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DISTRIBUIÇÃO GEOGRÁFICA, MODELAGEM DE NICHO ECOLÓGICO E TAXONOMIA DE ESPÉCIES ENDÊMICAS DE *MANIHOT* MILL. NO NORDESTE DO BRASIL

KAREN YULIANA SUAREZ CONTENTO

RECIFE, 2023

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Orientadora: Profª Drª Sarah Maria Athiê de Souza

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Dissertação apresentada em __16_____/__fevereiro__/__2023___

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RECIFE, 2023

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RESUMO

Dentre os táxons de Euphorbiaceae, *Manihot* Mill., destaca-se por sua grande importância cultural, econômica e social para o Brasil. O gênero inclui cerca de 150 espécies e possui distribuição exclusivamente Neotropical, sendo a Amazônia seu provável centro de origem. O Brasil possui aproximadamente 120 espécies, das quais aproximadamente 100 são endêmicas. As espécies silvestres constituem um patrimônio genético vegetal que pode ser utilizado em programas de melhoramento da espécie cultivável *Manihot esculenta*, através da transferência de genes de interesse, auxiliando na resolução de diversos problemas, como intolerância a períodos de seca, alta temperaturas, baixo conteúdo de proteínas e pragas. Ao mesmo tempo, populações selvagens, especialmente espécies endêmicas, estão sob constante ameaça devido à destruição de hábitats e mudanças climáticas. Neste trabalho, objetivamos identificar os padrões de distribuição das espécies de *Manihot* endêmicas do Nordeste brasileiro sob cenário climático atual e futuro (acentuação das mudanças climáticas) associado a um estudo taxonômico, avaliar os efeitos potenciais das mudanças climáticas sobre a distribuição geográfica das espécies endêmicas do gênero *Manihot* no Nordeste do Brasil e confirmar a presença da área de aptidão em áreas protegidas no futuro. No primeiro capítulo são apresentados os resultados do estudo taxonômico, incluindo descrições, ilustrações, lectotipificação, status de conservação, distribuição e riqueza de espécies endêmicas do Nordeste do Brasil. Foram reconhecidas 15 espécies endêmicas, dentre as quais cinco delas foram lectotipificadas (*M. dichotoma, M. jacobinensis, M. maracasensis, M. reniformis* e *M. zehntneri*). Dentre as espécies estudadas, 80% estão em alguma categoria de ameaça, 13% estão quase ameaçadas e apenas 7% enquadram-se na categoria de menor preocupação. A Bahia destaca-se pelo alto grau de endemismo de *Manihot* com 14 espécies. Apenas uma espécie foi encontrada sendo endêmica dos estados de Sergipe e Alagoas. A Caatinga registra o maior número de espécies (8), seguida pelo Cerrado (6) e Mata Atlântica (4). A Serra do Espinhaço, no setor da Bahia, abriga a maior riqueza de espécies endêmicas de *Manihot*, e estão especialmente associadas ao Parque Nacional da Chapada Diamantina. No segundo capítulo apresentamos os resultados da modelagem de nicho ecológico de 11 espécies endêmicas de *Manihot* para o Nordeste, das quais prevemos a distribuição geográfica atual e futura para o ano 2100, usando três diferentes modelos de circulação geral (CNRM, MIROC e MRI) e dois cenários de mudança climática. Descobrimos que 45% e 54% das espécies poderiam ter uma redução parcial de seu potencial total de distribuição até o ano de 2100 em um cenário otimista e pessimista, respectivamente, porém algumas outras espécies aumentarão sua distribuição. Constatamos que a área de aptidão no futuro para a maioria das espécies enquadra-se dentro dos limites de alguma área protegida. Porém, espécies que atualmente possuem distribuição

restrita e que seu alcance potencial será reduzido tanto no cenário otimista quanto no pessimista precisam ser priorizadas para conservação. Este estudo fornece informações valiosas sobre a distribuição futura das espécies endêmicas de *Manihot* e mostra que a mudança climática pode ter um efeito potencial positivo ou negativo na distribuição geográfica das espécies. Também ajudam a compreender a distribuição das espécies e podem fornecer subsídios para ações de desenvolvimento de políticas públicas para a conservação de táxons e domínios fitogeográficos, especialmente aqueles que estão seriamente ameaçados.

Palavras-chave: Crotonoideae · Status de conservação · Riqueza · Tipificação · Nicho ecológico

ABSTRACT

Among the taxa of Euphorbiaceae, *Manihot* Mill. stands out for its great cultural, economic and social importance for Brazil. The genus includes about 150 species and has a Neotropical distribution, with the Amazon being its probable center of origin. Brazil has approximately 120 species, of which approximately 100 are endemic. Endemic species of *Manihot* constitute a plant genetic heritage that can be used in breeding programs for the cultivable species *Manihot esculenta*, through the transfer of genes of interest, helping to solve several problems, such as intolerance to periods of drought, high temperatures, low protein and pest content. At the same time, wild populations, especially endemic species, are under constant threat due to habitat destruction and climate change. In this work, we aim to identify the distribution patterns of *Manihot* species endemic to the Brazilian Northeast under current and future climate scenarios (accentuation of climate change) associated with a taxonomic study, evaluate the potential effects of climate change on the geographical distribution of endemic species of genus *Manihot* in Northeast Brazil and confirm the presence of the suitability area in protected areas in the future. In the first chapter, the results of the taxonomic study are presented, including descriptions, illustrations, lectotypification, conservation status, distribution and richness of endemic species of Northeastern Brazil. Fifteen endemic species were recognized, five of which were lectotypified (*M. dichotoma, M. jacobinensis, M. maracasensis, M. reniformis* and M. *zehntneri*). Among the studied species, 80% are in some category of threat, 13% are near threatened and only 7% fit in the category of least concern. Bahia stands out for the high degree of endemism of *Manihot* with 14 species. Only one species was found to be endemic to the states of Sergipe and Alagoas. The Caatinga records the highest number of species (8), followed by Cerrado (6) and Atlantic Forest (4). The Serra do Espinhaço, in the Bahia sector, is home to the greatest richness of endemic species in *Manihot*, and they are especially associated with the

Chapada Diamantina National Park. The second chapter presents the results of ecological niche modeling of 11 *Manihot* endemic species for the Northeast, of which we predict the current and future geographic distribution for the year 2100, using three different general circulation models (CNRM, MIROC and MRI) and two climate change scenarios. We found that 45% and 54% of species could have a partial reduction in their total range potential by the year 2100 in an optimistic and pessimistic scenario, respectively, but some other species will increase their distribution. We found that the area of future suitability for most species is within the boundaries of some protected area. However, species that currently have a restricted distribution, and that their potential range will be reduced in both the optimistic and pessimistic scenarios, need to be prioritized for conservation. This study provides valuable information on the future distribution of the endemic species of *Manihot* and shows that climate change can have a potential positive or negative effect on the geographic distribution of the species. They also help to understand the distribution of species and can provide subsidies for actions to develop public policies for the conservation of taxa and phytogeographic domains, especially those that are seriously threatened.

Keywords: Crotonoideae · Conservation status · Richness· Typification · Ecological niche

FUNDAMENTAÇÃO TEÓRICA

Taxonomia e histórico da classificação de *Manihot* Mill.

Manihot Mill. está classificado na tribo Manihoteae, subfamília Crotonoideae (Euphorbiaceae) (WEBSTER, 1994; WURDACK *et al.,* 2005; TOKUOKA, 2007) e circunscreve cerca de 150 espécies com distribuição exclusivamente neotropical, sendo a Amazônia seu provável centro de origem (ROGERS e APPAN, 1973; POWO, 2020). *Manihot* tem quatro centros de diversidade para o gênero no mundo: Brasil Central, México, Nordeste do Brasil e Sul do Mato Grosso do Sul e a Bolívia (NASSAR, 1978, 2000; DUPUTIÉ et al., 2011). No entanto, diferentes microcentros de diversidade podem ser reconhecidos e a origem desses relaciona-se, provavelmente, a eventos de hibridação e características dos ambientes onde as espécies ocorrem, que ajudam a isolar pools gênicos fragmentados que levam à especiação (CROIZAT, 1943; NASSAR, 1978; NASSAR e DOREA, 1982).

Bauhin (1651) fez a primeira menção ao termo *Manihot* ao propor a espécie *M. theveti*, a qual foi descrita com base em espécimes brasileiros coletados por André Thevet. Inclusive, neste trabalho, o autor traz uma prancha com fotos do hábito e detalhes das folhas. Linnaeus (1753) tratou *M. theveti* como sinônimo de *Jatropha manihot* L. a qual foi alocada no novo gênero *Jatropha* L., sem, no entanto, mencionar a coleção original. Miller (1754) na 4ª Edição do Gardener's Dictionary, realizou a primeira descrição oficial de *Manihot.* Posteriormente, Pohl (1827) desenvolveu a primeira monografia do gênero na obra *Plantarum Brasiliae Icones et Descriptiones* onde foram descritas e ilustradas 48 espécies resultantes das coletas feitas durante suas viagens ao Brasil, a maioria destas espécies são reconhecidas até hoje (MARTINS, 2013). Para diferenciar as espécies, o autor utilizou caracteres como divisão do limbo foliar, divisão e forma do cálice das flores pistiladas e estaminadas, aspecto do estigma, disco nectarífero e formato das cápsulas.

Müller (1866), foi pioneiro no estabelecimento de categorias infragenéricas em *Manihot* dividindo-o em oito grupos, os quais circunscrevem 43 espécies. Além de ter publicado a primeira chave de identificação para o gênero, foi também responsável por ampliar o conceito sugerido por Pohl (1827) usando características do pecíolo, divisão do limbo foliar e forma das brácteas para diferenciar as espécies. Müller (1874) na "*Flora Brasiliensis*", reconheceu 72 espécies, das quais 33 foram estabelecidas por ele. Pax (1910) tratou 128 espécies em *Manihot*, 28 das quais novas, acomodadas em 11 seções: *Brevipetiolatae* Pax, *Glaziovianae* Pax, *Grandibracteatae* Pax, *Heterophyllae* Pax, *Indivisae* Pax, *Parvibracteatae* Pax, *Peltatae* Pax, *Quinquelobae* Pax, *Sinuatae* Pax, *Stipularis* Pax e *Weddelianae* Pax. Neste estudo, o

taxonomista reuniu a literatura taxonômica conhecida, examinou e citou a maioria das coleções clássicas, elaborou as primeiras hipóteses sobre as possíveis relações de parentesco dentro do grupo e forneceu chaves de identificação para todos os táxons.

Glaziou (1912), Ule (1914), Pax e Hoffman (1924), Standley (1937), Croizat (1942), e Cruz (1967), fundamentando-se nos conceitos propostos por Müller (1874) e/ou Pax (1910), descreveram diversas novas espécies para a ciência. Rogers e Appan (1973) revisaram as espécies de *Manihot* para a região Neotropical e propuseram o tratamento mais completo para o gênero. Foram propostas a sinonimização de alguns binômios e realizadas extensas expedições de campo por toda a região, resultando na descrição de 13 novas espécies. A circunscrição adotada por Rogers e Appan (1973) reconheceu 98 espécies classificadas em 19 seções fundamentando-se na distribuição geográfica e nas características morfológicas como hábito, inflorescência, número, forma e superposição dos lobos foliares e forma das brácteas e bractéolas.

Allem (1989a) revisou a seção *Quinquelobae* Pax utilizando dados morfológicos e anatômicos, reconhecendo 10 espécies e quatro variedades. Allem (1977, 1978, 1979abc, 1980, 1989a, 1989b, 1999, 2001) acrescentou um número considerável de táxons para diferentes seções do gênero, sendo uma valiosa contribuição para o conhecimento do gênero no Brasil. Adicionalmente, Allem (2002) contribuiu para o entendimento da evolução de quase 50 espécies brasileiras de *Manihot* ao propor um modelo fenético de classificação, organizando as espécies em 16 grupos sugerindo prováveis relações filogenéticas entre os mesmos. Martins (2013) na sua tese desenvolveu o mais recente trabalho taxonômico focado no Nordeste brasileiro, registrando 27 espécies das quais oito eram novas e 16 foram apontadas como endêmicas, também realizou a caracterização morfológica e molecular de sete espécies silvestres de *Manihot* e inferiu sobre a taxonomia da seção *Quinquelobae*. Melo (2017) revisou a seção *Graciles* Rogers e Appan utilizando dados morfológicos e ampliou a circunscrição da seção, restabelecendo espécies que haviam sido sinonimizadas e esclarecendo limites entre espécies próximas.

Mais recentemente, no Brasil um incremento notável no número de táxons para o gênero pode ser observado, com mais de 20 novas espécies descritas nos últimos anos (MARTINS, 2013; MARTINS *et al.*, 2011, 2014; MARTINS e LEDO, 2015; MENDOZA, 2018; MENDOZA e CAVALCANTI, 2015, 2020; MENDOZA *et al.*, 2015, 2016, 2018; SILVA, 2014, 2015a, b, 2016; SILVA e SODRÉ, 2014; SILVA *et al.*, 2013, 2016).

Atualmente no Brasil, são registradas aproximadamente 120 espécies, dessas cerca de 105 são endêmicas; o Centro-Oeste representa a região mais diversa com 76 espécies, seguido pelo Nordeste com 31 espécies, das quais 17 são exclusivas (FLORA E FUNGA DO BRASIL, 2022). A Bahia destaca-se na região por compreender a maior diversidade do gênero com 26 espécies (FLORA E FUNGA DO BRASIL, 2022). A maioria das espécies concentra-se, em geral, em pequenas áreas de vegetação de Caatinga e Cerrado (FLORA E FUNGA DO BRASIL, 2022). Ambos os domínios fitogeográficos são marcados por grande biodiversidade e alto grau de endemismo de espécies, e também são considerados altamente ameaçados (ALLEM, 1989a; ROGERS e APPAN, 1973; NASSAR, 1978, 2000; MARTINS *et al.*, 2011; MARTINS, 2013). Segundo Simões *et al.* (2019), a Caatinga é um centro importante de diversidade e endemismo do país, embora seja marcada por um regime de chuvas restrito e irregular em clima semiárido com predomínio de formação vegetacional denominada "floresta estacional sazonalmente seca (FTSS)" (ALEIXO *et al.*, 2010; DE LA BARREDA-BAUTISTA *et al.*, 2011; WERNECK *et al.*, 2011). Atualmente, as áreas de FTSS tem sofrido os maiores impactos nas flutuações climáticas ocasionados pelos fenômenos El Niño e La Niña, como aumento da desertificação e perda de biodiversidade (SHIMIZU, 2007; CASTANHO *et al.*, 2020).

Alguns trabalhos regionais e pontuais foram realizados na região Nordeste enfatizando *Manihot* ou tratando algumas de suas espécies. Na Bahia destacam-se os trabalhos de Barbosa *et al.* (2007) e Sátiro e Roque (2008). Em Pernambuco, destaca-se Alves (1998) que realizou o checklist das espécies de Euphorbiaceae Juss., listando 4 espécies de *Manihot* ocorrentes no semi-árido pernambucano. Nos estados do Ceará, Pernambuco e Paraíba, Siqueira-Filho *et al.* (2012) no livro sobre as Floras das Caatingas, listaram três espécies de *Manihot*. Na Flora do Brasil, (2020) foram listadas 76 espécies das quais 27 se encontram no Nordeste.

Aspectos morfológicos de *Manihot*

Algumas espécies de *Manihot* têm raízes tuberosas, esta característica é muito perceptível em *Manihot esculenta* Crantz e nas espécies arbustivas e subarbustivas das regiões mais secas (MARTINS, 2013). No entanto, não há muitas informações sobre este órgão em espécies silvestres e não há amostras suficientes desse órgão associadas a espécimes de herbário (ROGERS e APPAN, 1973).

O hábito varia de subarbusto decumbente, subarbusto semi-herbáceo, arbusto à pequenas árvores, dependendo do ambiente onde as espécies se encontram (DUPUTIÉ *et al.*, 2011). As espécies das regiões semiáridas tendem a ser arbóreas, as de floresta são lianescentes e as do cerrado apresentam-se arbustivas ou subarbustivas (ALLEM, 1999; NASSAR *et al.*,

2008; MARTINS, 2013). Esta variação no hábito tende a gerar muitas dúvidas taxonômicas, especialmente na análise de materiais de herbário onde as anotações sobre o hábito são escassas (ALLEM, 1999; MARTINS, 2013).

Manihot caracteriza-se por apresentar folhas normalmente lobadas e sem glândulas, com látex incolor, amarelado e viscoso contendo Ácido Cianídrico (HCN) (DUNSTAN *et al.*,1906). A lâmina foliar pode ser simples, às vezes profundamente lobulados, assemelhando-se a compostos, as quais possuem (2-)3-5(-9) lobadas, essa característica é altamente variável mesmo dentro da mesma espécie ou indivíduo, o que tem levado a identificações errôneas ou pouco precisas das espécies. *Manihot breviloba* P. Carvalho & M. Martins, *Manihot macrocarpa* P. Carvalho & M. Martins, *Manihot pandurata* M. Martins & M. Mend. e *Manihot reniformis* Pohl, apresentam folhas exclusivamente inteiras, outras têm folhas inteiras associadas apenas às inflorescências, como *Manihot alterniflora* P.Carvalho e M.Martins. Esta última característica é difícil de observar nas coleções dos herbários, o que dificulta sua correta identificação e pode resultar até na descrição errônea de novas espécies (MARTINS, 2013). Os lobos podem ser elípticos, deltoides, ovais, obovais, oblongos, lanceolados ou cuneados, as margens são geralmente inteiras a panduradas com nervação camptódroma ou craspedródroma, ápice normalmente agudo e acuminado, raramente obtuso, os pecíolos cilíndricos ou achatados dorsiventralmente com inserção basal ou peltada (ROGERS e APPAN, 1973; MARTINS, 2013).

