics, making palm good indicators of hot and humid climates (Walther et al. 2007). On a global scale, patterns of family diversity are driven by both current and paleo-climatic factors (Bjorholm et al. 2005; Bjorholm et al. 2006; Svenning et al. 2008; Blach-Overgaard et al. 2010; Kristiansen et al. 2011; Eiserhardt et al. 2011; Roncal et al. 2011; Kissling et al. 2012). However, the climatic changes of the Anthropocene have brought significant alterations in the distribution of some palm species, including expanding their distribution to temperate regions (Tripp & Dexter 2006; Walther 2000). Given this relationship with climate, several studies have shown the expansion of environmental suitability areas of palm throughout the world (Walther et al. 2007; Shabani et al. 2012, 2014). Studies of habitat reduction for palm species are also found but are generally associated with other variables that not only climate (Bach-Overgaard et al. 2015).

In the context of abiotic environmental gradients, the fundamental niche is governed by functional traits (McGill et al. 2006). Therefore, approaches that assess the relationship of functional ecology to different aspects of climate are of great relevance in understanding physiological strategies into a climate change scenario (Wright et al. 2005; Lebrija-Trejos et al. 2010). In this sense, we investigated the responses of neotropical palms species, with different leaf characteristics, to the impact of climatic changes. More specifically, were verified: (1) the potential richness and distribution pattern of neotropical palm trees in the future; (2) which leaf traits represented competitive advantages or disadvantages in climate change scenarios; and (3) which leaf traits can be good indicators to be used in risk assessment methodologies and sensitivity climate change analyzes.

5.4. Methods

5.4.1. Ecological niche modeling

A total of 79 palm species were selected in all neotropical regions, considering the availability of leaf traits data and a minimum of ten occurrence records in their original distribution. The occurrence data were obtained from the global biodiversity information facility (GBIF; www.gbif.org) and Species Link (SPLINK, www.splink.org.br) databases, with a minimum distance of 10 km each other. Automatic filters were used to eliminate records with clear errors of georeferencing (in the case of GBIF, we filtered through "no known coordinate problems" records and in SPLINK, we filtered for records whose coordinates were "not suspected") and a manual pre-treatment, excluding the duplicate and suspect points, keeping only one record of species per pixel.

Environmental variables, with a resolution of 5 minutes, were obtained from the Wordclim 1.4 database that provides climatic data of the present (1960-1990 historical series) and future (2050 and 2070). The 19 bioclimatic variables were grouped into a principal component analysis (PCA) with random points generated for the entire study area, and then the first 2 axes were used to identify which predictor variables best explained the distribution of these points. This procedure aims to aid in the decision of the predictor variables and helps to avoid the multicollinearity of the same. At the end, the variables used were: Temperatura máxima do mês mais quente (Bio 5), Temperatura mínima do mês mais frio (Bio 6), Amplitude térmica anual (Bio 7), Sazonalidade da Precipitação (Bio15) and Precipitação do trimestre mais chuvoso (Bio16). For the projections in the future, seven models of global circulation were used, which were selected because of their lower similarity, according to Knutti et al. (2013): (Knutti et al. 2013): CCSM4 (CC), CNRM CMJ (CN), HadGEM2-ES (HE), IPSL-CM5A-LR (IP), MIROC5 (MC), MPI-ESM-LR (MP), and MRI-CGCM3(MG) in two different scenarios: RCP 4.5 (optimistic) and RCP 8.5 (pessimistic)

The models were generated using five different algorithms: Bioclim, Maxent, Generalized linear models (GLM), Random Forests (RF) and Support vector machines (SVM). For pseudo-absences was used one hundred times the presence number, randomly distributed in the range of each species, calculated through the mean distance between the occurrence records. Three rounds

of calibration and tests of adjustment were performed, which were evaluated using the True Skill Statistics (TSS), which varies from -1 to 1 (Allouche et al. 2006). The higher the values of TSS, closer to one, the better the adjustment of the model, thus, only partitions with TSS> 0.40 were used.

The continuous consensual projections for each species used the average of up to 7 GCM and 5 algorithms, separated by period (present, 50 and 70 years) and scenario (RCP 4.5 and 8.5). Due to the lack of consensus to define a threshold for future models, it was decided to maintain the continuous representation of future models. In order to classify the species according to the variation of environmental suitability, the difference between the future models of the future of each species was made using the average of environmental suitability within the distribution of the species. Thus, our calculations we estimate the increase (or reduction) of the suitability value in a predefined area, which does not necessarily reflect the expansion or retraction of the area. It is important to observe, that, the average increase in environmental suitability in the delimited area (buffer of mean points of distance) may reflect a suitability increase in areas of species presence or the emergence of new areas with suitability within the delimited region or even a set of these. These values were categorized as reduction (<- 0.1), neutral (> -0.1 and <+ 0.1) or increase (> + 0.1) of environmental suitability. Thus, these cuts do not allow the movement / dispersion of the species to be verified. These values were tabulated for each species and correlated with values of foliar traits in order to verify if there is a relationship between suitability and leaf traits.

5.4.2. Leaf functional traits

Three samples of approximately $3cm^2$ of dry leaves deposited in the Kew Gardens herbarium were collected for each species. The dry weight of each sample was obtained on a precision scale and the samples were hydrated for at least 60 hours to obtain rehydrated measurements of area and thickness leaf. The leaf area was evaluated using ImageJ software and used as a numerator to obtain the specific leaf area (SLA = leaf area / leaf dry mass).