As estípulas são caracteres taxonômicos importantes para a delimitação das espécies (ROGERS e APPAN, 1973), porém, em sua maioria, são predominantemente caducas o que dificulta seu uso para a diagnose dos táxons. Estas podem ser elípticas, lanceoladas ou filiformes, foliáceas, semifoliáceas ou setáceas com margem lisa ou laciniada, glabras ou pubescentes com ápices agudos e acuminados. Destaca-se que a maioria das estípulas apresenta margem lisa, com exceção de *Manihot alterniflora, Manihot dichotoma* Ule. e *Manihot zehntneri* Ule. que são as únicas espécies deste trabalho com as estípulas de margem laciniada.

Em *Manihot* as inflorescências foram descritas detalhadamente pela primeira vez por Müller (1874) no tratamento do gênero para a Flora Brasiliensis. Nessa ocasião, o autor usou o termo racemo espiciforme para nomear as inflorescências com flores masculinas sésseis e panícula para as inflorescências compostas ou ramificadas. Posteriormente, foram apresentadas por Rogers e Appan (1973) subdivididas em 19 subtipos de inflorescências e agrupadas em três grupos: racemos, panículas e cimeiras; esses termos foram usados na maioria dos tratamentos taxonômicos e na descrição de novas espécies (MENDOZA, 2018). As inflorescências são

acompanhadas por brácteas e bractéolas normalmente evidentes e de cores vistosas (ROGERS e APPAN, 1973).

As brácteas e bractéolas, podem ser foliáceas com mais de 0.5 cm de largura, semifoliaceas variando entre 0,2 e 0,4 cm de largura e setáceas com cerca de 0.1 cm de largura (MARTINS, 2013), opostas ou alternas, com margem inteira ou laciniada, ovais, obovais, filiformes ou deltoides, comumente caducas, variavelmente pubescentes. Tanto o padrão da inflorescência quanto a forma das brácteas e bractéolas são úteis na distinção das espécies (ALLEM, 1984).

As espécies de *Manihot* são caracterizadas por serem monóicas com flores pistiladas e estaminadas na mesma inflorescência (ROGERS e APPAN, 1973), as flores estaminadas estão localizadas na porção superior da inflorescência, são gamossépalas, com cinco sépalas soldadas até 1/2 ou 1/3, apresentando-se glabras ou indumentadas. Os botões florais são ovoides, obovoides, orbiculares, piramidais ou bifusiformes. As flores pistiladas estão localizadas na porção inferior do eixo da inflorescência, às vezes solitárias e partindo da base da inflorescência, são dialissépalas, com cinco sépalas, glabras ou indumentadas. Os botões florais são ovoides, obovoides, orbiculares, piramidais ou bifusiformes. As flores são frequentemente esverdeadas, em virtude das sépalas apresentarem tons esverdeados externamente e esbranquiçados internamente, que podem ou não conter traços lilases, avermelhados ou arroxeados. Entretanto, há algumas flores que podem apresentar-se inteiramente amarelas, verdes, creme-esverdeadas ou brancas ou esbranquiçadas e essa variação pode ocorrer dentro dos indivíduos de uma mesma espécie (ORLANDINI, 2016).

Assim como as inflorescências, os frutos podem ser úteis para a distinção de espécies em *Manihot* (CROIZAT, 1943; MARTINS, 2013). São comumente cápsulas, porém, frutos bacáceos podem ser encontrados em um pequeno número de espécies pouco relacionadas (ALLEM, 1999; DUPUTIÉ *et al.*, 2011), tem abertura septicida e loculicida, valvas lenhosas e ápice da columela usualmente truncada com projeções laterais membranáceas. A indeiscência dos frutos em espécies de *Manihot* aparentemente tem relação com o tipo de ambiente e está diretamente correlacionado com o tipo de dispersão apresentado por algumas espécies. Os frutos apresentam-se de forma orbicular, ovais, obovais ou elípticos, normalmente com costelas retilíneas ou às vezes onduladas, a superfície pode ser lisa ou variavelmente verrucosa, de cor verdes, amarelados ou purpúreos, sobretudo sobre os septos. As Sementes são variadamente carunculadas segundo a espécie, ovoides, obovoides, ou elípticas com face ventral plana ou convexa, geralmente cinéreas a pardas, com manchas escuras na testa, geralmente com carúncula parda ou amarelada bem desenvolvida (MARTINS, 2013).

Importância econômica

Dentre os táxons de Euphorbiaceae, *Manihot*, destaca-se por sua grande importância cultural, econômica e social para o Brasil (MARTINS, 2013; ORLANDINI, 2016), especialmente *M. esculenta* Crantz conhecida popularmente como aipim, macaxeira ou mandioca. A raiz e outras partes da planta são consumidas frescas e servem como matéria prima para a produção de fécula e farinha. De acordo com dados da FAO (2013), a mandioca provém a alimentação de aproximadamente 800 milhões de pessoas no mundo, especialmente em países em desenvolvimento, sendo amplamente cultivada nas Américas tropicais, África e Ásia (HERSHEY, 2008). Além do uso das raízes in natura, os derivados da mandioca podem ser utilizados em várias indústrias, como a farmacêutica, têxtil, produção de papel e celulose e na produção de etanol (biocombustível) (FAO, 2013).

Diversos estudos e ações voltadas ao melhoramento genético e maior aproveitamento da espécie cultivada *M. esculenta* já foram e estão sendo desenvolvidos em diferentes escalas (mundial, nacional e estaduais) (FUKUDA, 1995; NASSAR e ORTIZ, 2007; FUKUDA, 2009; FUKUDA e IGLESIAS, 2006; FAO, 2013; DE SOUZA *et al*., 2020; KARIM *et al*., 2020; SANTOS *et al.*, 2020). No âmbito do Nordeste, a EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária) e o IPA (Instituto Agronômico de Pernambuco) vem desenvolvendo um conjunto de pesquisas para fomentar a cadeia produtiva da mandioca englobando desde o melhoramento genético, conhecimento etnobotânico até alternativas para escoamento de produção na região, em especial na Bahia e Pernambuco, respectivamente (MATTOS e GOMES, 2000; CARVALHO e FUKUDA, 2006; FERREIRA FILHO *et al.*, 2013).

As espécies silvestres de *Manihot* constituem patrimônio genético vegetal que pode ser utilizado em programas de melhoramento genético da cultura, através da transferência de genes de interesse, contribuindo com soluções para diversos problemas prejudiciais ao cultivo, tais como tolerância à seca e altas temperaturas, deterioração fisiológica pós-colheita de raízes, alto teor proteínas, raízes maiores, resistência maior a pragas, dentre outras (NASSAR, 1978; NASSAR e DOREA, 1982; ALLEM, 1999; AKINBO *et al.*, 2015).

Modelos de distribuição como ferramentas aliadas à conservação

As mudanças climáticas provocam alterações físico-químicas na atmosfera resultando em ciclos de aquecimento e resfriamento (DE OLIVEIRA *et al.*, 2017; SIMÕES *et al.*, 2019). Essas mudanças têm impactos na biodiversidade, reduzindo a distribuição geográfica e aumentando a taxa de extinção de muitas espécies no mundo (JUMP e PENUELAS, 2005; THUILLER, 2005; RAVENSCROFT *et al.*, 2015; GARZA *et al.*, 2020) especialmente nas

áreas com alta riqueza de espécies ou endemismo (SIMÕES *et al.,* 2019). Nas plantas, o aumento das temperaturas durante os meses mais quentes e a diminuição das chuvas mudam sua distribuição, porque têm que se deslocar em busca de lugares com as condições climáticas mais adequadas (WALTHER *et al.,* 2002; PARMESAN e YOHE, 2003; WALTHER, 2003). No entanto, para plantas raras, endêmicas, com distâncias de dispersão mais baixas ou que persistem em áreas fragmentadas, essa mudança será difícil e tenderá a causar extinção (JUMP e PENUELAS, 2005; ISIK, 2011; ZUBER e VILLAMIL, 2016; ROCHA *et al.*, 2020; GARZA *et al.,* 2020).

Na atualidade, os bancos de dados fornecem informações sobre a presença de espécies em um subconjunto de sítios ocupados, mas não dão informações sobre os locais que ainda não foram coletados ou que poderão ser colonizados no futuro (RONDININI *et al.,* 2006; HOEGH-GULDBERG *et al.,* 2008; GUISANT *et al.,* 2013). Nesse sentido, as previsões de presença que combinam registros biológicos com dados espaciais são importantes para o planejamento de ações de conservação da biodiversidade (GUISANT *et al.,* 2013; SAFAEI *et al.,* 2018; DE LIMA *et al.,* 2020). Uma das ferramentas úteis para determinar o papel dos fatores ambientais na previsão de padrões de distribuição de espécies em áreas inexploradas é a modelagem de nicho ecológico (ENM). Esta ferramenta mostra a relação entre os pontos de ocorrência de uma espécie e as variáveis ambientais (PULLIAM, 2000; PHILLIPS *et al.,* 2006; FARIAS *et al.,* 2017; DE LIMA *et al.,* 2020; GARZA *et al.,* 2020) e contribui na compreensão da distribuição das espécies e o mapeamento de áreas cujas condições ambientais são potencialmente adequadas à probabilidade de ocorrência das mesmas (GUISAN e ZIMMERMANN, 2000; LOISELLE *et al.,* 2003; ARAÚJO e GUISAN, 2006; GUISAN *et al.,* 2006; SIQUEIRA e DURIGAN, 2007).

Esta ferramenta tem sido utilizada por vários autores para avaliar a eficácia das áreas protegidas na conservação de espécies no presente e no futuro e para calcular a perda de áreas de ocupação das espécies no futuro (GUISAN e ZIMMERMANN, 2000; COETZEE *et al.,* 2009; ARAÚJO *et al.,* 2011; QIN *et al.,* 2017). Em *Manihot*, por exemplo, Garza *et al* 2020 avaliaram os efeitos potenciais das mudanças climáticas na distribuição de uma espécie de *Manihot* em U.S. e no México (*Manihot walkerae* Croizat) e evidenciaram uma redução potencial na distribuição geográfica da espécie. Também avaliaram a utilidade de áreas naturais protegidas na conservação futura da espécie, como resultado encontraram várias áreas protegidas potencialmente adequadas para *M. walkerae* nos E.U.A, enquanto no México não há áreas protegidas dentro do hábitat da espécie.

Além disto os modelos podem ajudar na identificação de áreas prioritárias de conservação (JINGA e ASHLEY, 2019), na identificação de processos de invasão biológica (BARBET-MASSIN *et al.*, 2018), mapeamento de habitats adequados para reintrodução e/ou cultivo de espécies-alvo (SANCHEZ *et al.*, 2010) e projetar áreas protegidas (TAYLOR *et al.*, 2017). Desta forma a ferramenta pode ajudar a resolver problemas ou lacunas de conhecimento no gênero, especialmente nas espécies endêmicas e ameaçadas.

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1. CAPITULO I

A LOOK AT ENDEMIC MANIHOT SPECIES FOR NORTHEASTERN BRAZIL: TAXONOMY, RICHNESS, DISTRIBUTION AND CONSERVATION

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A LOOK AT ENDEMIC *MANIHOT* SPECIES FOR NORTHEASTERN BRAZIL: TAXONOMY, RICHNESS, DISTRIBUTION AND CONSERVATION

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Running title: *Manihot* in Northeast Brazil

Abstract

Manihot includes about 150 species and has a Neotropical distribution. Wild *Manihot* species constitute a genetic reservoir that can be used in programs to improve the cultivable species *M. esculenta* Crantz (cassava). However, wild populations, especially endemic species, are under constant threat due to habitat destruction and climatic changes. The aim of this study was to elaborate a taxonomic treatment of the species of *Manihot* endemic to Northeast Brazil, providing data on their geographic distribution, conservation status, richness, and solving typification problems. The study was based on the analysis of exsiccates as well as field observations. Fifteen endemic species of *Manihot* were found, we propose lectotypes for five of them and a neotype. Most species are found in the state of Bahia, growing in Caatinga, Cerrado and Atlantic Forest. Only *M. breviloba* P. Carvalho & M. Martins was found in the states of Sergipe and Alagoas. The area with the greatest richness was found in the Espinhaço

Range (Bahia sector), precisely in the Chapada Diamantina National Park. Regarding the conservation status of the species, 80% of them are in some category of threat, 13% are in the category of near threatened, and only 7% are in the category of least concern.

Keywords: Crotonoideae·Euphorbiaceae ·Conservation status · Richness· Typification

Resumo

Manihot inclui cerca de 150 espécies e tem uma distribuição Neotropical. As espécies silvestres de *Manihot* constituem um patrimônio genético vegetal que pode ser utilizado em programas de melhoramento da espécie cultivável *Manihot esculenta* Crantz (mandioca). No entanto, populações selvagens, especialmente as endêmicas, estão sob constante ameaça devido à destruição de hábitat e mudanças climáticas. O objetivo deste manuscrito foi elaborar um tratamento taxonômico das espécies endêmicas de *Manihot* registradas no Nordeste do Brasil; determinar a distribuição geográfica das espécies, a riqueza, seu estado de conservação e resolver problemas de tipificação. O estudo foi baseado na análise de exsicatas depositadas em herbários nacionais e internacionais, bem como em observações de campo. Quinze espécies endêmicas de *Manihot* foram encontradas, propomos lectótipos para cinco delas e um neótipo. A maioria das espécies está distribuída no estado da Bahia, crescendo em ambientes de Caatinga, Cerrado e Mata Atlântica. Apenas *M. breviloba* foi encontrado nos estados de Sergipe e Alagoas. A área de maior riqueza foi encontrada na Serra do Espinhaço (setor Bahia), precisamente no Parque Nacional da Chapada Diamantina. Em termos de estado de conservação, 80% das espécies endêmicas estão em alguma categoria de ameaça, 13% estão na categoria de quase ameaçadas e apenas 7% estão na categoria de menor preocupação.

Palavras-chave: Crotonoideae · Euphorbiaceae ·Status de conservação · Riqueza · Tipificação

Introduction

Manihot Mill. (1754) is placed in the tribe Manihoteae, subfamily Crotonoideae (Euphorbiaceae) (Webster 1994; Wurdack 2005; Tokuoka 2007) and is characterized by a shrub, subshrub, arboreal or, lianescent habit, presence of latex, leaves simple, alternate, entire to lobed blades, with margin entire wavy or pandurated, unisexual flowers with nectariferous disk, androecium with 10 stamens, trilobed stigma, capsular fruits, and carunculated seeds (Pax 1910; Rogers & Appan 1973; Orlandini 2016).

The genus stands out for its great cultural, economic and social importance in different regions of the planet, especially so in the case of *Manihot esculenta* Crantz (cassava) whose roots are one of the main sources of starch for approximately 800 million people in the world (FAO 2013), mainly in developing countries, being widely cultivated in tropical America, Africa and Asia (Hershey 2008). Wild *Manihot* species constitute a genetic reservoir that can be used in crop genetic improvement programs through the transfer of genes of interest, bringing solutions to various problems that affect the crops, providing higher tolerance to drought, higher protein content, larger roots, greater resistance to pests, among others (Nassar & Dorea 1982; Allem 1999; Akinbo *et al.* 2015).

Nearly 150 species are circumscribed in the genus *Manihot*. They are distributed exclusively in the Neotropics, with the Amazon as the probable center of origin (Simon *et al.* 2021). Currently, approximately 120 species are registered in Brazil, of which approximately 105 are endemic to the country (Flora e Funga do Brasil 2020). The Northeast is the second region of Brazil with the largest number of species (Flora e Funga do Brasil 2020) and is considered one of the centers of diversity of the genus in the world (Nassar 1978; 2000). In this region, the state of Bahia stands out with the greatest diversity with 26 species, mostly concentrated in small areas of Caatinga and Cerrado (Flora e Funga do Brasil 2020). These phytogeographic domains are characterized by high biodiversity and endemism and are also considered highly threatened (Rogers & Appan 1973; Nassar 2000; Martins *et al.* 2011; 2013). Knowing the distribution of species can contribute to public policies for the conservation of

taxa and phytogeographic domains highly threatened by fragmentation, habitat destruction, introduction of exotic species, environmental pollution, and climate change (Reed 2004; Newbold *et al.* 2015).

The taxonomy of *Manihot* has already been addressed in a large number of studies (Miller 1754; Müller 1866; 1874; Rogers & Appan 1973; Allem 1989, Martins 2013; Orlandini 2016; Mendoza 2018; Mendoza & Cavalcanti, 2020). Recently, phylogenetic approaches have been added with the contributions of Chacon *et al.* (2008), Duputié *et al.* (2011), and Simon *et al.* (2021). Nevertheless, nomenclatural problems persist due to the great phenotypic plasticity and homogeneity of its taxa (Rogers & Appan 1973). The distinction of species is not easy, especially of those occurring in the same geographic areas. Additionally, typifications and nomenclatural propositions are still necessary, especially for the species endemic to Northeast Brazil.

In this context, the objective of this study was to elaborate a taxonomic treatment of *Manihot* species endemic to Northeast Brazil, providing data on their geographic distribution, conservation status, richness, and solving typification problems. This work is part of an investigation that includes ecological niche modeling of *Manihot* species endemic to Northeast Brazil under current and future scenarios. The results of this work will help reduce taxonomic problems and contribute to knowledge that is relevant for the conservation of endemic *Manihot* taxa.

Methodology

For the morphological analysis, the collections, including the type specimens, deposited in the following herbaria were consulted: ALCB, ASE, BAH, BHCB, CEN, CEPEC, CPAP, EAC, ESA, F, FLOR, FUEL, FURB, G, HBR, HDJF, HEPH, HRCB, HTSA, HUEFS, HUESB, HUFSJ, HUNEB, HURB, HVASF, HVC, IAC, IAN, INPA, IPA, JPB, MAC, MBM, MG, MO, MOSS, NY, P, PEUFR, R, RON, SP, SPF, UB, UEC, UFP, US, VIC, VIES and HST (not

indexed) (acronyms according to Thiers (updated continuously)). Geographic distribution, altitude, phenology, and habitat data were obtained from exsiccate labels, available reference literature, and online databases such as Flora Neotropica (Rogers & Appan 1973), SpeciesLink (CRIA 2020), Reflora Virtual Herbarium and the Global Biodiversity Information Facility (GBIF 2020) and field expeditions carried out between 2010 - 2018 and 2021 - 2022.

Vegetative and reproductive characters (stem, latex, leaves, stipules, petioles, inflorescences, bracts, bracteoles, sepals, fruits, and seeds) were used to delimit the species. The terminology used in the descriptions follows Rogers and Appan (1973), Harris and Harris (2001), and Beentje (2010). Stipule and bract terminologies and definitions are based on Rogers and Appan (1997) and Martins (2013): foliaceous (greater than 5 mm wide), semifoliaceous (2-4 mm wide), and setaceous (about 1 mm wide). In some cases, morphological comparisons were made with species occurring outside the study area because some *Manihot* samples analyzed were misidentified in the herbarium collections. The illustrations presented here are based on the field and herbarium material analyzed. The illustrations of *Manihot alterniflora* P. Carvalho & M. Martins, *Manihot macrocarpa* P. Carvalho & M. Martins, *Manihot pandurata* M. Martins & M. Mend., *Manihot quinquefolia* Pohl, and *Manihot reflexifolia* P. Carvalho & M. Martins were not included in this work because they were recently described and illustrated (Martins *et al.* 2017; Mendoza & Martins 2018; Santos *et al.* 2019).

The current conservation status of taxa was defined based only on the “B” criterion proposed by the International Union for Conservation (IUCN) Red List, version 13 (IUCN 2017). Based on this criterion, the species had their “Extent of occurrence” (EOO) and “Area of occupancy” (AOO) calculated using the GeoCAT tool (http://geocat.kew.org/) (Bachman *et al.* 2011), using the IUCN default cell width of 2 km. Boxplots were produced using the 'boxplot' function of the 'graphics' package (R Core Team 2022) to visualize the altitude range of *Manihot* species endemic to Northeast Brazil. The richness in the Northeast was calculated as the total number of species present per grid square (1° x 1°) using the DIVA-GIS 7.5 program

(Hijmans *et al.* 2012). The distribution and richness of *Manihot* taxa was represented through maps made using the Quantum GIS 3.8 program (QGIS 2020).

Results

Fifteen endemic species of *Manihot* were found in Northeast Brazil: *M. alterniflora*, *Manihot bellidifolia* P. Carvalho & M. Martins, *Manihot breviloba* P. Carvalho & M. Martins, *Manihot compositifolia* Allem, *Manihot diamantinensis* Allem, *Manihot dichotoma* Ule, *Manihot jacobinensis* Mull. Arg., *Manihot longiracemosa* P. Carvalho & M. Martins, *M. macrocarpa*, *Manihot maracasensis* Ule, *M. pandurata*, *M. quinquefolia*, *M. reflexifolia*, *Manihot reniformis* Pohl, *Manihot zehntneri* Ule. Some typification problems were found during the revision of the protologues, type specimens, and historical collections. Thus, we propose lectotypes for 5 species: *M. dichotoma, M. jacobinensis, M. maracasensis, M. reniformis*, and *M. zehntneri*. Regarding the conservation status, 47% of the species were categorized as Endangered (EN), 33% as Critically Endangered (CR), 13% as Least Concern (LC), and 7% as Near Threatened (NT).

Regarding the habit, 40% of the species were shrubs, 27% were lianas, 20% were subshrubs, and 13% were trees. The arboreal habit was found exclusively in Caatinga, the shrubby and subshrubby habit was found in Caatinga and Cerrado, and the lianescent habit was observed in Atlantic forest. The domain with the greatest richness was Caatinga with 39% of the species, followed by Cerrado with 33%, all corresponding to species found in rock fields, and finally the Atlantic Forest with 28% of the species, of which four were found in forests and one (*M. breviloba*) in restinga. The results on the distribution of the species showed that all of them except *M. jacobinensis* have a restricted distribution: 80% occurred exclusively in one domain and 20% in more than one domain.

Most species were found in the state of Bahia and only *M. breviloba* was found exclusively in Sergipe and Alagoas. The species were distributed from 0 m to 1700 m (SI),

mostly between 500 and 1000 m. The area with greatest richness was the Espinhaço Range (Bahia sector), mostly corresponding to the Chapada Diamantina National Park. In this area (Fig. 1), there were seven species (*M. bellidifolia, M. dichotoma, M. jacobinensis, M. maracasensis, M. reflexifolia, M. reniformis*, and *M. zehntneri*), and *M. bellidifolia* occurred exclusively in this area (Fig. 2). Five species were found in the second area with greater richness, and *M. longiracemosa* and *M. reflexifolia* occurred exclusively in this area.

Discussion

Rogers & Appan (1973) reported 10 species distributed exclusively in Northeast Brazil, five of which remain with this endemic distribution until the present day. The catalog Flora e Funga do Brasil (2020) reports 17 species endemic to the Northeast, but in this work we consider 15 of them because the catalog cites *Manihot fortalezensis* Nassar, Ribeiro, D. G., Bomfim & P.T.C. Gomes, which is probably originating from a natural hybridization process between *M. esculenta* and *Manihot glaziovii* Müll. Arg., *Manihot pohliana* Müll. Arg., a species described by Müller Argoviensis (1874) from only two samples, which are presently deteriorated and do not allow the observation of the key characteristics of the species. An exhaustive search was carried out during the field expeditions in the locality where *M. pohliana* was originally collected, but nothing was found.

The conservation status proposed by other authors is confirmed in this study for 13 species (Martins 2013; Martins *et al.* 2017; Martins *et al.* 2018; Santos *et al.* 2019). The only two modifications concern the status of *M. quinquefolia*, which is being changed from Least Concern, proposed by Martins *et al.* (2018), to Endangered, and of *M. maracasensis*, which is being changed from Vulnerable, proposed by Martins (2013), to Endangered. Currently, only *M. dichotoma* is included in the IUCN list of threatened species (Fernandez *et al.* 2021, IUCN 2022) in the category of Least Concern. Although the distribution range of this species increased, its conservation status remains the same. None of the species reported here as endemic are included in any category of threat in the National Center for the Conservation of

Flora (CNC Flora). In Northeast Brazil, *M. dichotoma* occupies small areas in Caatinga and Cerrado, which are, therefore, biomes biogeographically relevant for the study of this taxon (Nassar *et al.* 2008; *Duputié et al.* 2011). Caatinga and Cerrado are recognized as biodiversity hotspots for their high richness and endemism levels of different biological groups (Klink & Machado 2005). These two biomes are considered seriously threatened mainly due to habitat loss and fragmentation, introduction of exotic species, environmental pollution, and climate change (Newbold *et al.* 2015). Despite a restricted and irregular rainfall regime and a semi-arid climate with predominance of seasonally dry forests, Caatinga is an important center of diversity and endemism in Brazil (Werneck *et al.* 2011, Simões *et al.* 2020). *Manihot* species from the Caatinga were predominantly trees to subshrubs, those from Cerrado were predominantly shrubs, and those from Atlantic Forest were exclusively lianescent. This pattern of predominance of habits in each domain has already been identified in other studies and is related to the nutrient availability and environmental conditions (Rogers & Appan 1973; Nassar *et al.* 2008; Simon *et al.* 2021).

The areas with the highest species richness are associated with the Espinhaço Range which is a mountain chain extending from the state of Minas Gerais to the state of Bahia recognized as an important center diversity and endemism (Bitencourt & Rapini 2013, Campos *et al.* 2017), housing approximately 10% of the plant diversity recorded in Brazil (Rapini 2010). Our results showed that the Bahia portion of the Espinhaço Range, specifically the Chapada Diamantina, has a great richness of *Manihot* species endemic to Cerrado, with two species restricted to the Chapada Diamantina. Other area in Brazil with high endemism levels of *Manihot* species is the Chapada dos Veadeiros, with 11 species restricted to this area (Silva 2014; Mendoza *et al.* 2015). The Chapada Diamantina is characterized by rupestrian field vegetation and presents one of the highest levels of plant endemism in Brazil (Giulietti & Pirani 1987; Rapini *et al.* 2008; Bitencourt & Rapini 2013). However, despite their ecological

importance, these ecosystems are being threatened by exploration processes (Fernandes et al., 2020).

The remarkable presence of *Manihot* species in the Chapada Diamantina has been reported in other studies (Duputié *et al.* 2011; Martins 2013, Simon *et al.* 2021) and is explained by a combination of several factors such as the large altitude range provided by the mountainous topography and the intersections between Caatinga, Cerrado and Atlantic Forest. This scenery provides conditions for the establishment of plant lineages with different requirements, leading to high levels of endemism and diversity.

Taxonomic treatment

***Manihot* Mill.,** Gard. Dict. Abr., ed. 4. (1754). TYPE: Lectotype, Figs 4 e 5 na Merian, Dissertatio de generatione et metamorphosibus insectorum Surinamesium. 1726.

Trees, shrubs, subshrubs or lianas, which may be erect or postrate. **Roots** sometimes tuberous. **Stem** cylindrical, smooth, rarely with swollen knots, green to purple, glabrous or pubescent; latex white to lightly cream or translucent, abundant. **Stipules** foliaceous, semifoliaceous or setaceous, triangular, ovate, filiform or linear to linear-lanceolate, with entire edges, lacinated or dentate, generally not persistent. **Petioles** dorsiventrally flattened or cylindrical, pubescent, or glabrous, greenish to purple, basally or peltate inserted. **Leaves** simple 3–5–7-lobed or not lobed, sometimes with deeply lobed leaves, with a large constriction at the base of the lobes, rarely with lateral lobes smaller or extremely reduced, glabrous or pubescent, green or greensh with purple ribs, lobes oblong, elliptic, lanceolate, suborbicular, oval or reniform to cordate, margin entire, pandurate or revolute, apex acute, acuminate or cuspidate, base acute, obtuse to slightly decurrent, venation camptodromous. **Inflorescences** terminal in racemes or paniculate; bracts and bracts setaceous, semifoliaceous or foliaceous, pubescent or glabrous, oval, ovate, lanceolate, filiform or triangular, with margin entire, lacinated or serrated, apex acute to obtuse, sometimes semi-reflexed or rarely arched over the floral buds. **Staminate buds** orbicular,

ovate, ovoid, bifusiform, pyramidal or conical. **Staminate flowers** gamotepalous, fused to halfway or 1/3 of the length, greenish, yellowish, purple, sometimes green with purplish lines or yellow with purple margins, glabrous or pubescent, staminal disk white or yellow**. Pistillate buds** 2, pyramidal, bifusiform or ovate, opposite to subopposite. **Pistillate flowers** dialipetalous, green, purple or sometimes green to purple with purple lines, glabrous or pubescent, nectary disk yellow, orange or purple. **Capsules** ovate, orbicular, elliptic or short-cylindrical, smooth or with slight rectilinear ribs or sometimes with evident undulating ribs, green or green with purplish lines, apex rounded or slightly acuminate or apiculate. Seeds suborbicular, ovate, obovate, oblong or ellipsoid, brown or gray, sometimes with small dark spots. **Caruncle** triangular, rarely extending beyond the apex of the seed, yellowish, brown or white.

Key to *Manihot* species endemic to Northeast Brazil

1. Plants with leaves not lobed

    2. Leaf lobes reniform to cordate; petioles dorsiventrally flattened; seeds oblong.....4. *M. reniformis*

    2'. Leaf lobes elliptic-oval, oblong-lanceolate to linear lanceolate; petioles cylindrical to slightly canaliculate on the adaxial face; seeds ellipsoid

        3. Subshrub 15-25 cm tall; leaf lobes oblong-lanceolate to linear-lanceolate, margin strongly to slightly pandurate ….....11. *M. pandurata*

        3'. Shrub to climbing vine, 2-10 m tall; leaf lobes elliptic-oval, margin entire ……..…….……..……9. *M. macrocarpa*

1'. Plants with lobed leaves

    4. Petioles dorsiventrally flattened, leaf lobes short-lanceolate to suborbicular

5. Leaf lobes short-lanceolate, leaf blade held parallel to the stem axis with basal lobes oriented downwards…….....……2. *M. bellidifolia*

5'. Leaf lobes suborbicular, leaf blade not held parallel to the stem axis without basal lobes oriented downwards ……..……..……7. *M. jacobinensis*

4'. Petioles cylindrical; leaf lobes obovate, elliptic, ovate, or oblong

6. Tree, 2-12 meters high; stipules brown; capsules with slight undulating ribs…….……6. *M. dichotoma*

6´. Shrub, subshrub to climbing vine, 50 cm - 8 meters high; stipules green or black; capsules without undulating ribs.

7. Stem, petioles and leaves pubescent; capsules with ribs……..…..…10. *M. maracasensis*

7´. Stem, petioles and leaves glabrous; capsules without ribs

8. Stipules persistent; leaf lobes acute at the apex

9. Subshrub, prostrate, ≤ 50 cm tall; stem smooth; stipules persistent, semifoliaceous; inflorescence a pseudoterminal single raceme, 9.5–12.5 cm long…….…...……..... 1. *M. alterniflora*

9'. Shrub, erect, 1-4 m tall; stem with swollen knots; stipules deciduous, foliaceous; inflorescence a terminal panicle, 6-9 cm long…….....…15. *M. zehntneri*

8´. Stipules deciduous; leaf lobes acuminate, apiculate or cuspidate at the apex.

10. Stipules semifoliaceous, triangular, black; leaf lobes apiculate at the apex; capsules bacaceous, 4 cm diam…….4. *M. compositifolia*

10´. Stipules setaceous, filiform, green; leaf lobes acuminate or cuspidate at the apex; capsules not bacaceous, 1-2,5 cm diam

11. Bracts setaceous; capsules 2-2.5 cm diam, with slight rectilinear ribs, green without white lines.

12. Leaves 3-lobed with lateral lobes extremely reduced, margin entire; capsules ovate to elliptic.……. …….……...3. *M. breviloba*

12'. Leaves 3–5-lobed with lateral lobes not extremely reduced, margin pandurate; capsules orbicular…..……..…..……5. *M. diamantinensis*

11´. Bracts foliaceous or semifoliaceous; capsules 1-1.5 cm diam, without slight rectilinear ribs, green with white lines

13. Petiole greenish; leaves deciduous, deeply lobed, with a large constriction at the base of the lobes, resembling compound leaves, margin slightly pandurate; bracts semifoliaceous, linear…….12. *M. quinquefolia*

13´. Petiole purple, leaves permanent, not deeply lobed, without a large constriction at the base of the lobes, not resembling compound leaves margin entire; bracts foliaceaous, ovate.

14. Leaf lobes lanceolate, 15-21 cm long; inflorescence 20-25 cm long, bracts arched over the flower buds, ovate with obtuse apex……...……...……8. *M. longiracemosa*

14'. Leaf lobes elliptic to short lanceolate, 5–8 cm long; Inflorescence 6-15 cm long, bracts semi-reflexed, ovate lanceolate with acute apex ……..……..……..…….13. *M. reflexifolia*

Taxonomic treatment

1. ***Manihot alterniflora*** P. Carvalho & M. Martins, Nordic J. Bot. 36(3)-e01615:2 (2018). —TYPE**:** Brazil, Bahia, Municipality of Jussara, 10°44′07.8″ S, 41°14′50.9″ W, 475 m. 13 March 2010, *M. Martins et al. 1740*. Holotype: HURB (398!); isotypes: HVAS (23784!), CEN (108613!), CEPEC (92178!), HUEFS (247392!), K (n.v.), NY!, P (n.v.), RB (01402719!). Fig.1 [Martins et al. 2018 p. 62].