The species were divided into three groups of microhabitats: forest understory species, forest canopy species and open area species; and later for the analyses in two groups: forest species and open areas species. In the Pearson correlation analysis, the degree of relationship

between the leaf traits and the environmental suitability variation of each future projection was verified: 2050 (RCP 4.5), 2050 (RCP8.5), 2070 (RCP 4.5) and 2070 RCP 8.5).

5.5. Results

Our results show that environmental suitability of the models did not differ significantly between the projected years ($F= 0.005$, $Df= 1$, $p= 0.944$) and RCPs ($F= 0.002$, $Df= 1$, $p= 0.969$), generating similar future models of species richness. So, to facilitate the interpretation, the results will be described from now on as present and future models.

The models showed increase in environmental suitability for all Neotropical palms, with an increment in richness especially in arid regions (Figure 1).
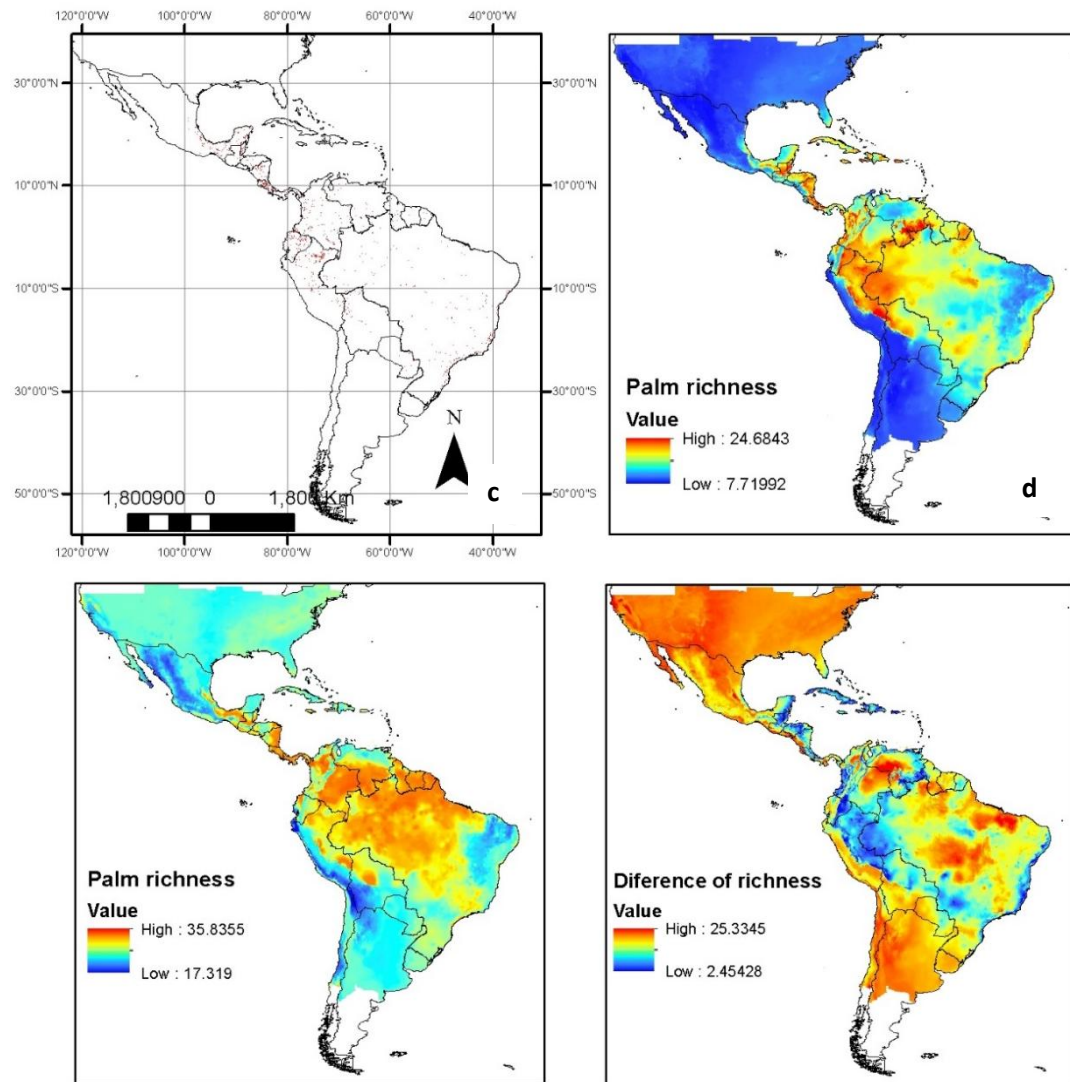
Figure 1. Consensus models of neotropical palm trees (N = 79): (a) currently richness; (b) current potential richness; (c) future potential richness; and (d) difference between current and future potential richness.