Subshrub 50 cm tall, erect or prostrate. **Roots** not tuberous. **Stem** glabrous, smooth, cylindrical, latex white. **Stipules** semifoliaceous, persistent, ovate, ca. 5 mm long, margin laciniate. **Petioles** cylindrical, 3–8.5 cm long, greenish, glabrous, basally inserted to the lamina. **Leaves** simple, 3–5-lobed, rarely entire, glabrous, glaucous green, lobes obovate, median lobe 6.5–9 × 2–4 cm, margin entire to pandurate, acute at apex, venation camptodromous. **Inflorescence** a single pseudoterminal raceme, 9.5–12.5 cm long; bracts semifoliaceous, margin entire; bracteoles semifoliaceous, margin entire or laciniate. **Staminate buds** orbicular to ovate, 0.9–1.2 × 0.6–0.8 cm; pedicel 2.5–4.2 cm long. **Staminate flowers** gamotepalous, fused to halfway, green with purplish lines, glabrous, staminal disk white. **Pistillate buds** 2, ovoid, 0.7–1 × 0.5 cm, alternate; pedicel ca. 1.7 cm long. **Pistillate flowers** dialipetalous, creamy green, glabrous, disk light yellow. **Capsules** orbicular, ca. 2 cm in diameter, smooth, green, rounded at apex. **Seeds** ellipsoid, ca. 1.5 × 0.6 cm, gray, with small dark spots. **Caruncle** triangular, ca. 4 mm long, light yellow, at apex with slight central recess, extending beyond the apex of the seed.

Phenology: Flowering and fruiting in February to March in the field, and from October to May under cultivation at Universidade Federal do Recôncavo da Bahia (UFRB).

Distribution and habitat: Bahia. Municipality of Jussara and Sento Sé (Fig. 3), in the understory of shrubby Caatinga in Cambissol soils.

Conservation status: Critically Endangered (CR B1a; IUCN), due to its small extent of occurrence (less than 100 km^2).

Notes: *Manihot alterniflora* is similar to *M. carthagenensis* (Jacq.) Müll. Arg. in the obovate leaf lobes, persistent semifoliaceous stipules and orbicular fruits, but it is easily distinguished by its subshrub habit, height of less than 50 cm, racemose inflorescences, and caruncle extending beyond the apex of the seed (vs. shrubby or arboreal habit, 1-5 m tall, paniculate inflorescences and caruncle restricted to the ventral part of the seed in *M. carthagenensis*).

Specimens examined: BRAZIL. Bahia: Jussara, Baixão dos Honoratos, 3 Apr 1984, *O. A. Salgado* & *H. P. Bautista 342* (HUEFS); Sento Sé, road Jussara-Sanharó, km 42, 13 Mar 2010, *M. L. L. Martins et al. 1740* (HUEFS).

2. ***Manihot bellidifolia*** P. Carvalho & M. Martins, Syst. Bot. 39: (2) pp 485. 2014. — TYPE: Brazil, Bahia, Municipality of Catolés, 12 December 2013, *Martins, M.L.L. et al.,* 2161. Neotype designated here: HURB (HURB8838!), Isoneotype: CEPEC (148521!). Fig. 4 A-I.

Shrub 1.0–2.5 m tall, erect. **Roots** not tuberous. **Stem** glabrous, smooth, branches cylindrical, latex white. **Stipules** setaceous, deciduous, filiform, ca. 0.5 mm long, margin entire. **Petioles** dorsiventrally flattened, (2–) 4–8 (–10) cm long, glabrous, basally inserted to the lamina. **Leaves** simple, 3–5-lobed, alternate, glabrous, chartaceous, abaxial surface lighter, leaf blade held parallel to the stem axis with the basal lobes oriented downwards, lobes short-lanceolate, median lobe (3–) 5–10 × 0.9–2.5 cm, margin entire to revolute, apex acuminate, venation camptodromous. **Inflorescence** a single terminal raceme, 15–25 cm long; bracts foliaceous, reflexed, oval-lanceolate with acute apex, margin entire, greenish at base and purplish at apex; bracteoles foliaceous, oval-lanceolate, acute apex, margin entire, white-purple. **Staminate buds** bifusiform, 0.5–1 × ca. 0.5 cm. **Staminate flowers** gamotepalous, fused to halfway, greenish with purplish lines, glabrous, staminal disk yellow. **Pistillate buds** 2,

pyramidal, 1–1.5 × 0.5–1 cm, subopposite**. Pistillate flowers** dialipetalous, greenish to purplish with purple lines on the outside, disk purplish. **Capsules** ovate to orbicular, 1.5–2 cm in diameter, smooth, green with purplish lines, apex rounded or slightly apiculate. **Seeds** ovate, 0.5–0.7 × 0.5 cm, brown-gray. **Caruncle** triangular, ca. 2 mm long, yellowish.

Phenology: Flowering and fruiting all year round.

Distribution and habitat: This species is found in Bahia, is endemic to rupestrian field vegetation in the southern region of the Chapada Diamantina (Fig. 3), generally on rocky slopes and sandy ground with shrub vegetation, above 1,000 m altitude.

Conservation status: According to IUCN criteria, this species is considered Endangered (EN B2a), with an area of occurrence less than 500 km^2.

Notes*:* *Manihot bellidifolia* has traditionally been identified as *M. acuminatissima* Müll. Arg. in herbarium collections due the shape of the leaf lobes and apex but differs by having 3–5-lobed leaves oriented parallel to the stem axis and inflorescences with long racemes (vs. exclusively 3-lobed leaves and short inflorescences in *M. acuminatissima).*

Taxonomic comments: *Manihot bellidifolia* was described by Carvalho & Martins (2014) based on the specimen collected by *M. Martins 1713 and P. C. Carvalho* at municipality of Catolés in 2010 and stored in the HUEFS herbarium, with duplicates in the CEN, CEPEC, HURB, K, P, RB, SP. However, neither the type material were found. The authors revisited the HURB, HUEFS and CEPEC collections and did not locate the material. Herbaria curators where isotypes were deposited were also contacted, but also unsuccessful. We speculate that there may have been misconduct during transport. We chose as a neotype the specimen *Martins 2161* because it is compatible morphologically with the protologue, as it comes from the same locality as the original collection and is deposited in the HURB herbarium, where the author of the species works.

Specimens examined: BRAZIL. Bahia: Abaíra, Boa Vista, 12 Nov 1992, *W. Ganev 1409* (HUEFS); Chapada Diamantina, 20 Dec 1991, *Harley et al. 50159* (ALCB); Chapada Diamantina, 01 Nov 2014, *Guedes et al. 22839* (ALCB); Bicota, between new Garimpo and Bicota. 15 Dec 1993, *W. Ganev 2678* (HUEFS); Chapada Diamantina, 31 Dec 1996, *L. Queiroz & M. da Silva 3848* (ALCB); Road Abaíra to Ouro Verde, 15 May 2016, *L. Brauner et al. 69* (UB); Guarda-Mor, 15 Sep 1993, *W. Ganev 2244* (HUEFS); Road to Serra do Barbado, 17 Nov 2015, *D. S. Carneiro 1334* (HUEFS); Salão, 9 km from Catoles on the road to Abaira, 28 Dec 1991, *R. M. Harley et al. 50522* (HUEFS); trail from Boa Vista to Bicota, 09 Jul 1995, *F. França et al. 1283* (HUEFS); trail from Ribeirão de Baixo to Piatã, 10 Jul 1995, *L. P. Queiroz et al. 4413* (CEN); top of Morro da Serrinha, 31 May 2003, *M. J. Andrade et al. 345* (HUEFS); Catolés, Serrinha, 19 Jun 2011, *P. L. Ribeiro 700* (HURB); Road to Catolés, 12 Dec 2013, *M. L. L. Martins 2161* (CEPEC), Piatã, road between Catolés/Barra de Catolés, 13º16' S 41º52' W, 1,180 m a.s.l , 19 Oct 1992, *W. Ganev 1276* (HUEFS).

3. ***Manihot breviloba*** P. Carvalho & M. Martins, Phytotaxa. 32: 57. 2011. —TYPE: Brazil, Sergipe, Santo Amaro das Brotas, 12º53' S, 41º18' W, 9.8 m. 14 May 2011, *M. Martins et al. 1800.* Holotype HUEFS (179120!), isotypes CEPEC (136510!), P (02090099!), SP (363773!). Fig. 4 J-R.

Shrub to climbing vine, 1.5–4 m tall. **Roots** not tuberous. **Stem** glabrous, smooth, cylindrical, latex white. **Stipules** setaceous, deciduous, and filiform **Petioles** cylindrical, clasping, 1–4 cm long, slightly purple, glabrous, basally inserted to the lamina. **Leaves** simple, 3-lobed, lateral lobes extremely reduced, glabrous, green, lobes obovate, median lobe 3–8 × 2–5 cm, margin entire, apex acuminate, venation camptodromous. **Inflorescence** terminal, racemose to paniculate, 10–17 cm long; bracts and bracteoles setaceous, margin entire. **Staminate buds** ovate, 0.6–1.2 cm; pedicel ca. 2.5 mm long. **Staminate flowers** gamotepalous, fused to halfway, yellow with purple margins, glabrous, staminal disk yellow. **Pistillate buds** 2, pyramidal, 0.7–1.2 cm long, opposite; pedicel 0.7–2.5 cm long. **Pistillate flowers**

dialipetalous, yellowish green with purple margins, glabrous, nectary disk orange with a purple base. **Capsules** ovate to elliptic, 2–2.5 cm in diameter, smooth, green, with slight rectilinear ribs, apex acuminate. **Seeds** oblong, ca. 1 cm long, greyish-brown, with small dark spots along the edges. **Caruncle** triangular, ca. 0.2 mm long, cream colored.

Phenology: Flowering and fruiting from February to November.

Distribution and habitat: *Manihot breviloba* occurs in Sergipe and Alagoas (Fig. 3) growing in restinga, in the shrubby vegetation of coastal sandy plains.

Conservation status: According to IUCN criteria, this species is considered Endangered (EN B1a), with an extent of occurrence less than 5000 km^2 .

Notes: *Manihot breviloba* is distinguished from all other species of the genus by its vine-like habit, leaf blades with extremely reduced or no lateral lobes, and clasping petioles. The species grows in the coastal sandy plains, an unusual habit for *Manihot* species; only *M. baccata* Allem, *M. pohlii* Wawra and *M. tripartita* (Spreng.) Müller have been reported from restingas (Pereira & Assis 2000; Sá 2002; Martins *et al.* 2020).

Specimens examined: BRAZIL. Alagoas: Feliz Deserto, Várzea of Marituba, 12 Sep 2009, *Chagas-Mota 5492* (MAC); Marituba, 23 Sep 1987, *M. N Rodriguez 1082* (MAC); Mun. Penedo, 9 km from Penedo towards Piaçabuçu, 27 Oct 1982, *M. N. Staviski et al. 346* (MAC); Penedo, 10 km from Penedo, sentido Piaçabuçu, 30 Mar 2013, *M. L. L. Martins* & *P. A. S. Marbach 1942* (HURB); Penedo, Marreca, 18 Oct 1988, *L. Lemos 1572* (MAC); Piaçabuçu, 7 km after the bridge of Penedo/Piaçabuçu, 15 Mar 2003, *L. Lemos 7414* (MAC); Piaçabuçu, 18 May 2011, *Chagas-Mota et al. 10331* (MAC). Sergipe: Barra dos Coqueiros, close to the port of Sergipe, *M. Landim et al. 590* (HUEFS); Barra dos Coqueiros, 20 Feb 1998, *A. Cruz* & *E. Santos 11* (ASE); Farm Procase, 30 Jun 1981, *M. Fonseca 534* (ASE); Ilha das Flores, Betume, Island of flores, 22 Jun 1982, *G. Viana 524* (IPA). Ilha das Flores, Betume, 28 Jan 2011, *M. C. Santana 900* (ASE), Japaratuba, Hugo Heredia, 24 Nov 2014, *S. A. Damasceno 53* (ASE);

Japaratuba, Sapucaia, *W. E. Santos et al. 14* (ASE); Japaratuba, São José Village, Right bank of the highway, 18 Jan 2013, *M. Farias et al. 398* (ASE); Mun. Pirambu, Saint Sebastian, 13 Jul 2011, *D. M. Oliveira 108* (ASE); Pirambu, Paraiso, 26 May 2012, *A. P. Prata et al. 3048, 3104* (ASE); Pirambu, Paraiso, next to Lagoa Redonda, 18 Apr 2011, *M. C. Santana 907* (ASE); Pirambu, 09 May 2013, *Farias et al. 115* (ASE); Pirambu, road to São José Village, 14 Sep 1995, *M. Landim 593* (HUEFS); Santo Amaro das Brotas, road to the Port of Sergipe, 16 Jun 2000, *G. Sousa et al. 367* (CEPEC, SP); Santo Amaro das Brotas, farm Prhocase, 30 Jun 1981, *M. Fonseca 27837* (IPA), Santo Amaro das Brotas, Jatobá, 18 Jun 2011, *J. Nascimento et al. 821* (ASE); Santo Amaro das Brotas, 23 Apr 2012, *M. Farias et al. 209* (ASE); Santo Amaro das Brotas, 30 Feb 2012, *S. Carvalho* & *H. Avila 323* (ASE), Santo Amaro das Brotas, Village Hugo Heredia, 11 Feb 2016, *Felix et al. 80* (ASE); Santo Amaro das Brotas, 14 May 2011, *M. L. L. Martins 1800* (HUEFS); Santo Amaro das Brotas, next to Rio Poronga, 15 Nov 2002, *A. Ribeiro 202* (UEC).

4. ***Manihot compositifolia*** Allem, Revista Brasil. Biol. 49: 650. 1989 publ. 1990. — TYPE: Brazil, Bahia, Jussari, 1 km E of Jussari, along the road that ends at BR-101 road, *Allem 3750* & *Werneck* (Holotype: CEN (37666!), Isotypes K (000600409!), NY [image!]. Fig.5 A-F.

Shrub to climbing vine, 8.0 m tall. **Roots** not tuberous. **Stem** glabrous, smooth, cylindrical, latex white, abundant. **Stipules** semifoliaceous, deciduous, triangular, ca. 2 mm long, black. **Petioles** cylindrical, 5–15(–20) cm long, purple, glabrous, basally inserted to the lamina. **Leaves** deeply lobed, with a large constriction at the base of the lobes, (3–)5(–7)-lobed, glabrous, lobes elliptic to ovate, median lobe 4–12(–14) × 2-4 cm, margin entire, persistent, apex apiculate, venation camptodromous. **Inflorescence** terminal, racemose to paniculate, 7–15 cm long; bracts and bracteoles setaceous, triangular, margin entire. **Staminate buds** bifusiform, 1–1.5 cm. **Staminate flowers** gamotepalous, fused to 1/3 of the length, green to purple, glabrous, staminal disk yellow. **Pistillate buds** bifusiform, 1.5 cm long, opposite to

subopposite; pedicel 4 cm long. **Pistillate flowers** dialipetalous, greenish yellow to purple, glabrous, nectary disk yellow. **Capsules** bacaceous, ovate to elliptic, 4 cm in diameter, indehiscent, smooth, green with purplish lines, apex rounded. **Seeds** obovate, ca. 2 cm long, variably brown. **Caruncle** triangular, 1 mm long, yellow-brown.

Phenology: Flowering and fruiting from December to May.

Distribution and habitat: *Manihot compositifolia* is reported from the Atlantic Forest of Bahia. It is usually found growing near cocoa and cassava plantations in ombrophilous forest, near roads and mixed with weeds (Allem, 1989). The species grows in blackish and muddy organic soils and is locally known as "mandioca brava" (Fig. 6).

Conservation status: According to IUCN criteria, this species is considered Endangered (EN B1a), with an extent of occurrence less than 5000 km^2 .

Notes: *Manihot compositifolia* can be recognized by the deeply lobed leaves (with a large constriction at the base of the lobes), pistillate flowers with long pedicels (4 cm) and bacaceous, conical to ovoid fruits. *Manihot compositifolia* resembles *M. baccata* in the lianescent habit, but differs from it by having black stipules, leaves with a large constriction at the base of the lobes, apiculate apex and ovate to elliptic bacaceous capsules (vs. green stipules, leaves without a large constriction at the base of the lobes, acuminate apex, and ovate to orbicular bacaceous capsules in *M. baccata*).

Specimens examined: BRAZIL. Bahia: Camacan, BR-101- km 517, 23 Oct 1981, *J. Vieira, 162* (CEN); Cruz das Almas, agronomy school UFBA, 03 Mar 1978. *C. Allem 1976* (CEN); Mun. Cruz das Almas, agronomy school UFBA, 06 Mar 1978. *C. Allem 1977* (CEN); Ibicaraí trail between Poções and Ibicaraí, 09 Apr 1988, *C. Costa* & *Werneck 54* (CEN), Ibicarai, towards Itabuna *C. Allem 4073* (CEN, HUEFS); Ibicarai, 18 km after the entrance to the city, towards Itabuna, 23 May 1993, *C. Allem et al., 4526* (CEN, HUEFS); Ibicarai, 18.6 km from Ibicaraí, along the BR – 415, 08 Feb 1995, *A. C. Allem 4527, 4528, 4529* (CEN),

Ilhéus, Pimenteira, 12 Dec 2014, *A. M. Amorim 8472* (CEPEC); Itapebi, road to Itapebi, 8 Jul 1967, *R. S. Pinheiro* & *T. S. Santos 383* (CEPEC); Itabuna, BR–101 Itabuna to Buerarema, 2.5 km after Posto Fiscal, 10 abril 1988, *I. R. S. Costa et al., 55* (CEN); Itarantim, Boi Rajado, 14 km of Bandeira, 08 Oct 2003, *A. Salino et al., 9148* (SP); Jussari,1 km east of Jussar, along the BR-101, 14 Dec 1987, *A. C. Allem* & *W. L. Werneck 3750, 3751, 3570* (CEN); Jussari, road to Jussari-Palmira, 7.5 km from Jussari, Farm teimoso, RPPN Serra of Teimoso, 21 Nov 1998, *A. M. A. Amorim et al., 2711* (CEPEC, SP); Jussari, 3 km before Jussari BR–101, 19 Ago 2010, *M. Martins et al., 1673* (HURB, CEPEC); Jussari, RPPN Serra do Teimoso, 13 Dec 2018, *J. Kulkamp 608* (HUEFS); Burarema, 15 km southwest of Itabuna, 25 Aug 1985, *C. Allem 3364* (CEN); Burarema, 15 km southwest of Itabuna, 14 Dec 1987, *A. C. Allem 3749* (CEN); Mun. Burarema, 15 km southwest of Itabuna, 25 Aug 1985, *C. Allem 3365* (CEN).

5. ***Manihot diamantinensis*** Allem, Revista Brasil. Biol. 49: 658, 1989 publ. 1990. — TYPE: Brazil, Bahia, Morro do Chapéu, ca. 10 km southwestward from the city, along the BA–052 road, towards Irecê, *Allem 3734* & *Werneck*. Holotype: CEN (00037667!) Isotypes: K (000600408!), NY (263623!), SP [n.v]. Fig. 5 G-O.

Shrub or subshrub, 1.5–4 m tall, erect or prostrate. **Roots** not tuberous. **Stem** glabrous, smooth, cylindrical, green to purple, latex white. **Stipules** setaceous, deciduous, filiform**.** **Petioles** cylindrical, 3–7(9) cm long, green to purple, glabrous, basally inserted to the lamina. **Leaves** simple, 3–5 (7)-lobed, glabrous, abaxial surface glaucous, adaxial surface dark-green, lobes elliptic to ovate, median lobe 3–5(7) × 0.5–2 cm, outermost lobes smaller in size than median lobes, margin pandurate, apex acuminate to cuspidate, venation camptodromous. **Inflorescence** a single terminal raceme, 3–8(–10) cm long; bracts and bracteoles setaceous, deciduous, glabrous, filiform, margin laciniate. **Staminate buds** bifusiform to ovate, 0.5–1.5 cm. **Staminate flowers** gamotepalous, fused to halfway, green with purple lines, glabrous, staminal disk yellow. **Pistillate buds** 2, ovate to pyramidal, 1 × ca. 0.5 cm long, pedicel up to 3 mm long. **Pistillate flowers** dialipetalous, yellow to purple, glabrous, nectary disk orange.

Capsules orbicular, 2 cm in diameter, smooth, green, with slight rectilinear ribs, apex rounded. **Seeds** suborbicular, 1.3 cm long, yellow, with small grey spots. **Caruncle** triangular, 4 mm long, yellow-brown.

Phenology: Flowering and fruiting from December to April.

Distribution and habitat: It is found in Bahia growing in marginal areas of Caatinga, in sandy soil. It was found growing in an embankment close to a road together with *M. carthagenensis* (Fig. 6).

Conservation status: According to IUCN criteria, this species is considered Critically Endangered (CR B1a), with an extent of occurrence less than 100 km^2.

Notes: *Manihot diamantinensis* is very distinctive by having prostrate habit, thin branches, deeply pandurate leaf margins, and orbicular fruits. Its individuals are very difficult to locate in the field because the darkened upper surface of the leaves make them inconspicuous in the surrounding environment. The species is used as food for cattle and it is frequently pruned because it grows near weeds.

Specimens examined: BRAZIL. Bahia: Morro do Chapéu, Rod. BA–052, about 10 km SW of the city, along highway BA-052, 10 Dec 1987, *C. Allem 3734 & W. Werneck* (CEN); Morro do Chapéu, 10 km SW of the city, along highway BA-052, 12 Dec 1987, *C. Allem 3745 & W. Werneck* (CEN); Morro do Chapéu, highway BA–052, about 10 km SW of the city, 11 Dec 1987, C. *Allem 3744 & W. Werneck* (CEN, HUEFS); Morro do Chapéu, highway BA–052, 16 Apr 1988, *I. R. S.Costa et al. 71* (CEN); Morro do Chapéu, exactly 9.1 km (church, reference) SW of the city, along highway BA - 052 towards Irecê, 05 Feb 1995, *C. Allem 4504* (CEN, HUEFS); Morro do Chapéu, exactly 9.9 km (church, reference) SW of the city, along highway BA - 052 towards Irecê, 05 Feb 1995, *C. Allem 4505* (CEN, HUEFS); Morro do Chapéu, exactly 9.9 km (church, reference) SW of the city, along highway BA - 052 towards Irecê, 05 Feb 1995, *C. Allem 4506* (CEN); Morro do Chapéu, BR - 052 Irecê towards Morro do

Chapéu, 45.2 km after Ipanema, 11 Jun 1996, *W. Werneck 881* (CEN); Morro do Chapéu, BR–052, km 10, 23 Feb 2012, *M. L. L. Martins et al. 2039* (HURB); Morro do Chapéu, 11.4 km from Morro do Chapéu towards Irecê, 09 Mar 2013, *M. L. L. Martins 2166* (CEPEC, HURB); Morro do Chapel, towards Irecê. 23 Oct 2021, *K. Suarez 07* (PEUFR).

6. ***Manihot dichotoma*** Ule, Notizbl. Königl. Bot. Gart. Berlin. 5: 2, 1907. 5: 19, pl. 1. 1908. — TYPE**:** Brazil, Bahia, Calderão, October 1906, *Ule 7045*. Lectotype **designated here**: MG: (MG023959!), Isolectotypes: HBG [HBG515959 Image!], G [Image! n.v], K (K000600445!), L [0020816 Image!]. Fig. 7 A-J.

Tree 2-12 m tall, erect. **Roots** not tuberous. **Stem** glabrous, smooth, cylindrical, latex white, abundant. **Stipules** setaceous, deciduous, brown, margin laciniate. **Petioles** cylindrical, 5–15 cm long, glabrous, basally inserted to the lamina. **Leaves** simple 3–5-lobed, lateral lobes smaller, glabrous, lobes elliptic to ovate, median lobe 6–10 × 2–5 cm, margin entire to pandurate, apex acuminate, venation camptodromous. **Inflorescence** terminal, racemose and pendulous, 4–6 cm long; bracts and bracteoles setaceous, margin laciniate. **Staminate buds** pyramidal, 2–3 × 1–1.5 cm. **Staminate flowers** gamotepalous, fused to halfway, green, glabrous, staminal disk yellow. **Pistillate buds** ovate to pyramidal, 1–2 x 0.5 cm long, opposite to subopposite; pedicel 1-3 cm long. **Pistillate flowers** dialipetalous, green, glabrous, nectary disk orange. **Capsules** orbicular to oblong, 2–3.5 cm in diameter, smooth, with evident undulating ribs, apex rounded. **Seeds** oblong, 1.8 × 1.2 cm long, greyish-brown, smooth, with small dark spots. **Caruncle** triangular, ca. 1 mm long, yellow brown.

Phenology: Flowering and fruiting from November to May.

Distribution and habitat: *Manihot dichotoma* is recorded only in Bahia, in Caatinga (Fig. 6).

Conservation status: Least Concern, with an extent of occurrence of 77,480.332 km^2

Notes: It is recognized by the orbicular fruits with undulating ribs evident from the beginning of its development. *Manihot dichotoma* resembles *M. elongata* P. Carvalho & M. Martins in the arboreal habit and leaves commonly with 3 to 5 lobes, but differ from it by the stipules with laciniate margins and the green orbicular capsules with undulating ribs (vs. stipules with entire margins and oblongoid or ovoid, usually purplish capsules with discrete, straight ribs in *M. elongata*).

Taxonomic comments: In the protologue, Ule (1907) did not mention the type, however, the location (Bahia, Bei Calderao) and collector (*Ule 7045*) data were added in Ule (1908). Possibly based on this information, Pax (1910) indicated the collection *Ule 7045* in his description of *Manihot dichotoma* var. *genuina* Pax. After that, Rogers & Appan (1973) and Allem (2001) also mentioned the same specimen as part of the original collection. Despite this, none of them clarified which herbarium is the depositary. In fact, only Martins (2013) indicated the MG herbarium, however this decision was not published. We decided to follow Martins' (2013) suggestion and selected the collection of MG (MG023959) as a lectotype because this specimen is in conformity with the protologue, presenting flowers and one fruit, and it is also in good condition. Another specimen deposited in this herbarium (MG023962) has information compatible with the protologue, but the sample does not correspond to *M. dichotoma.*

Specimens examined: BRAZIL. Bahia: Barra da Estiva, 15 Dec 2011, *M. L. L. Martins 1837* (HURB); Barra da Estiva, 31 Jul 2012, *M. L. L. Martins 1870* (HURB); Barra do Mendes, Road to Canarina, Carretão locality, 15 Dec 2009, *E. Melo 7512* (HUEFS); Boa nova, BR-116, Km 75, 7 Jun 1996, *W. L Werneck 853* (CEN); Boa Nova, 28.7 km to SW of Manoel Vitorino, 8 Feb 1995, C. *Allem 4525* (CEN); Brumado, 5 km to Rodovia Brumado–Caetité, 27 Dec 1989, *Carvalho et al., 2634* (SP); Brumado, about 76 km SE of Caetité, 6 Dec 1987, *C. Allem 3719* (HUEFS); Brumado, about 77 km SE of Caetité, 22 May 1993, *C. Allem 4071* (CEN); Cruz das almas, Embrapa, Germplasm Bank, 8 Mar 2012, *M. L. L. Martins 1422* (HURB); Itapetinga, Matinha Park, 3 Feb 1994, *W. Thomas et al., 10252* (SP); Jequié, 7 Oct 1965, *N. D. Cruz 109*,

110 (US, SP); Jequié, southeast, 2 Nov 2001, *D. L. Santana et al., 494* (ALCB); Jequié, Morro da Torre, 13 Apr 2007, *Queiroz 12904* (HUEFS); Livramento, on the way to Itanagé, 20 Apr 2010, *M. L. L. Martins* 56 (CEPEC); Manoel Vitorino, km 8, 16 Feb 1979, *L. A Mattos-Silva 279* (CEPEC); Manoel Vitorino, 107 km N of Vitória da Conquista, 11 Nov 1984, *C. Allem 2941* (CEN); Manoel Vitorino, Rodovia BR-116, 11 Nov 1984, *C. Allem 3724 (*CEN); Manoel Vitorino, 100 m ahead of the intersection of the highway BR - 116 with the road to Catingal, 8 Feb 1995, *C. Allem 4520, 4521, 4522* (CEN); Manoel vitorino, 107 Km N from Vitória da Conquista, 11 Nov 1984, *C. Allem et al 2934* (SP); Milagres, Serra do Jatobá, 3 Dec 1993, *R. M. Harley 22025* (CEPEC); Manoel Vitorino 3 km road to Catingal, 5 Jun 2022, *K. Suarez 15* (PEUFR); Rio de Contas, Boa Sentença, road to Jataí, 21 Apr 2003, *A. M. Giulietti et al. 2434* (HUEFS); Rio de Contas, 17.4 km from Rio de Contas, 5 Feb 1999, *M. Silva et al 39* (SP).

7. ***Manihot jacobinensis*** Mull.Arg., Linnaea 34: 205.1865. — TYPE: Brazil, Bahia, Mun. Jacobina, Serra da Jacobina, 1836. *Blanchet 2553.* Lectotype **designated here**: G (G00441885 [Image!]), Isolectotype: F [F0056893F Image!], MA [MA251074 Image! n.v], NY (NY00263633!), P [P00648621 Image!], K (000600349!). Fig. 7 K-S and Fig. 13 A-H.

Shrub 0.7–2(–3) m tall, erect. **Roots** not tuberous. **Stem** glabrous, smooth, branches cylindrical, latex white, abundant. **Stipules** semifoliaceous, deciduous, margin entire. **Petioles** dorsiventrally flattened, (1–)6–10 cm long, purple, glabrous, basally inserted to the lamina. **Leaves** simple, 3–5 lobed, deeply divided, glabrous, lobes normally suborbicular, occasionally elliptic or oval, median lobe (2.5–)6–8 × (1.5–)3-4.5 cm, margin entire, apex acuminate, venation camptodromous. **Inflorescence** terminal, erect, (6–)10–15 cm long; bracts foliaceous, ovate, apex acute semi-reflexed, margin entire, yellowish-green at the basal portion and purplish at the apex, glabrous; bracteoles semifoliaceous, margin entire, glabrous, yellowish-green to purple. **Staminate buds** bifusiform, 0.5–2 cm. **Staminate flowers** gamotepalous, fused to 2/3 of the length, yellowish, glabrous, staminal disk yellow. **Pistillate buds** 2,

bifusiform, 1.2–1.8 × ca. 0.5 cm long, opposite to subopposite; pedicel 1 cm long. **Pistillate flowers** dialipetalous, greenish yellow to purple, glabrous. **Capsules** orbicular to ovate, ca. 1 cm in diameter, smooth, green with purplish lines, apex acuminate. **Seeds** oblong, ca. 1.5 × 0.6 cm, grey with small dark spots. **Caruncle** triangular, ca 0.3 mm long, white.

Phenology: Flowering and fruiting all year round.

Distribution and habitat: Found in Bahia, in Cerrado and Caatinga, growing in a rupestrian field and sandy soil (Fig. 8).

Conservation status: Least concern, with an extent of occurrence of 108,946.587 km^2

Notes: *Manihot jacobinensis* is characterized by its erect shrubby habit, suborbicular leaf lobes, erect raceme with semifoliaceous bracts with entire margins, and dorsiventrally flattened petioles. The dorsiventrally flattened petioles is also shared with other species such as *M. bellidifolia* and *M. reniformis*. However, *M. jacobinensis* has suborbicular lobes, stipules semifoliaceous, capsules with acuminate apex and caruncle white (vs. flat leaves with short-lanceolate lobes, stipules setaceous, capsules with rounded apex and caruncle yellow in *M. bellidifolia* and entire, reniform leaves, stipules setaceous, capsules with rounded apex and caruncle yellow in *M. reniformis*).

The specimens identified as *M. jacobinensis* from sites outside of the Northeast region correspond to *M. violacea* Pohl. *Manihot jacobinensis* can be confused with *M. violacea* (which occurs in the Central-West region of Brazil) by the racemose inflorescences, semifoliaceous bracts and bracteoles, and leaves less than 8 cm long. *Manihot jacobinensis*, however, has suborbicular leaf lobes, erect shrubby habit, and erect and longer (between 10.0 and 15.0 cm) inflorescences (vs. recurved and oblanceolate lateral leaf lobes, prostrate subshrubby habit, and pendulous and short inflorescences < 5.0 cm in *M. violacea*).

Taxonomic comments: The type information in the protologue of *M. jacobinensis* was "*In Brasilia Bahiensis in montibus Jacobina (Blanchet n. 2553!)"* without mentioning the

depositary herbaria. Rogers & Appan (1973) mentioned the same collection stored at F, G, BM, K, NY, P and W as the type of *M. jacobinensis*, but they did not propose the lectotypification, with clear indication of the herbarium of the lectotype. Martins (2013) chose the specimen deposited in K, but this choice was not officially published. Furthermore, *Moricand* is listed as a collector and there is no mention of *Blanchet* in the specimen. For this reason we do not consider this specimen deposited in K part of the type collection. Since the main herbarium of Müller Argoviensis is G, we choose the collection deposited there, and two specimens from this collection were found; the one deposited under G00441885 is selected as the lectotype because this specimen has inflorescences and also because it more preserved. Another specimen deposited in this herbarium has information compatible with the protologue, but the collector number is different (*3553*). Because it has a different number and a later collection date when compared to the original, we believe that this specimen is not part of the type material.