Fifty-two species of Neotropical palms would gain of environmental suitability, 24 have no alteration in the area and only one species had loss of area.
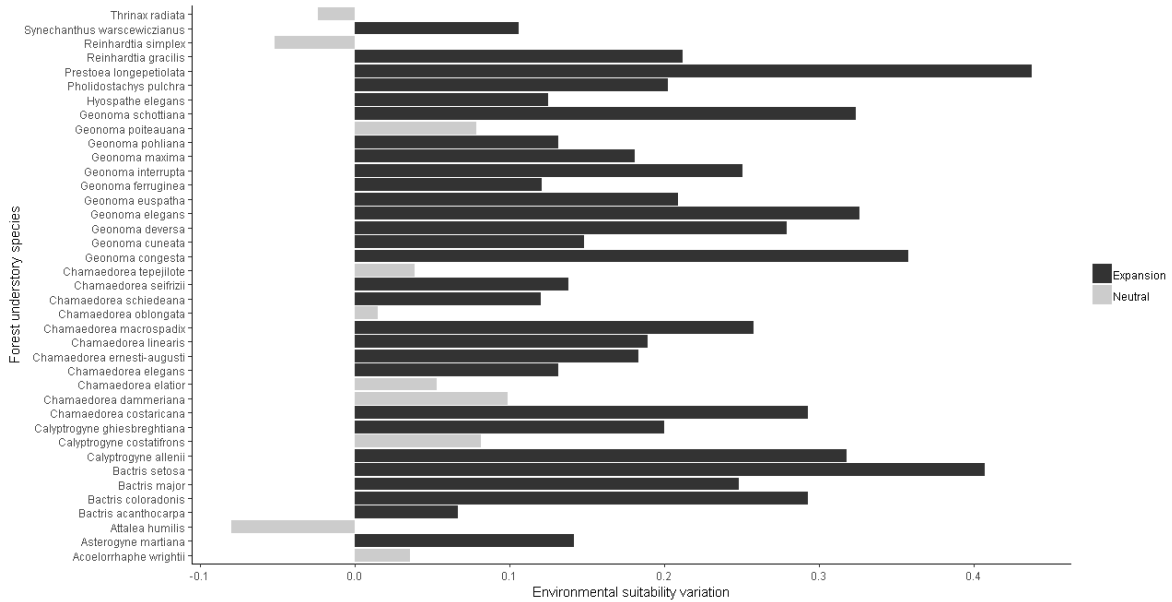
Figure 2. Variation of environmental suitability between the current and future models, representing an increase (positive values) and a reduction in environmental suitability (negative values) for neotropical palm species occurring in forest understory species.
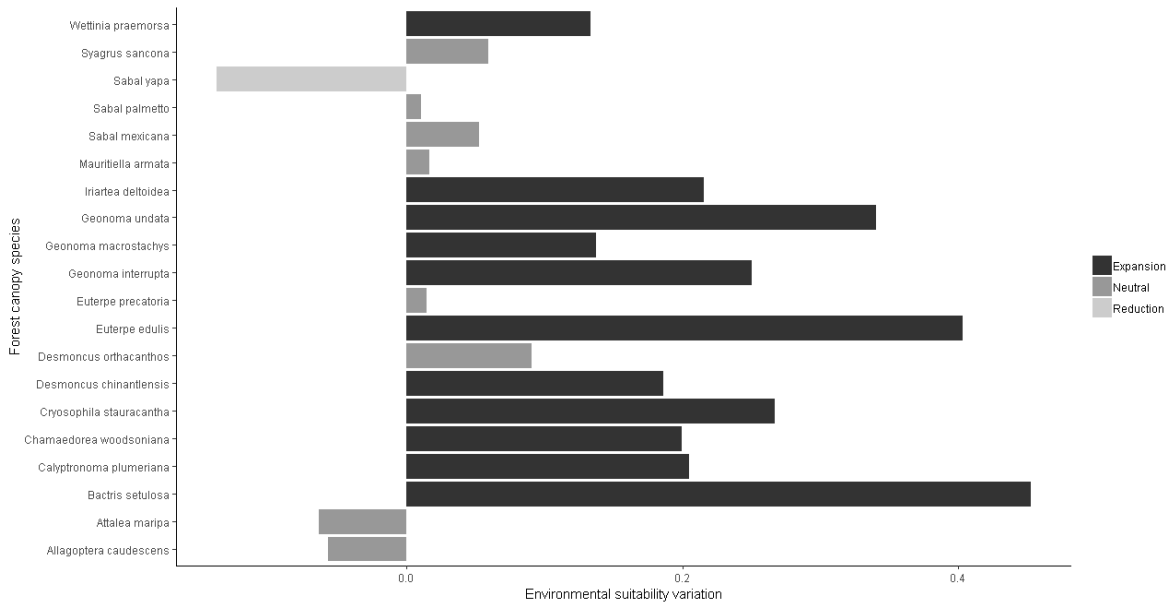
Figure 3. Variation of environmental suitability between the current and future models, representing an increase (positive values) and a reduction in environmental suitability (negative values) for neotropical palm species occurring in forest canopy species.
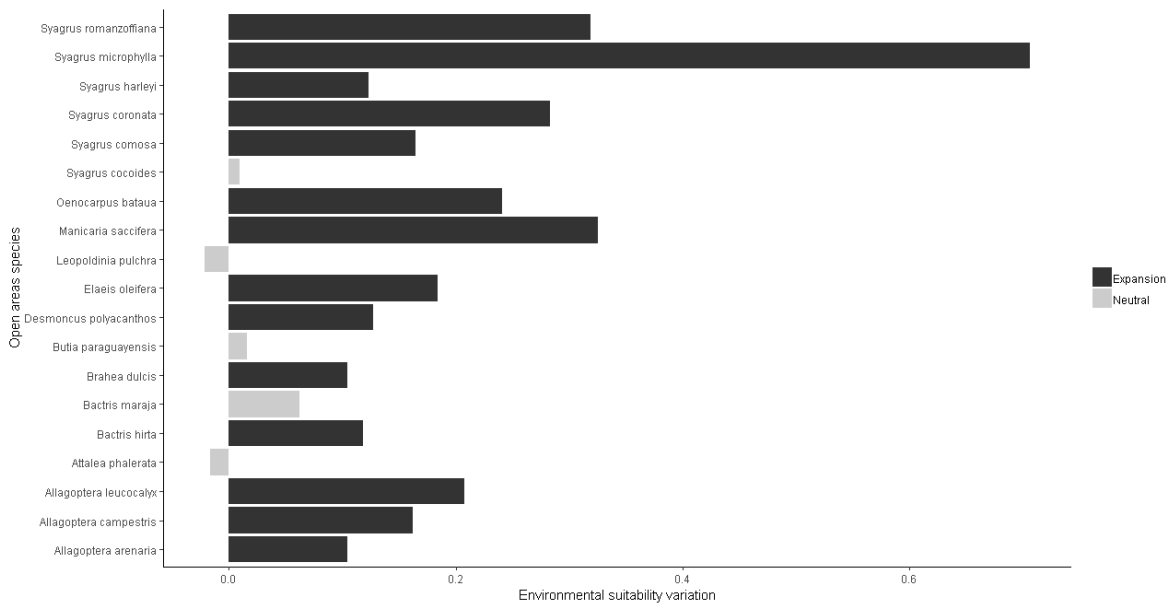

Figure 4. Variation of environmental suitability between the current and future models, representing an increase (positive values) and a reduction in environmental suitability (negative values) for neotropical palm species occurring in open area species.

Species with high leaf thickness, that tend to occur in open areas showed an increase in environmental suitability in all years and climate change scenarios (R= 0.482, p= 0.03671) (Figure 3), however the same did not occur for forest species (R= 0.283, p= 0.8316). In addition, no relationship was found between the values of SLA and the impact (increase or reduction) in environmental suitability, associated with climate change, either for forest (R= 0.142, p= 0.2824) or open area (R= -0.299, p= 0.2139) species.
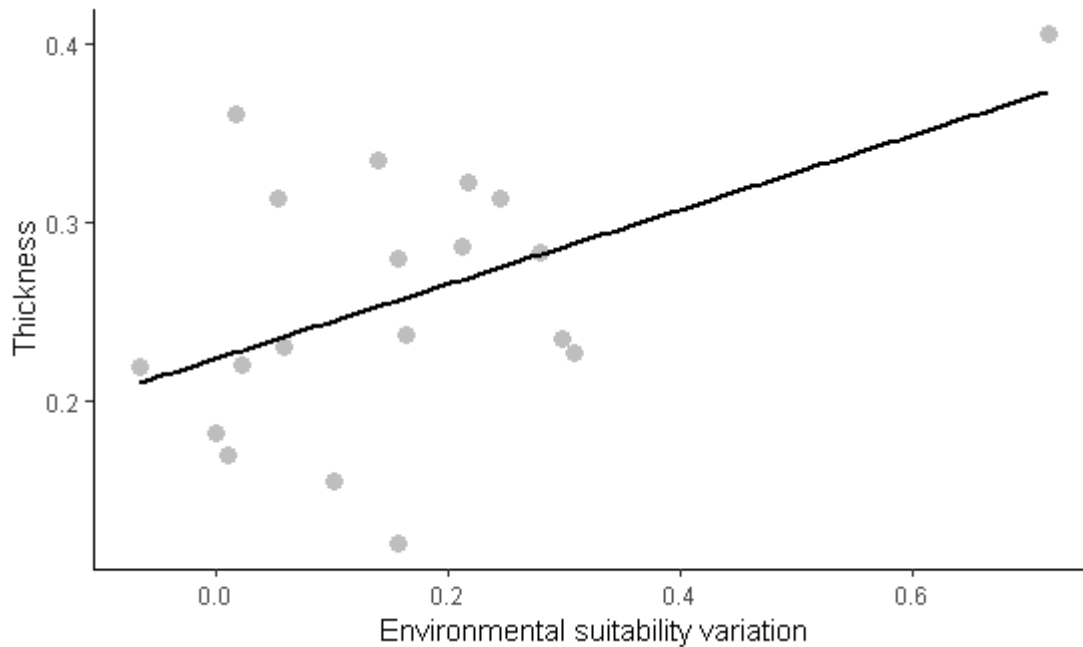
Figure 5. Relationship between leaf thickness (cm) of neotropical palms species which occur in open areas and environmental suitability variation of between the current and future models.

5.6. Discussion

According to Henderson et al. (1995), there are seven palm diversity regions in the Neotropics, in order of richness: Amazon, Central America, Andes, Caribbean, Central Brazil, Atlantic Coastal Forest and Mexican. Our current richness model was compatible with the diversity patterns, with the exception of the Andes and Mexican regions, which may have been underestimated. Therefore, although we have used only approximately 10% of all neotropical palm species, the models can be considered as a good predictor of the richness and distribution patterns of Neotropical palm at least under current climatic conditions.

Our results showed an increase of environmental suitability for most species analyzed, corroborating other studies across the world (Walther et al. 2007; Shabani et al. 2012, 2014). Some palms of economic importance in western South America also have great potential for expansion, amongst them: *Attalea phalerata* Mart. Ex Spreng, *Iriartea deltoidea* Ruiz & Pav. and *Oenocarpus bataua* (Mart.) Burret. (Vedel-Sørensen et al. 2013; Vaz et al. 2016), species also modeled in this study, which showed neutrality or increase of environmental suitability.

The species that will be most climatically favored is *Syagrus microphylla* Burret, with an increase in mean of environmental suitability up to 72% of its original suitability. *S. microphylla* is found in mountain savannah of northeastern Brazil and has adaxial fiber bundles mostly long and thick (Noblick 2013), adapted to these arid regions. Other species that will present considerable increase in environmental suitability greater than 40%. are: *Bactris setulosa* H.Karst., *Bactris setosa* Mart., *Prestoea longepetiolata* (Oerst.) H.E.Moore and *Euterpe edulis* Mart.. The only species that presented significant reduction in environmental suitability, even at the limit of the neutral impact variation, was *Sabal yapa* C.Wright ex Becc. However, it is important that the specific comparison with other studies is often hampered, not only by the methodological differences, but also by the presentation of the results.