Specimens examined: BRAZIL. Bahia: Andaraí, Road from Mucugê to Igatu, 28 Jan 2015, T. *Carnero 1277* (HUEFS); Andaraí, south of the city heading to Mucugê, near Xique-Xique, 14 Feb 1977, *R. M. Harley 18674* (CEPEC); Andaraí, Old Andarai/Mucugê road via Igatu, 2 km south of Igatu, 23 Dec, *S. A. Mori 13196,* (CEPEC); Bela Vista, 25 Mar 2004, *M. V. Moraes 641* (HUEFS); Bonito, 24 Feb 2012, *M. L. L. Martins. 2044* (HURB); Campo Formoso, Morro do Cruzeiro, 15 May 1999, F. *França, 2936* (HUEFS); Conde, north coast way to Cavalo Russo, 27 Apr 2014, M. L. *Guedes et al., 21600* (ALCB); Feira da Mata, Medium São Francisco, 1 km from the Cariranha River bank, 20 Jul 2007, M. L. *Guedes 13660* (HUEFS); Ibicoara, Chapada Diamantina, 13 Oct 2007, M. L. *Guedes et al., 13924* (ALCB); Igatu, 17 Feb 2012, *A. K. A. Santos 1277* (HUEFS); Jacobina, Jacobina road/Morro do Chapéu, ca. 24 km from the seat of the municipality of Serra do Tombador, 28 Oct 1995, *A. M. Amorim 1804* (CEPEC); Jacobina, 2 km road to Feira de Santana, 03 Nov 1987, *A. M. de Carvalho 2386* (CEPEC); Jacobina, Serra do Tombador - 10 km East Jacobina, 02 Mar 1978, *C. Allem 1751* (CEN); Jacobina, Itaitú village, 16 Nov 2014, *B. L. R Barbosa 7* (HUEFS); Jacobina, Serra of

Brite, 05 Jul 1996, *H. P Bautista 3417* (ALCB); Jacobina, 24 Jun 1999, *França, F. 3093* (HUEFS); Jacobina, 23 Oct 1990, *Freire-Fierro, A 2051* (SPF); Jacobina, On the road to Pico Jacaraguá, 09 Apr 2015, *R. M. Harley 57231* (HUEFS); Jacobina, 12 Jun 1996, *W. Werneck 889* (CEN); Jacobina, road to Santo Toca Fole, 21 Oct 2021, *K. Suarez* 03 (PEUFR); Lençóis, Along the BA-850 highway, 25 May 1993, *A. Allem 4081* (CEN); Lençóis, access road to the municipality, 26 Jan 1998, *A. M. Amorim 2158* (CEPEC); Lençóis, Serra da Chapadinha, Serra do Brejão, 28 Sep 1994, *A. M. Giulietti 882* (CEPEC); Lençóis, Chapada Diamantina, 10 Jul 2004, s/n, (CEPEC); Lençóis, near the city cemetery, 26 Aug 2005, *S. F Conceição,. 242* (HUEFS); Lençóis, BR 242, ca. 15 km West of Lençóis, 04 Oct 2007, *L. P. Queiroz, 13085* (HUEFS); Morro do Chapéu, Piemonte da Diamantina, 01 May 2006, *P. H. Cardoso et al., 72* (ALCB); Morro do Chapéu, Alto do Cruzeiro, 09 Apr 2000, *I. Cordeiro 2228* (HUEFS); Morro do Chapéu, Guariba, 04 May 2007, *F. França 5663* (HUEFS); Morro do Chapéu, road to Bonito, 24 Feb 2012, *M. L. L. Martins 2041*(HURB); Morro do Chapéu, Guariba Farm, 02 Jul 2007, *E. Melo. 498* (HUEFS); Morro do Chapéu, 15 km from the city towards Jacobina, 11 Mar 1996, *R. Lima 2240* (CEPEC); Morro do Chapéu, road to ferro doido, 22 Oct 2021, *K. Suarez 05* (UFRPE); Mucugê, Poço do Padre Trail, 26 Nov 2016, *D. S. Carneiro-Torres 1501* (HUEFS); Mucugê, 21 Jul 1981, *J. R. Pirani 1640* (CEPEC); Mucugê, 1 km east to town, 09 Aug 2007, *D. S. Pastore 2119* (HUEFS); Mucugê, 30 Oct 2003, *C. S. Santana 9* (HUEFS); Palmeiras, 22 Aug 2009, *J. C. Brito 121* (HUEFS); Palmeiras, 13 Dec 2016, *G. Costa et al., 2332* (HURB); Palmeiras, *12 Mar 1997, P. Gasson PCD6190* (HUEFS); Palmeiras, Chapada Diamantina, 25 Sep 1994, *Guedes, ML et al., s/n* (ALCB); Palmeiras, BR-242 Highway, 12 Oct 1987, *L.P. Queiróz, et al., 1975* (MBM).

8. ***Manihot longiracemosa*** P. Carvalho & M. Martins, Syst. Bot. 39:(2) 487. 2014. — TYPE**:** Brazil, Bahia, Municipality of Igatu, Labirinto, 12º53′81″ S, 41º19′31.9″ W, 16 November 2011, *M. Martins* et al. *1840.* Holotype HUEFS (224331!); isotypes: CEN

(CEN00094334!), HURB (5156!), RB (RB01160799!), SP (488266!). Fig. 9 A-J and Fig. 13 I-K.

Shrub 1–7 m tall, erect. **Roots** not tuberous. **Stem** glabrous, smooth, branches cylindrical, latex white, abundant. **Stipules** setaceous, deciduous, ca. 0.1 mm long, margin entire. **Petioles** cylindrical, (1–) 10–15 cm long, purple, short in apical leaves, glabrous, basally inserted to the lamina. **Leaves** simple 3–5-lobed, glabrous, lobes lanceolate, adaxial surface green with slightly purplish veins, median lobe (10–)15–21 × 4–8.5 cm, margin entire, apex acuminate, venation camptodromous. **Inflorescence** a single terminal raceme, erect, (15–)20–25(–38) cm long; bracts foliaceous, arched over the floral buds, ovate, apex obtuse, margin entire, greenish-yellow at base and purplish at the apex, pubescent; bracteoles setaceous, apex obtuse, margin entire, greenish-yellow, pubescent along the margins. **Staminate buds** bifusiform, 1.5–2 cm; pedicel 1 cm long. **Staminate flowers** gamotepalous, fused to halfway, greenish-yellow, glabrous, staminal disk yellow. **Pistillate buds** 2, pyramidal, 1.5–2 cm long, opposite; pedicel 1 cm long. **Pistillate flowers** dialipetalous, greenish-yellow, glabrous. **Capsules** ovate to elliptic, 1–1.5 cm in diameter, smooth, green with purplish lines, apex acuminate. **Seeds** oblong, 1 cm, light grey. **Caruncle** triangular, ca. 0.2 mm long, white.

Phenology: Flowering and fruiting all year round.

Distribution and habitat: This species is endemic to the Chapada Diamantina Range in Bahia, in rupestrian field vegetation with rock outcrops (Fig. 8).

Conservation status: According to IUCN criteria, this species is considered Endangered (EN B1a), with an extent of occurrence less than 5000 km^2 .

Notes: *Manihot longiracemosa* is similar to *M. jacobinensi*s and *M. reflexifolia* in the shrubby habit and racemose inflorescences with foliaceous bracts, but differs from them by the larger leaves with reflexed and short-lanceolate lobes (10–)15–21 × 4–8.5 cm, longer inflorescences (ca. 15 cm), bracts with obtuse apex arching over the bifusiform staminate buds

(vs. suborbicular leaf lobes, (2.5–)6–8 × (1.5–)3-4.5 cm, inflorescences less than 15 cm long, bracts with acute semi-reflexed apex in *M. jacobinensis* and short-lanceolate lobes, (3–)5–8(–10) × 1–3 cm inflorescences less than 15 cm long, bracts reflexed with acute apex in *M. reflexifolia*).

Specimens examined: BRAZIL. Bahia: Mun. Andaraí, trail Andaraí/Lençóis, 03 Jun 1995, *F. França et al. 1200* (HUEFS); Mun. Andaraí, Serra do Cornelius, 13 Oct 1942, *R. de Lemos 12647* (NYBG); District Igatu, 16 Nov 2011, *M. L. L. Martins 1840* (CEN, HUEFS, HURB); District Igatu, 29 Sep. 2017, *T. Vieira 306* (HUEFS); District Igatu, Labirinto, 04 Mar 2009, *N. S. Brito 20* (HUEFS); road between Vale da Fumacã and Vale da Sucupira, 22 Jan 2010, *B. Russ 36* (HUEFS); Serra do Sincorá, 05 Oct 2001, *Nonato et al. 998* (HUEFS); Chapada Diamantina National Park, Ribeirão do Meio, 22 Jan 1996, *E. Ramos 1266* (CEN); climbing the trail to Pati, 10 May 2003, *Anjos et al. s/n* (ALCB, CEPEC); Mun. Cruz das Almas, Embrapa Mandioca e Fruticultura, Banco Ativo de Germoplasma, 05 Jun 2009, *M. L. L. Martins 1423* (HURB); Mun. Cruz das Almas, Federal University of the Recôncavo of Bahia, 9 Jun 2022, *K. Suarez 17* (PEUFR); Embrapa Mandioca e Fruticultura, Banco Ativo de Germoplasma, 17 Mar 2011, *M. L. L. Martins 1789* (HURB, CEPEC); Mun. Lençóis, Afloramento do Veneno, 02 Oct 2005, S. *Neves et al., 51* (HUEFS). Ribeirão Meio, 03 Apr 1996, *L. Werneck 814* (CEN); trail to Veneno, 05 Jun 2013, *M. L. L. Martins 2148* (HURB); Mun. Mucug, 28 km south of Andaraí towards Mucugê, 14 Nov 1984, *C. Allem 2970* (CEN); Semper-Viva Municipal Park, 31 Oct 2011, *P. Oliveira 1906* (HUEFS).

9. ***Manihot macrocarpa*** P. Carvalho & M. Martins, Phytotaxa 309(2): 179. 2017. — TYPE: Brazil, Bahia, Municipality of Ibirapitanga, administrative head office of Área de Proteção Ambiental do Pratigi, near the restaurant, 13º53′51.2″ S, 39º27′25.9″ W, 691 m. 27 March 2013, *M. Martins* & *C. Ledo 1928*. Holotype: HURB (5202!); isotypes CEN (108611!), CEPEC (95603!), HUEFS (108611!), SP (515140!). Fig.1 [Martins et al. 2017 p. 181].

Shrub to climbing vine, 10 m tall. **Roots** not tuberous. **Stem** glabrous, cylindrical, with evident nodes along the basal portion, latex white. **Stipules** setaceous, deciduous, filiform, ca. 3 mm long, margin entire. **Petioles** cylindrical, voluble, 1–8 cm long, green, glabrous, basally inserted to the lamina. **Leaves** simple, not lobed, glabrous, blade elliptic to oval, base obtuse, blade (5–)10(–12) × 2–5 cm, margin entire, apex acute, venation camptodromous. **Inflorescence** paniculate or rarely racemose, erect to pendulous, 7–11(–15) cm long; bracts and bracteoles setaceous, margin entire, blackened. **Staminate buds** ovoid, 0.8–1.5 × 0.5–0.7 cm, greenish yellow with purple inner spots. **Staminate flowers** gamotepalous, fused to 1/3 of the length, glabrous, staminal disk yellowish. **Pistillate buds** 2, pyramidal, 2 × 0.5 cm long, opposite to subopposite; pedicel 1-2 cm long, greenish yellow with purplish spots. **Pistillate flowers** dialipetalous, greenish-yellow, glabrous, nectary disk light yellow. **Capsules** orbicular, (3–)4–5(–5.3) cm in diameter, indehiscent, smooth, green, rarely ribbed, ribs ca. 1 mm long, tenuous. **Seeds** ellipsoid to oblongoid, (2.5–) 3.5–4 × 2–2.5 cm, smooth, dark brown, sometimes with small dark spots. **Caruncle** triangular, ca. 1 × 5 mm long, yellowish white.

Phenology: Flowering during March and October and fruiting during March, May and June.

Distribution and habitat: The species occurs in southern Bahia, in montane rain forest, in the Serra do Papuã (Fig. 8). It was found at forest edges, profusely branched, near disturbed areas. Individuals can measure up to 15 m tall.

Conservation status: According to IUCN criteria, this species is considered Critically Endangered (CR B1a), with an extent of occurrence less than 100 km^2 .

Notes: This species resembles *M. compositifolia* in its lianescent habit and indehiscent fruits, but it is distinguished by having simple leaves, without lobes, and orbicular fruits (vs. (3–)5(–7) lobed deeply lobed leaves and ellipsoid fruits in *M. compositifolia*).

Specimens examined: BRAZIL. Bahia: Ibirapitanga, Serra do Papuã, APA de Pratigi; wood behind the bungalow 1, 15 Mar 2013, *L. Y. S. Aona et al., 2516* (HURB); Ibirapitanga, Serra do Papuã, APA de Pratigi, In front of the restaurant, 08 Jun 2022, *K. Suarez 16 (*PEUFR); Itacaré, road between Embratel Tower and highway BR-101/Itacaré, 21 Dec 1979, *S. A. Mori & F. Benton 12851* (CEPEC).

10. Manihot maracasensis Ule, Bot. Jahrb. Syst. 42: 221, 1908. —TYPE: Brazil, Bahia, Municipality of Maracás, October 1906, *Ule 7003*. Lectotype **designated here**: HBG (HBG515957 Image!); Isolectotypes: F [F0BN005457 Image!], G [G00441862 Image! n.v], L (L0020819!), NY (n. v.). Fig. 9 K-U.

Shrub erect to climbing vine, 1.5–8 m tall. **Roots** not tuberous. **Stem** glabrous or pubescent, cylindrical, latex pale white, abundant. **Stipules** setaceous, deciduous, filiform, 0.5 mm long, margin entire. **Petioles** cylindrical, 6–12 cm long, pubescent, basally inserted to the lamina. **Leaves** simple, 3–5-lobed, pubescent, lobes elliptic to oblong, median lobe 10–13 × 3–5 cm, margin entire, apex acute, venation camptodromous. **Inflorescence** paniculate erect or pendulous, 8–12 cm long; bracts foliaceous, ovate, apex obtuse, margin entire, greenish to purple, pubescent; bracteoles semifoliaceous, short lanceolate, margin entire, greenish to purple, pubescent. **Staminate buds** ovoid to bifusiform, 1–1.5 × ca. 0.7 cm, greenish to purple. **Staminate flowers** gamotepalous, fused to halfway, pubescent, staminal disk yellowish. **Pistillate buds** 2, ovate to bifusiform, 1–1.5 × 0.6-0.9 cm long, opposite. **Pistillate flowers** dialipetalous, greenish-yellow to purple, pubescent. **Capsules** orbicular to ovate, 1.5–2.5 cm in diameter, smooth, with ribs ca. 2 mm long. **Seeds** oblong, 1.6 cm, smooth, light brown with small brown spots. **Caruncle** triangular, 3 mm long, yellowish brown.

Phenology: Flowering and fruiting from January to May.

Distribution and habitat: Bahia, in Caatinga and semideciduous seasonal forest (Fig. 10). It is usually found at forest edges in red clayey soil.

Conservation status: According to IUCN criteria, this species is considered Endangered (EN B2a), with an area of occurrence less than 500 km^2.

Notes: Distinguishable by generalized pubescence, paniculate inflorescences with foliaceous bracts and slightly ribbed capsular fruits. *Manihot maracasensis* resembles *M. caerulescens* Pohl because of its stipules, bracts and fruits, but differs by having lianescent habit, white latex and paniculate inflorescences (vs. shrubby to arboreal habit, yellow latex and racemose inflorescences in *M. caerulescens*). It also resembles *M. brachyandra* Pax & K. Hoffm. by having lianescent habit, pubescent leaves and paniculate inflorescences, but differs by having foliaceous bracts, lobes elliptic to oblong, 10–13 × 3–5 cm, apex acute and seeds oblong (vs. setaceous bracts, lobes oval 5.0-10.0 × 2.0-5.0 cm, apex acuminate and seeds elliptic in *M. brachyandra*). *Manihot maracasensis* is used as an ornamental plant in the municipality of Rui Barbosa, Bahia. It is locally known as "Maniçoba" (Rogers & Appan 1973).

Taxonomic comments: Ule (1908) cited *Ule 7003* from Maracas, in Bahia, without mentioning the depositary herbaria. Rogers & Appan (1973) recognized this specimen as a syntype but they did not specify the herbarium where it was deposited. Martins (2013) chose the specimen deposited in L, but this choice was not officially published. We choose HBG515957 as lectotype because it is in conformity with the protologue by presenting flowers and leaves and because it is in good condition.