However, the same does not happen with the representation of species richness models, in which continuous and without cutting models are used. These results show an expansion of potential richness areas, especially for the north of the northern hemisphere and to the south of the southern hemisphere, toward temperate regions. In addition, arid areas in the tropics (e.g. Central Brazilian region and the Mexican region) also had an increase in potential richness. The process of expansion of open areas, as a counterpoint to the reduction of tropical forest cover areas, has been found in several studies (Nepstad et al. 2001, Salazar et al. 2007), related with the "savannization" of portions of the Amazon rainforest and the "aridization" of parts of the Northeast of Brazil (Salazar et al. 2007).

Despite of the neutrality or expansion of environmental suitability areas in the Amazon, the "savannization", at more local scales, bordering these biomes, may limit species' distribution, especially those with restricted distribution or with less dispersal ability. Furthermore, some studies have shown that large-scale deforestation in the Amazon can modify significantly the regional climate, through to the decreased precipitation and increased temperature (Nobre et al.

1991; Dickinson & Kennedy 1992; Zhang & Henderson-Sellers 1996; Hoffmann & Jackson 2000). The conversion of tropical forests into pastures results in a reduction in precipitation and an increase in the frequency of dry periods in the wet season, consequently this may require a greater evapotranspiration, which in turn could result in reduced amount of water in the soil (Hoffmann & Jackson 2000).

In semi-arid regions, other studies have determined that overgrazing may also result in similar changes in precipitation and temperature (Xue & Shukla 1993). The Cerrado, tropical savannah covering 22% of the Brazilian territory, has suffered significant human impacts during the last three decades especially promoted by the expansion of livestock and soybean cultivation (Klink et al. 1993; Ratter et al. 1997). The potential territorial increase of this biome, promoted by the climatic changes, does not guarantee survival of its species, since much of its vegetation cover has been suppressed by the human activities. In this scenario, actions such as the consolidation of the current conservation units (only 5.2% of the Cerrado is protected by some conservation regime), the development of large ecological corridors and the improvement of legislation to protect undisturbed areas are important for Cerrado's conservation (Ratter et al. 1997).

Given the expansion and retraction scenarios of tropical biomes, the most adapted species that can withstand the new conditions are typically those of the tropical and subtropical savannas (Salazar et al. 2007). These are naturally more adapted to warmer climates, with marked seasonality in the rains and long periods of drought. Our results showed that in open habitats, species with greater leaf thickness were favored in a climate change scenario. That is, species with such characteristics have broadened their areas of environmental suitability. These results are compatible with the expected, since thicker leaves can buffer the increased temperature variation, given the same leaf area or SLA. (Michaletz et al. 2016; Soudzilovskaia et al. 2013). As a result, it is expected that species lower thickness will be more sensitive to climatic changes, as has been found in other studies (e.g. Soudzilovskaia et al. 2013). Thus, plants with thick leaves become a vegetative component increasingly important in climates with higher average temperatures and higher solar radiation. As expected, the same relation was not found for forest species, since there is a low relation of the leaf traits of forest sub-forest to the climate. It is likely that the different forest strata and the microclimate will reduce this relationship.

Despite the relationship between the specific leaf area and the climate, a relation of this attribute with environmental suitability was not found. The SLA-related climatic variable is usually the aridity index, which is the relation between precipitation and evapotranspiration. Therefore, the aridity index presents a nonlinear relation with the environmental suitability (inputs variables), different to what happens with the temperature, used in the correlation with the leaf thickness. In addition, precipitation variations are more difficult to interpret than temperature, that is, while temperature progressively increases throughout the world, precipitation varies (increasing or decreasing) according to regions of the world (IPCC 2014).

Finally, this relationship of traits with future environmental suitability can be an important conservation tool for use in standardized methodologies of risk assessment and climate change vulnerability. The leaf thickness was a good predictor but is necessary to evaluate its efficiency in other plant groups as well as to investigate other traits.

References

Allouche O., Tsoar A., Kadmon R. (2006). Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). Journal of Applied Ecology 43, 1223-1232.

Begon M., Wall, R. (1987). Individual variation and competitor coexistence: a model. Functional Ecology, 1.

Bjorholm S., Svenning J.C., Baker W.J., Skov F., Balslev H. (2006). Historical legacies in the geographical diversity patterns of New World palm (Arecaceae) subfamilies. Botanical Journal of the Linnean Society 151: 113-125.

Bjorholm S., Svenning J.C., Skov F., Balslev H. (2005). Environmental and spatial controls of palm (Arecaceae) species richness across the Americas. Global Ecology and Biogeography 14: 423-429.

Blach-Overgaard A., Balslev H., Dransfield J., Normand S., Svenning J-C. (2015). Global-change vulnerability of a key plant resource, the African palms. Scientific Reports 5: 12611. Doi: 10.1038/srep12611

Blach-Overgaard A., Svenning J.C., Dransfield J., Greve M., Balslev H. (2010). Determinants of palm species distributions across Africa: the relative roles of climate, non-climatic environmental factors, and spatial constraints. Ecography 33: 380-391.

Callaway R. M., Pennings S.C., Richards C. R. (2003). Phenotypic plasticity and interactions among plants. Ecology 84(5).

Colombo A.F., Joly C.A. (2010). Brazilian Atlantic Forest lato sensu: the most ancient Brazilian forest, and a biodiversity hotspot, is highly threatened by climate change. Braz. J. Biol. 70(3): 697-708.

Cornelissen J.H.C., Lavorel S., Garnier E., Díaz S., Buchmann N., Gurvich D.E., Reich P.B, Ter Steege H., Morgan H.D., Van Der Heijden M.G.A., Pausas J.G., Poorter H. (2003). A Handbook of protocols for standardised and easy measurement of plant functional traits worldwide. Australian Journal of Botany 51(4).

Diaz S., Cabido M. (1997). Plant Functional Types and Ecosystem Function in Relation to Global Change. Journal of Vegetation Science 8(4).

Dickinson R.E., Kennedy P. (1992) Impacts on regional climate of Amazonian deforestation. Geophys. Res. Lett. 19: 1947–1950.

Dransfield J., Uhl N.W., Asmussen C.B., Baker W.J., Harley M.M., Lewis C.E. (2008). Genera Palmarum. Richmond, UK: Royal Botanic Gardens, Kew.

Eiserhardt W.L., Svenning J-C., Kissling W.D., Balslev H. (2011). Geographical ecology of the palms (Arecaceae): determinants of diversity and distributions across spatial scales. Annals of Botany 1–26. Doi: 10.1093/aob/mcr146

Gamfeldt L., Kallstrom B. (2007). Increasing intraspecific diversity increases predictability in population survival in the face of perturbations. Oikos 116.

Göldel B., Kissling W.D., Svenning J. (2015). Geographical variation and environmental correlates of functional trait distributions in palms (Arecaceae) across the New World. Botanical Journal of the Linnean Society. DOI: 10.1111/boj.12349

Guitay H., Noble I.R. (1997). What are functional types and how can we seek them? In: Smith T.M., Shugart H.H., Woodward F.I. (eds.). Plant functional types: their relevance to ecosystem properties and global change. Cambridge: Cambridge University Press.

Henderson A.J., Galeano G., Bernal R. (1995). Field Guide to the palms of the Americas. Princeton: Princeton University Press.

Hoffmann W.A., Jackson R.B. (2000). Vegetation–Climate Feedbacks in the Conversion of Tropical Savanna to Grassland. Journal of climate (13): 1593-1602.

Hughes L. (2000). Biological consequences of global warming: is the signal already apparent? Trends in Ecology & Evolution 15: 56-61. Doi: 10.1016/S0169 5347(99)01764-4

International Panel on Climate Changes/IPCC. (2014). Climate change 2014: mitigation of climate change. In: Edenhofer, O. et al. (Ed.). Contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change. Cambridge: Cambridge University Press, 2014c. Disponível em: <https://www.ipcc.ch/pdf/assessment-report/ ar5/w g3/ipcc_wg3_ar5_full.pdf>. Acesso em: 10 jun. 2015.

Kissling W.D., Baker W.J., Balslev H., Barfod A.S., Borchsenius F., Dransfield J., Govaerts R., Svenning J-C. (2012). Quaternary and pre Quaternary historical legacies in the global distribution of a major tropical plant lineage. Global Ecology Biogeography 21: 909-921. Doi: 10.1111/j.1466-8238.2011.00728.x

Klink C.A., Moreira A.G., Solbrig O.T. (1993). Ecological impact of agricultural development in the Brazilian Cerrado. In: Young M.D., Solbrig O.T. (eds). The world's savannas. Economic driving forces, ecological constraints and policy options for sustainable land use. Parthenon Publishing, London 259–83

Knutti R., Masson D., Gettelman A. (2013). Climate model genealogy: Generation CMIP5 and how we got there. Geophysical Research Letters 40: 1194–1199. Doi:10.1002/grl.50256, 2013

Kristiansen T., Svenning J-C., Pedersen D., Eiserhardt W., Grández C., Balslev H. (2011). Local and regional palm (Arecaceae) species richness patterns and their cross-scale determinants in the western Amazon. Journal of Ecology 99: 1001-1015. Doi:10.1111/j.1365-2745.2011.01834.x.

Lebrija-Trejos E., Pérez-García E.A., Meave J.A., Bongers F., Poorter L. (2010). Functional traits and environmental filtering drive community assembly in a species-rich tropical system. Ecology 91(2): 386–398.

McGill B.J., Enquist B.J., Weiher E., Westoby M. (2006) Rebuilding community ecology from functional traits. Trends in Ecology & Evolution 21: 178–185.

Michaletz S.T., Weiser M.D., McDowell N.G., Zhou J., Kaspari M., Helliker B.R., Enquist B. (2016). The energetic and carbon economic origins of leaf thermoregulation. Nature Plants 2: 16129

Nepstad D., Carvalho G., Barros A.C., Alencar A., Capobianco J.P., Bishop J., Moutinho P., Lefebvre P., Silva U. L., Prins E. (2001). Road paving, fire regime feedbacks, and the future of Amazon forests. Forest Ecol. Manage. 154: 395– 407.

Noblick L.R. (2013). Leaflet anatomy verifies relationships within Syagrus (Arecaceae) and aids in identification. PhytoKeys (26): 75–99.

Nobre C.A., Sellers P. J., Shukla J. (1991). Amazonian deforestation and regional climate change. J. Clim. 4: 957– 988.