Specimens examined: BRAZIL. Bahia: Abaíra, s/n, *R.M. Harley, 50515* (NYBG), Abaíra, 13 Dec 2013, *M. L. L. Martins*. 2116, (CEPEC); Abaíra, 28 Dec 1992, *R.M. Harley*, et al., 50515 (SP); Andaraí, Km 39 of the Andaraí highway - BR-242, 04 Mar 1978, *A.C Allem*, 1799 (CEN); Andaraí, Km 39 of the Andaraí highway - BR-242, 04 Mar 1978, *A.C Allem 1800* (CEN); Andaraí, Km 39 of the Andaraí highway - BR-242, 04 Mar 1978, *A.C Allem 1803* (CEN); Andaraí, 14 km from the junction of BR - 242, towards Andaraí, 14 Nov 1984, *A.C Allem 2956* (CEN); Andaraí, 3 km southeast of the junction of highway BR - 242 with the highway that leads to Andaraí, 25 May 1993, *A.C Allem 4083* (CEN); Andaraí, 25 km southeast

of the junction of highway BR - 242 with the highway that leads to Andaraí, 25 May 1993, *A. C Allem 4084* (CEN); Andaraí, 25.2 km southeast of the junction of highway BR - 242 with the highway that leads to Andaraí, 06 Feb 1995, *A.C Allem 4512* (CEN); Andaraí, 25.2 km southeast of the junction of highway BR - 242 with the highway that leads to Andaraí, 06 Feb 1995, *A.C Allem 4513* (CEN); Andaraí, 25.5 km southeast of the junction of highway BR - 242 with the highway that leads to Andaraí, 06 Feb 1995, *A.C Allem 4515* (CEN); Andaraí, 29.1 km from BR-324 to Andaraí, 18 Mar 2010, *M. L. L. Martins 2162* (CEPEC); Andaraí, 8 km from the junction of the BR - 242, towards Andaraí, 14 Nov 1984, *A.C Allem .2655* (HUEFS); Andaraí, 15 Nov 1992, *M.M. Arbo et al., 5782* (SP); Antari, 1906, *E.H.G. Ule 7003* (G); Barra da Estiva, 31 Jul 2012, *M. L. L. Martins. 1871* (HURB); Boa Vista do Tupim, Paraguaçu, Fazenda Esperança, 27 Mar 2016, *M. Casaes* & *M. L. Guedes 59* (ALCB); Itaberaba, 25 Sep 2018, *M. L. L. Martins. et al., 2233* (HURB); Itaetê, border of the Mucugê/Itaetê highway, right side, 25 Apr 2013, *M. L. L. Martins et al., 1970* (HURB); Itaête, 13 Apr 2001, *M.L. Guedes et al., 8291* (ALCB); Lajedinho, Chapada Diamantina, 24 Aug 2014, *R.S. Souza 78* (HST); Lajedinho, 26 Nov 2014, *G.E.L. Macedo 2298* (HUESB); Lençóis, 06 Feb 1995, *A.C. Allem, 4511* (CEN); Maracás, road to Marcionílio Souza, ca. 12.6 km from the city, 03 Nov 2011, *E. Melo 10556* (HUEFS); Marcionilio Souza, 07 Jun 1996, *Werneck, W.L. 855* (CEN); Ruy Barbosa, 27 Mar 2005, *D. Cardoso 385* (HUEFS); Ruy Barbosa, 18 Dec 2004, *, L.P. de Queiroz 9904* (HUEFS); Ruy Barbosa, 20 Sep 2005, *D. Cardoso 782* (CEPEC); Ruy Barbosa, 07 Jun 1996, *W.L. Werneck 857* (CEN); Ubiraitá, 3.4 km from BR 324 to Andaraí-Ubiraitá, 18 Apr 2010, *M. L. L. Martins 2146* (HURB); Wagner, Road from Morro do Chapéu to Wagner, 107 km from Morro de Chapéu (section between Utinga and Wagner), 16 Apr 1988, *R.S. Costa 73* (CEN); Wagner, 2 km from the junction of the BR-242, towards Andaraí, 15 Nov 1984, *R.S. Costa 2978* (CEN); Wagner, 11 Mar 2016, *M.L. Guedes 24294* (ALCB); Wagner, 11 Mar 2016, *M.L. Guedes et al., BIOC05 24318* (ALCB).

11. Manihot pandurata M. Martins & M. Mend., Novon 26(1): 61, f. 2.2018. — TYPE**:** Brazil, Bahia, Municipality of Cocos, Fazenda Trijunção, road to Guará, 14°40′55″ S, 45°50′39″ W, 825 m. 12 December 2001, *M. Fonseca et al., R. C. Mendonça, B.M. T.Walter* and *E. Cardoso 3088*. Holotype: CEN (45424!); isotypes: HUEFS (233766!), SP (361361!). Fig.2 [Mendoza et al. 2018 p. 3].

Subshrub 15–25 cm tall, erect to decumbent. **Roots** not seen. **Stem** suberect to decumbent, glabrous, smooth, 2 or 3 arising from a woody base giving the appearance of a reduced caespitose plant, latex white. **Stipules** setaceous, deciduous, linear to linear-lanceolate, margin usually entire sometimes dentate. **Petioles** reduced and slightly canaliculate on the adaxial face, 0.5 mm long. **Leaves** simple, not lobed, sessile to subsessile, spirally alternate and regularly distributed along the stem, glabrous, blade oblong-lanceolate to linear-lanceolate, (5–)9–11(–12) × (0.5–)1–2.5(–3.5) cm, margin strongly to slightly pandurate, apex acuminate to acuminate-attenuate, base acute to slightly decurrent, venation camptodromous. **Inflorescence** terminal, racemose, 1.5–2.5 cm long; bracts foliaceous, ovate-lanceolate, apex attenuate, margin strongly laciniate, glabrous; bracteoles setaceous and linear. **Staminate buds** conical, 10–12 × 7–8 mm, greenish to purplish. **Staminate flowers** gamotepalous, fused to halfway. **Pistillate buds** and **pistillate flowers** not seen. **Capsules** short-cylindrical, 1.2–1.3 cm in diameter, pale green, with fine white lines, apex rounded. **Seeds** ellipsoid, 7–8 × 4–5 mm **Caruncle** triangular, slightly prominent.

Phenology: Flowering and fruiting in December.

Distribution and habitat: This species is restricted to the municipality of Cocos in Bahia, where it grows in sandy soil and in well-preserved fragments of “campo sujo” (shrubby cerrado) vegetation, preferentially in shady places (Fig. 10).

Conservation status: According to IUCN criteria, this species is considered Critically Endangered (CR B1a), with an extent of occurrence less than 100 km^2 , known only from 2 collections.

Notes: *Manihot pandurata* is similar to *M. weddelliana* Baill. in the presence of sessile to subsessile leaves which are neither peltate neither with entire margins, deciduous stipules, inflorescences with laciniate margins and pedicellate flowers, but differs from *M. weddelliana* by having subshrubby habit with two or three suberect to decumbent stems arising from the base, oblong-lanceolate and strongly pandurate leaves(vs. erect habit, 40 to 60 cm tall, with a single erect stem, and linear-lanceolate leaves with irregularly serrate to serrate-toothed margins in *M. weddelliana). Manihot pandurata* also resembles *M. salicifolia* Pohl (distributed in the Midwest and North of Brazil) in the presence of sessile to subsessile leaves but differs by presenting pandurate leaf margins (vs. entire margins in *M. salicifolia).*

Specimens examined: BRAZIL. Bahia: Cocos, Trijunção farm, 12 Dec 2001, *M.L. Fonseca et al,. 3088* (HUEFS); Cocos, Santa Luzia farm, campo sujo, 13 Dec 2001, *M. C. Mendonça 4632* (HUEFS); Cocos, Fazenda Trijunção, 10 Dec. 2001, *M. L. Fonseca et al., 3027* (HUEFS).

12. Manihot quinquefolia Pohl, Pl. Bras. Icon. Descr. 1: 56. 1827. — TYPE: Brazil, Bahia, near Sincorá, *Martius s.n.* (lectotype: M (M0233289!); isolectotype: G (G00441834!), [Martins *et al.* 2018 p. 6]).

Shrub 1.5–4 m tall, erect. **Roots** not tuberous. **Stem** glabrous, smooth, cylindrical, with evident nodes on upper branches, latex creamy with light consistency. **Stipules** setaceous, deciduous, filiform, 1.5 mm long, margin entire, greenish. **Petioles** cylindrical, 5–7 cm long, greenish, glabrous, basally inserted to the lamina. **Leaves** deeply lobed, with a large constriction at the base of the lobes, 5(3) lobed, rarely spontaneously deciduous, abaxial surface glaucous, adaxial surface green, glabrous, lobe elliptic, median lobe (3–)4(–5) × ca. 1.5 cm, margin

slightly pandurate, apex acuminate, venation camptodromous. **Inflorescence** racemose**,** pendulous, 6–14 cm long; bracts semifoliaceous, linear, yellowish, glabrous; bracteoles setaceous, linear, yellowish, glabrous. **Staminate buds** ovoid, 5–7 × 3–5 mm. **Staminate flowers** gamotepalous, fused to halfway, greenish, glabrous, staminal disk yellowish. **Pistillate buds** 2, ovoid, 6 × 5 mm long, opposite. **Pistillate flowers** dialipetalous, with vinaceous lines on the outside, glabrous, nectary disk slightly yellowish. **Capsules** orbicular to slightly ovoid, 1–1.5 cm in diameter, smooth, green with white lines on septa, apex rounded. **Seeds** oblong, 1 x 0.5 cm, brown, with small dark spots. **Caruncle** triangular, ca. 2 mm long, yellowish.

Phenology: Flowering and fruiting in January, August, October, November and December.

Distribution and habitat: Bahia. Shrubby Caatinga vegetation, in rocky and sandy clayey soil (Fig. 10).

Conservation status: According to IUCN criteria, this species is considered Endangered (EN B1a), with an extent of occurrence less than 5000 km^2 .

Notes: Martins (2013) proposed that *M. quinquefolia* was probably extinct, because the species was known from only a single collection made by Pohl in 1827. Martins et al. (2018) rediscovered the species in the Municipality of Santa Terezinha. *Manihot quinquefolia* resembles *M. compositifolia*, but differs by its erect habit, semifoliaceous bracts and capsular fruits (vs. lianescent habit, inconspicuous bracts, and bacaceous fruits in *M. compositifolia*).

Specimens examined BRAZIL. Bahia: Santa Teresinha, 15 Aug 2010, *Martins, M.L.L. et al., 1661* (HURB); Santa Teresinha, 14 Oct 2010, *M. L. L. Martins. et al., 1706* (HURB); Santa Teresinha, 16 Nov 2011, *M. L. L. Martins 1847* (FLOR); Santa Terezinha, 15 Feb 2018, *G. Costa 3251* (HUEFS); Tucano, 01 Jun 2013, *G. Costa 852* (HURB).

13. Manihot reflexifolia P. Carvalho & M. Martins, Pl. Syst. Evol., 1-12, 19 2019 305(8): 671. 2019 — TYPE: Brazil, Bahia, Municipality of Mucugê, rock field ca. 3.0 km from

the Byzantine cemetery, next to Escola Agrotécnica, 13°53′51.2″ S, 39°27′25.9″ W, 691 m. 24 April 2013, *M. L. L. Martins et al., 1965*. Holotype: HURB (5476!); isotypes: CEN (n.v), CEPEC (1965!), HUEFS (n.v). (See [Santos et al. 2019 p. 10] and Fig.13 L-N.

Shrub 1–3 m tall, erect. **Roots** not tuberous. **Stem** glabrous, smooth, branches cylindrical, latex white to lightly cream, translucent, abundant. **Stipules** setaceous, deciduous, margin entire. **Petioles** cylindrical, (2–) 6–9 (–11) cm long, purple, glabrous, basally inserted to the lamina. **Leaves** simple 3–5-lobed, glabrous, green, abaxial surface lighter, lobes elliptic to short lanceolate, reflexed to semi-reflexed, median lobe (3–)5–8(–10) × 1–3 cm, margin revolute, apex acuminate, venation camptodromous. **Inflorescence** terminal, racemose, 6–15(–25) cm long; bracts foliaceous, ovate lanceolate, apex acute semi-reflexed, margin entire, cream to purple; bracteoles semifoliaceous, ovate lanceolate, apex acute semi-reflexed, cream to purple, glabrous. **Staminate buds** bifusiform, 0.8–1.2 × ca. 0.7 cm; pedicel 0.5–0.8 cm long, purple, glabrous. **Staminate flowers** gamotepalous, fused to halfway, purple, glabrous, staminal disk yellowish. **Pistillate buds** 1 or 2, pyramidal, 1–1.5 × ca. 0.5, purple; pedicel 5–10 cm long. **Pistillate flowers** dialipetalous, purple, glabrous, nectary disk light yellow. **Capsules** orbicular to ovoid, 1–1.5 cm in diameter, smooth, green with purple lines, apex rounded or apiculate. **Seeds** ovate, 1 cm long, grayish brown with dark brown spots. **Caruncle** slightly triangular, ca. 2 mm long, yellowish.

Phenology: Flowering and fruiting all year round.

Distribution and habitat: Bahia, Municipality of Mucugê, restricted to the Chapada Diamantina, in the municipality of Mucugê, on rocky outcrops with open shrub vegetation and sandy soil (Fig. 11).

Conservation status: According to IUCN criteria, this species is considered Endangered (EN B1a), with an extent of occurrence less than 5000 km^2. Fires constantly affect the areas where the species lives.

Notes: *Manihot reflexiolia* is similar to other species occurring in the Chapada Diamantina, such as *M. jacobinensis* and *M. longiracemosa*, sharing with them characteristics such as the foliaceous bracts, racemose inflorescences and bifusiform staminate buds (Rogers & Appan 1973; Martins *et al.* 2014), but *M. reflexifolia* differs by the reflexed and lanceolate leaves, (3–)5–8(–10) × 1–3 cm, setaceous stipules, cylindrical petioles, and bracts with semi-reflexed and acute apices (vs. elliptic-round leaves, (10–)15–21 × 4–8.5 cm, semifoliaceous stipules, dorsiventrally flattened petioles in *M. jacobinensis* and long-lanceolate leaves and bracts with obtuse apices arching over the floral buds in *M. longiracemosa*).

Specimens examined: BRAZIL. Bahia: Andaraí, Road from Andaraí to Mucugê at 28 km, 16 Apr 1988, *R. Costa* 74 (CEN); Andaraí, Bank of the Paraguaçu River, 16 Dec 2006, *F. França* 5594 (HUEFS); Mucugê, 4 km on Mucugê Andaraí Road, s/n, *A. M. V. de Carvalho 3081* (NYBG); Mucugê, 2 km north of Mucugê, on the way to Andarai, s/n, *M. M. Arbo 75* (NYBG); Mucugê, Semper Viva Park - Trail to the Andorinhas waterfall, 16 Jun 2018*; Gama, H. et al., 38* (ALCB); Mucugê, Sustainable Management Unit, 03 Jan 1997, *H. P. Bautista et al., 45* (MBM); Mucugê, trail to Siberia, 26 Jun 1993, *M. C. Ferreira 488* (MBM); Mucugê, km 5 Mucugê-Andaraí, 04 Mar 1978, *A. Allem & G. Vieira* 1978 (MNHN); Mucugê, 09 Aug 2007, *J.F.B. Pastore* 2197 (HUEFS); Mucugê, highway to Andaraí, 16 Aug 1984, *G. Hatschbach 47974* (MBM); Mucugê, close to the Cumbuca River, 3 km North in the city, Rodoviaria to Andarai, 06 Jan 1982, *R. M. Harley 15987* (CEPEC); Mucugê, about BA-245, 7.1 km to Andaraí from Mucugê, 25 Oct 2021, *K. Suarez 9* (PEUFR).

14. Manihot reniformis Pohl, Pl. Bras. Icon. Descr. 1: 56, 1827. — TYPE**:** Brazil, Bahia, Serra de Sincorá, 1818. *Martius 1935.* Lectotype **designated here**: M (M0233293

Image!); isolectotypes: G (G00441908 Image!), K (K000600414!), L (L0020821!), M (M0233290 Image!), MO (MO-260659 Image!). Fig. 12 A-I and Fig. 13 O-T.

Shrub 0.8-2 m tall, erect. **Roots** not tuberous. **Stem** glabrous, smooth, cylindrical, latex white. **Stipules** setaceous, deciduous, margin entire. **Petioles** dorsiventrally flattened, 2.0-5 cm long, glabrous, peltate insertion to the lamina. **Leaves** simple, entire, not lobed, glabrous, green with purple ribs, abaxial face lighter, blade-reniform to cordate, leaves arranged parallel to the stem axis, blade (4)5–8 × 3–6 cm, margin entire, apex acuminate, base cordate, venation camptodromous. **Inflorescence** terminal, racemose, 6–15(–25) cm long, bracts foliaceous, ovate, pink to purple along the margin and at the apex, margin entire to serrate, glabrous, bracteoles 2, semifoliaceous, ovate, white-pink, margin entire, apex acute, glabrous. **Staminate buds** bifusiform, 0.8–1.2 × 0.5 cm; pedicel 1.0 cm long. **Staminate flowers** gamotepalous, fused to 2/3 of the length, greenish yellow with purple margin, glabrous, staminal disk white. **Pistillate buds** 2, bifusiform, 1–1.5 × 0.5–0.7 cm, opposite to subopposite; pedicel 1 cm long. **Pistillate flowers** dialipetalous, green to purple with purple lines. **Capsules** orbicular to oval, ca. 1 cm in diameter, smooth, green from base to apex with purplish dehiscence lines, apex rounded or slightly pointed. **Seeds** oblong, 0.5–0.8 cm long, greyish-brown. **Caruncle** triangular, ca. 2 mm long, yellowish.

Phenology: Flowering and fruiting all year round.

Distribution and habitat: Bahia, endemic to areas of rupestrian field vegetation in the southern region of the Chapada Diamantina. There is a large population that can be found on the edges of the road BA-142 growing on rocky and sandy soil (Fig. 11).

Conservation status: According to IUCN criteria, this species is considered Endangered (EN B1a), with an extent of occurrence less than 5000 km^2 .