Olivares I., Svenning J.-C., Van Bodegom P.M., Valencia R., Balslev H. (2017). Stability in a changing world – palm community dynamics in the hyperdiverse western Amazon over 17 years. Global Change Biology 23(3): 1232-1239

Pearman P.B., Guisan A., Broennimann O., Randin C.F. (2008). Niche dynamics in space and time. Trends Ecol. Evol. 23, 149–58

Petchey O. L., Gaston K. J. (2006). Functional diversity: back to basics and looking forward. Ecology Letter 9(6)

Peterson A.T., Soberón J. (2012). Species Distribution Modeling and Ecological Niche Modeling: Getting the Concepts Right. Brazilian Journal for Nature Conservation 10(2): 102-107.

Peterson A.T., Soberon J., Pearson R.G., Anderson R.P., Martinez-Meyer E., Nakamera M., Araújo M.B. (2011). Ecological Niches and Geographic Distributions. Princeton University Press, New Jersey.

Ratter J.A., Ribeiro J.F., Bridgewater S. (1997). The Brazilian Cerrado vegetation and threats to biodiversity Annals of Botany 80: 223–30

Reusch T.B.H., Ehlers A., Hämmerli A., Worm B. (2005). Ecosystem recovery after climatic extremes enhanced by genotypic diversity. Proceedings of the National Academy of Sciences of the United States of America 102(8): 2826-2831.

Richards C.L., Bossdorf O., Muth N.Z., Gurevitch J., Pigliucci M. (2006). Jack of all trades, master of some? On the role of phenotypic plasticity in plant invasions. Ecology Letters 9 (8): 981-93.

Roncal J., Blach-Overgaard A., Borchsenius F., Balslev H., Svenning J-C. (2011). A dated phylogeny complements macroecological analysis to explain the diversity patterns in Geonoma (Arecaceae). Biotropica 43: 324-334.

Sala O.E., Chapin F.S., Armesto J.J., Berlow E., Bloomfield J., Dirzo R., Huber-Sanwald E., Huenneke L.F., Jackson R.B., Kinzig A., Leemans R., Lodge D.M., Mooney H.A., Oesterheld M., Poff N.L., Sykes M.T., Walker B.H., Walker M., Wall D.H. (2000). Global biodiversity scenarios for the year 2100. Science 287: 1770-1774.

Salazar L.F., Nobre C.A., Oyama M.D. (2007). Climate change consequences on the biome distribution in tropical South America. Geophysical Research Letters 34: L09708. Doi:10.1029/2007GL029695

Sexton J.P., Mckay J.K., Sala A. (2001). Plasticity and the genetic diversity may allow saltcedar to invade cold climates in North America. Ecology Applications 12(6).

Shabani F., Kumar L., Taylor S. (2012). Climate Change Impacts on the Future Distribution of Date Palms: A Modeling Exercise Using CLIMEX. PLoS ONE 7(10): e48021.

Shabani F., Kumar L., Taylor S. (2014). Suitable regions for date palm cultivation in Iran are predicted to increase substantially under future climate change scenarios. Journal of Agricultural Science 152: 543-557. Doi:10.1017/S0021859613000816

Soudzilovskaia N.A., Elumeeva T.G., Onipchenko V.G., Shidakov I.I., Salpagarova F.S., Khubiev A.B., Tekeev D.K., Cornelissen J.H.C. (2013). Functional traits predict relationship between plant abundance dynamic and long-term climate warming. Proc. Natl. Acad. Sci. 110 (45): 18180–18184

Svenning J-C., Borchsenius F., Bjorholm S., Balslev H. (2008). High tropical net diversification drives the New World latitudinal gradient in palm (Arecaceae) species richness. Journal of Biogeography 35: 394-406.

Thomas C. D., Cameron A., Green R.E., Bakkenes M., Beaumont L.J., Collingham Y.C., Erasmus B.F.N., Siqueira M.F.D., Grainger A., Hannah L. (2004). Extinction risk from climate change. Nature 427 (6970): 145-148. Doi: 10.1038/nature02121

Thuiller W., Lavorel S., Araújo M.B. (2005). Niche properties and geographical extent as predictors of species sensitivity to climate change. Global Ecology and Biogeography 14(4).

Tripp E.A., Dexter K.G. (2006). Sabal minor (Arecaceae): a new northern record of palms in eastern North America. Castanea 71: 172-177.

Vaz U.L., Nabout J.C. (2016). Using ecological niche models to predict the impact of global climate change on the geographical distribution and productivity of Euterpe oleracea Mart. (Arecaceae) in the Amazon. Acta Botanica Brasilica 30(2). Doi: 10.1590/0102-33062016abb0036.

Vedel-Sørensen M., Tovaranonte J., Bøcher P.K., Balslev H., Barfod A.S. (2013). Spatial distribution and environmental preferences of 10 economically important forest palms in western South America. Forest Ecology and Management 307(1): 284-292.

Walther G.R. (2000). Climatic forcing on the dispersal of exotic species. Phytocoenologia 30: 409-430.

Walther G.R., Gritti E.S., Berger S., Hickler T., Tang Z.Y., Sykes M.T. (2007). Palms tracking climate change. Global Ecology and Biogeography 16: 801-809.

Webb C.T., Hoeting J.A., Ames G.M., Pyne M.I., Poff N.L. (2010). A structured and dynamic framework to advance traits-based theory and prediction in ecology. Ecology Letters 13(3).

Wright S.J. (2005). Tropical forests in a changing environment. Trends in Ecology & Evolution 20 (10). Doi: 10.1016/j.tree.2005.07.009

Xue Y., Shukla J. (1993). The influence of land surface properties on Sahel climate. Part I: Desertification. J. Climate 6: 2232–2245.

Zhang H., Henderson-Sellers A. (1996). Impacts of tropical deforestation.Part I: Process analysis of local climatic change. J. Climate 9: 1497–1517

6. CONSIDERAÇÕES FINAIS

Diversos fatores abióticos e bióticos podem influenciar a composição, diversidade e distribuição de palmeiras. Esses fatores atuam de forma conjunta e podem apresentar maior ou menor intensidade, dependendo da escala geográfica observada. Por exemplo, variáveis edáficas têm maior influência na distribuição de espécies numa escala mais fina, enquanto variáveis climáticas influenciam em escala mais grossa. Além disso, a intensa interação existente com a fauna faz com que fatores bióticos tenham forte influência na distribuição das espécies em diversas escalas.

As palmeiras são reconhecidas pela sua exuberância, muito utilizadas no paisagismo em todo o mundo. Além disso, a exploração de seus recursos e o seu intenso uso tradicional, artesanal ou industrial, faz com que muitas espécies entrem em listas de avaliação de risco, com algum grau de ameaça. Avaliando apenas medidas intrínsecas das espécies, foi visto que 56% por cento das espécies de palmeiras neotropicais apresentaram um alto grau de sensibilidade aos impactos antrópicos, 41% apresentaram sensibilidade moderada e 3% apresentaram baixa sensibilidade. Espécies de palmeiras com maior sensibilidade, em ordem decrescente de importância, são aquelas com distribuição restrita, arquitetura do estipe menos eficiente e menor habilidade de dispersão. Aparentemente as palmeiras parecem apresentar mais estratégias de dispersão do que de aclimatação frente a impactos ambientais, visto sua especificidade de habitats. No entanto, visto o grande número de paisagens fragmentadas, esse movimento ainda pode ser limitado. Os gêneros relativamente mais sensíveis são *Chamaedorea* Willd., *Syagrus* Mart., Geonoma Willd., Bactris Jacq. ex Scop. e Attalea Kunth. As espécies mais sensíveis concentram-se na região da América Central, seguidas pela região do Brasil Central e a Floresta Costeira Atlântica.

No entanto, dentre os impactos causados pelo homem, as mudanças climáticas são vistas como aquela de maior impacto à biodiversidade, sendo assim, identificar características das palmeiras que as tornem mais ou menos sensíveis às alterações previstas no clima, podem auxiliar em metodologias de avaliação de risco. Para isso, primeiramente avaliamos a relação de variáveis climáticas com atributos foliares, onde foi encontrada uma relação positiva entre a espessura foliar e a temperatura, e entre a área específica foliar e o índice de umidade. No

entanto, essa relação só foi significativa em áreas onde estes atributos estão mais expostos, como habitats abertos e dossel florestal. Sendo assim, é esperado que palmeiras com folhas mais grossas e com menor área específica foliar sejam menos sensíveis as mudanças climáticas, pelo menos em alguns tipos de habitats. Os modelos de riqueza corroboraram esse resultado para espessura foliar, visto o aumento de adequabilidade ambiental para espécies com folhas mais grossas. Essa relação de folhas mais grossas associadas a habitats abertos, se torna cada vez mais importante de ser explorado, já que é esperado maior expansão de áreas quentes e áridas na maior parte do globo. Esse fenômeno vem sendo descrito na literatura como "savanização" e "aridização", e é provável que palmeiras acompanhem esse padrão de expansão de espécies adaptadas a esse tipo de clima mais árido.

As palmeiras apresentam uma diversidade de formas e estão distribuídas em todo o estrato florestal, características foliares por exemplo, permitem que espécies sejam mais ou menos adaptadas a determinados microhabitats. Além disso, variações topográficas e microclimáticas existentes nos biomas tropicais podem ter contribuído para a ausência de relação dos atributos foliares com o espaço geográfico, isso é, espécies com estratégias fisiológicas semelhantes, por exemplo folhas grossas, não estão necessariamente localizadas na mesma faixa latitudinal. Consequentemente, este resultado ressalta a importância do uso complementar da sensibilidade e da exposição em análises de vulnerabilidade às mudanças climáticas. Isso porque, a exposição avalia o impacto em um determinado ponto independente das espécies que nele ocorrem e a sensibilidade avalia o impacto sobre a espécie independente de onde ela se encontre. Isso é, se existisse correlação do atributo foliar com o espaço geográfico, não seria necessário a utilização dos dois simultaneamente.

Sendo assim, nossos resultados corroboram a importância do uso de atributos funcionais como indicadores de resposta às mudanças climáticas, e incentivamos o seu uso em em metodologias de avaliação de risco e vulnerabilidade às mudanças climáticas. Para a família Arecaceae, a espessura foliar foi um bom preditor para espécies que ocorrem em habitat aberto, seu uso para outros grupos de plantas deve ser avaliado. Além disso, visto a alta diversidade das regiões tropicais, é importante que estes atributos além de eficazes, sejam ao mesmo tempo de rápida/fácil aquisição para que se possa acompanhar a velocidade de alteração do clima.

As mudanças climáticas são vistas como uma das principais ameaças à biodiversidade, no entanto, as palmeiras apresentam características que podem beneficiá-las em um cenário de mudanças climáticas. No entanto, efeitos indiretos das mudanças climáticas, tais como perda de habitat e fragmentação são impactos relevantes que não devem ser desconsiderados, especialmente para a família Arecaceae que apresenta muitas espécies de distribuição restrita. Além disso, a dependência da fauna para colonizar novas áreas favoráveis pode ser um limitante, visto os impactos da caça e defaunação em pequenos fragmentos desprotegidos, que hoje compõem grande parte da cobertura florestal dos neotrópicos.