Notes: *Manihot reniformis* is recognized by having petioles dorsiventrally flattened, reniform leaves with a chordate base and oriented parallel to the stem axis.

Taxonomic comments: Pohl (1827) mentioned in the protologue "*Habitat in locis petrosis aridis in adscensu orientali Serra de Sincora, capitania Bahiensis. Lecta mensi Novembri a Celeb. Dni. Eqn. de Martius*". Johann Baptist von Spix an and Carl Friedrich *Martius* traveled through Brazil from 1817 to 1820 (see Spix & Martius 1817-1820) collecting specimens of the fauna and flora, and according to the diary of this expedition, Martius passed through the place (Sincorá mountain range) indicated in the original description of *M. reniformis* in 1818.

Based on the indicated location and date, Müller Argoviensis (1866), Pax (1919) and Rogers & Appan (1973) recognized the specimen *Martius n. 1935* as the collection type, which corresponds to the date of the trip. However, they did not specify the herbarium where it was deposited. Specimens of this collection were found in G, K, L, M and MO. The herbarium M was chosen as depositary of the lectotype because most of the collections made by Martius in Brazil are found in this institution. However, four specimens of *Martius n. 1935* were located in M. In this sense, we selected M0233293 as the lectotype because it is in conformity with the protologue by presenting flowers and because it is in good condition.

Specimens examined: BRAZIL. Bahia: Andaraí, road to Mucugê, 02 Mar 2008, *E. Melo 5492* (HUEFS); Andaraí, right bank road towards Mucugê/Andaraí, 14 Sep 2018, *J.E.Q. Faria & T. N. Vasconcelos 5918* (HEPH); Barra da Estiva, Serra do Sincorá Chapada Diamantina 23 Mar 1980, *R.M. Harley 20806* (CEPEC); Barra da Estiva, Serra do Sincorá Chapada Diamantina, 07 Mar 1996, *F.R. Salimena-Pires et al., PCD2142* (ALCB); Cascavel, Western edge of the PNCD, 24 Mar 2005, *R. Funch 753* (HUEFS); Ibicoara, Gerais do Licuri, Chapada Diamantina, 25 Jun 2012, *H.A. Ogasawara & G.B. Siqueira 230* (ALCB); Ibicoara, Pau Ferrada Batava/Baixão, 12 Jan 2005, *R. Funch, 466 (*HUEFS); Ibicoara, Machombongo, Chapada Diamantina area around the Toca, 20 Sep 2012, *K.M. Pimenta, 479* (HUEFS); Ibicoara, way to Brejão Campo Redondo, 23 Apr 2013, *M.L.L Martins et al., 1963 (*HURB); Ibicoara, surroundings of Licuri waterfall, 28 Jan 2018, *C.S. Santana, 8* (HUEFS); Ibicoara, 06

Mar 2005, *P.D. Carvalho, 79* (HUEFS); Iramaia, road from Iramaia to Ibicoara, 08 Oct 2014, *M.L.L Martins 2152* (CEPEC); Mucugê, Right side of the Piabas River bridge, 04 Apr 1996, *W.L. Werneck,* 815 (CEN); Mucugê, Km 4 of the Mucugê - Andaraí highway (Serra do Sincorá), 04 Apr 1978, *A. C. Allem. 1784* (CEN); Mucugê, Km 14 of the Mucugê - Andaraí highway (Serra do Sincorá), 04 Apr 1978, *A. C. Allem. 1790* (CEN); Mucugê, 28 km south of Andaraí towards Mucugê, 14 Nov 1984, *A. C. Allem. 2969* (CEN); Mucugê, about BA-245, 5.2 km to Andaraí from Mucugê, 25 Oct 2021, *K. Suarez. 10, 1* (PEUFR); Mucugê, Exactly 26 km ahead of the bridge over the Paraguaçu River (Andaraì), along the road, 06 Feb 1995, *A. C. Allem. 4515* (CEN); Mucugê, Chapada Diamantina, 15 Feb 2003, *Barbosa,et al. 04* (ALCB); Mucugê, 17 Feb 2016, , *E.S. Chaves 97* (HUEFS); Mucugê, Chapada Diamantina, 11 Oct 1998, *S. B. Silva 103* (ALCB); Mucugê, Chapada Diamantina, Boiadeiro stream, 29 Apr 2011, *F. Hurbath, 128* (ALCB); Mucugê, Chapada Diamantina, Semper Viva project area, 27 Sep 2002, *M. J. Andrade, 145* (HUEFS).

15. Manihot zehntneri Ule, Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie 114: 10. 1914. — TYPE**:** Brazil, Bahia, Riacho de Santa Anna, 21 November 1912, *Zehntner 598.* Lectotype **designated here**: R (R000006811!); isolectotypes: F (n.v), IAN (6225 Image!), M [M0233303 Image!). Fig 12 J-P.

Shrub 1–3(4) m tall, erect. **Roots** tuberous and elongate. **Stem** glabrous, smooth, cylindrical, with swollen knots, latex white. **Stipules** foliaceous, persistent, triangular, margin laciniate. **Petioles** cylindrical, 5–15 cm long, greenish, peltate insertion to the lamina. **Leaves** simple 3–5–7-lobed, glabrous, green, lobes oblong, median lobe 10-18 × 3-7 cm, margin entire, apex acute, venation camptodromous, leaves close to inflorescences simple (not lobed). **Inflorescence** terminal, paniculate, 6–9 cm long, bracts and bracteoles setaceous and filiform. **Staminate buds** ovoid, 0.2–0.5 cm; pedicel 0.1 mm long. **Staminate flowers** gamotepalous, fused to halfway, light green with purple base. **Pistillate buds** pyramidal, 0.5–1 cm long; pedicel 0.5-0.8 cm long. **Pistillate flowers** dialipetalous, creamy green, glabrous. **Capsules**

orbicular, 1.5 × 2 cm in diameter, smooth, green, apex rounded. **Seeds** ovoid, smooth, **Caruncle** triangular.

Phenology: Flowering and fruiting from September to December.

Distribution and habitat: Bahia, in Caatinga, found in anthropic areas of Riacho de Santana and Mucugê (Fig. 11).

Conservation status: According to IUCN criteria, this species is considered Critically Endangered (CR B1a), with an extent of occurrence less than 100 km^2 . Known only from 2 localities.

Notes: *Manihot zehntneri* resembles *M. esculenta* in the shrubby habit and stems with swollen knots. For this reason, Martins et al. (2013) proposes *M. zehntneri* as a probable synonym of *M. esculenta*. However, *M. zehntneri* differs from *M. esculenta* by having a shrubby to arboreal habit, stipules with laciniate margins, oblong leaf lobes and more than 10 cm long (vs. shrubby habit, stipules with entire margins and oval to elliptic leaf lobes less than 10 cm long in *M. esculenta*). *Manihot zehntneri* was described as a weed capable of invading newly created urban spaces, and it is frequently found on limestone-derived and well-drained soils (Nassar et al. 2008)

Taxonomic comments: The collection "*Wildwachsend bei Riacho de Sant Anna, 21 November 1912 (L. Zehntner n. 598)"* was mentioned in the protologue of *M. zehntneri* without giving any information about the depositary herbaria. Rogers & Appan (1973) mentioned the same collection stored at F and NY as the type of *M. zehntneri*, but they did not clearly indicate in which herbarium the lectotype was deposited. We chose the specimen deposited in R (R000006811) because it has flowers and fruits, it is in conformity with the protologue, and it is in good condition.

Specimens examined: BRAZIL. Bahia: Riacho de Santana, 12 Nov 2013, *M.L.L Martins 2114* (CEPEC); Riacho de Santa Anna, 21 Nov 1912, *Zehntner 598* (R); Mucugê, In

front of the gas station, next to the Byzantine cemetery, 26 Sep 2018. *M.L.L Martins et al. 2231* (HURB).

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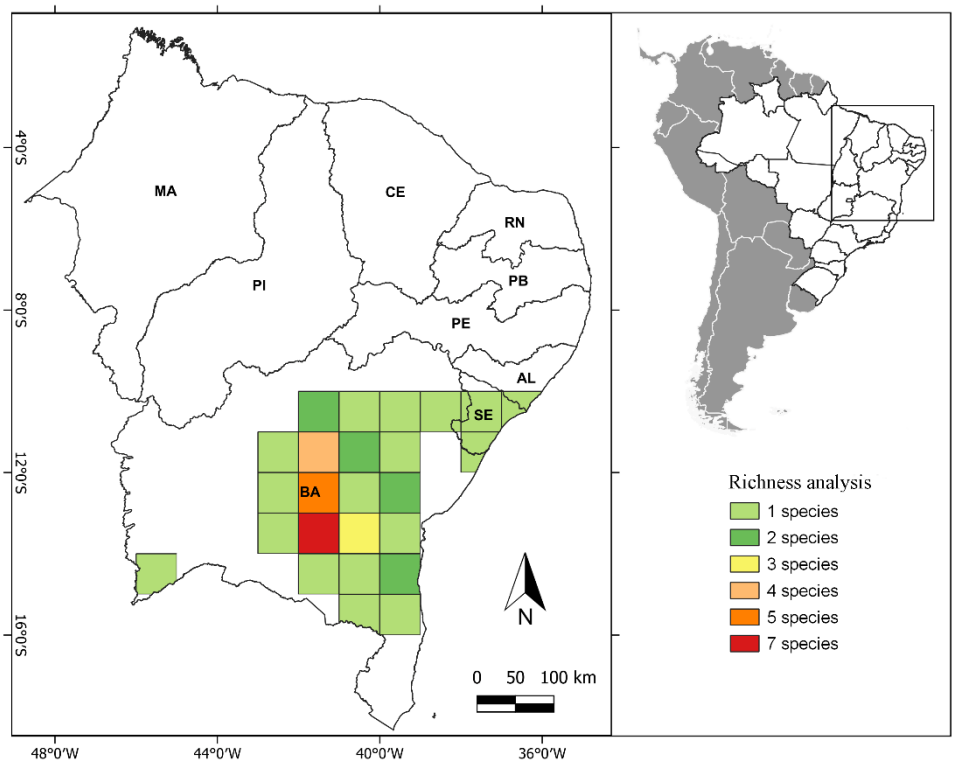


Figure 1. Map showing the richness of *Manihot* species endemic to Northeast Brazil.

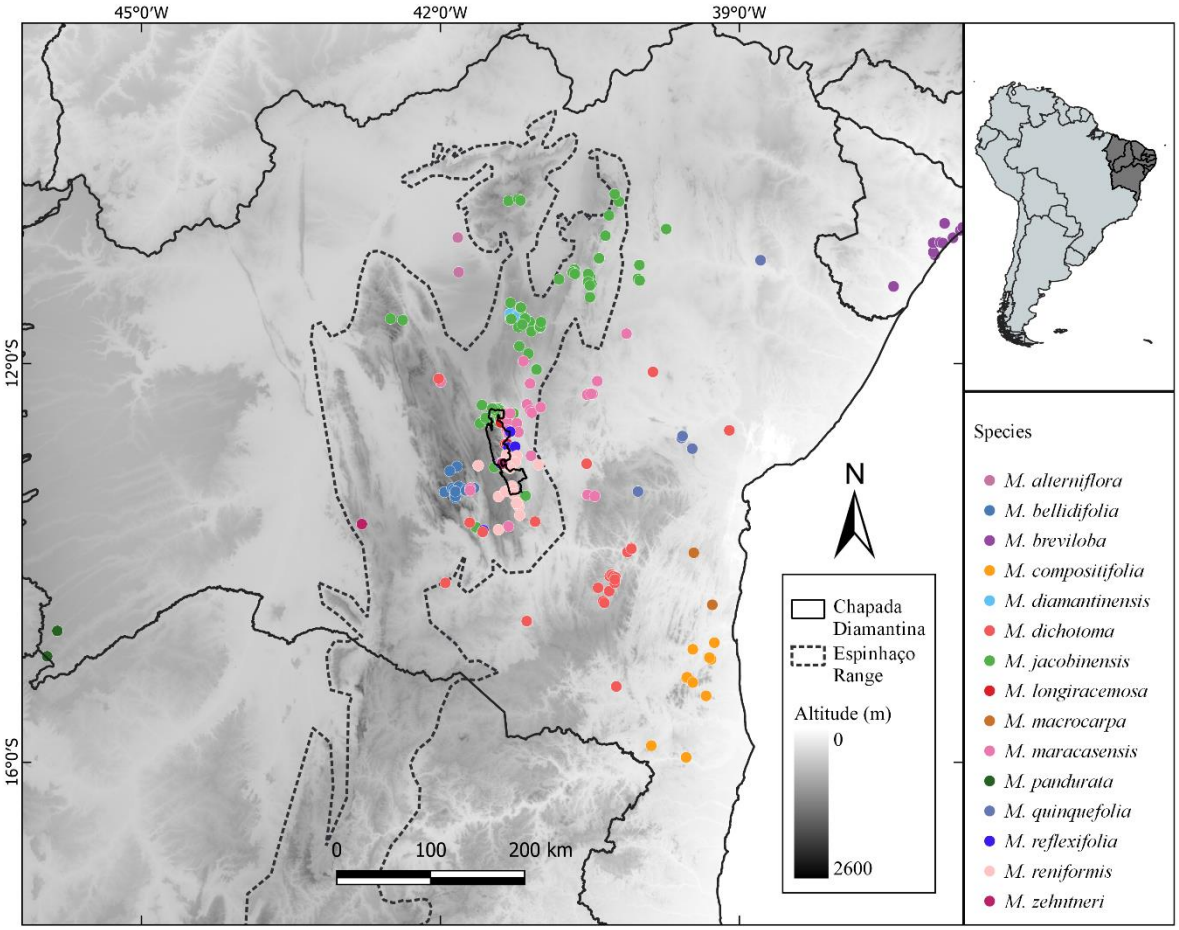


Figure 2. Map showing the geographic distribution of *Manihot* species endemic to Northeast Brazil.

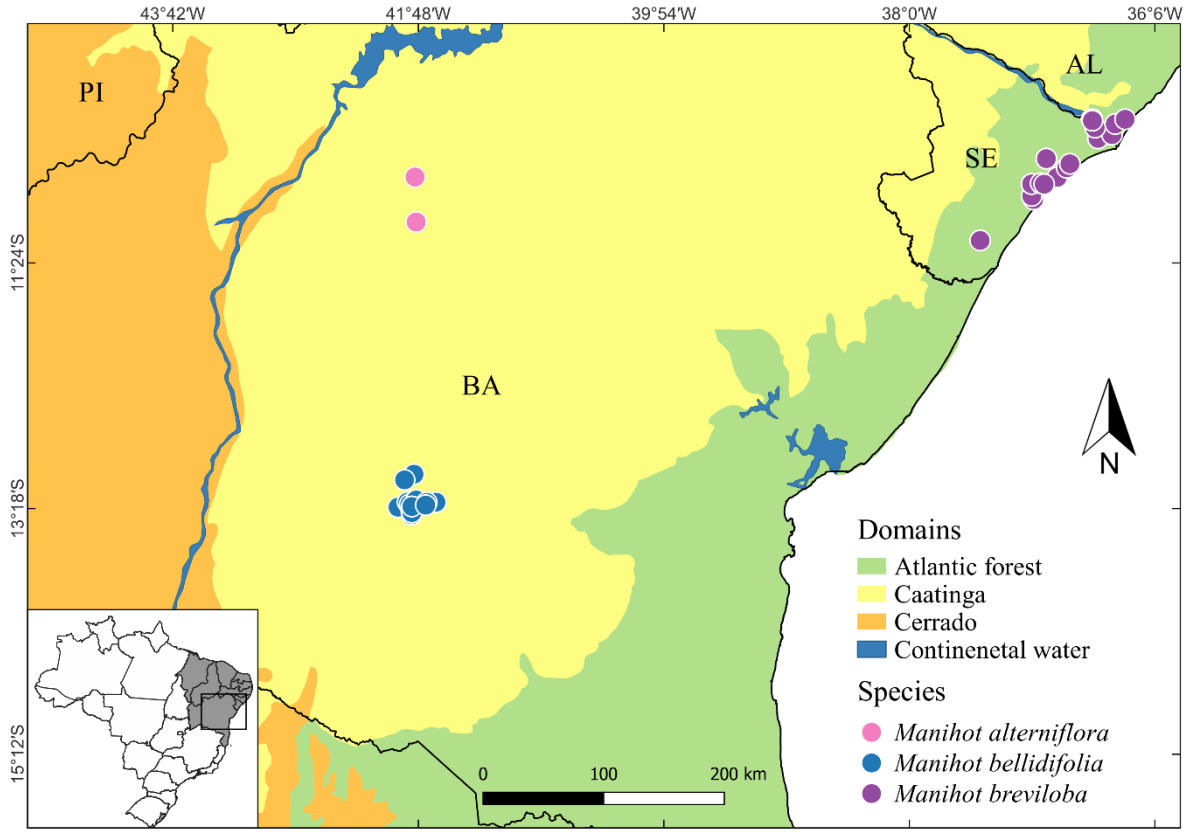


Figure 3. Distribution map of *Manihot alterniflora* P. Carvalho & Martins, *M. bellidifolia* P. Carvalho & Martins and *M. breviloba* P. Carvalho & Martins, species endemic to Northeast Brazil.

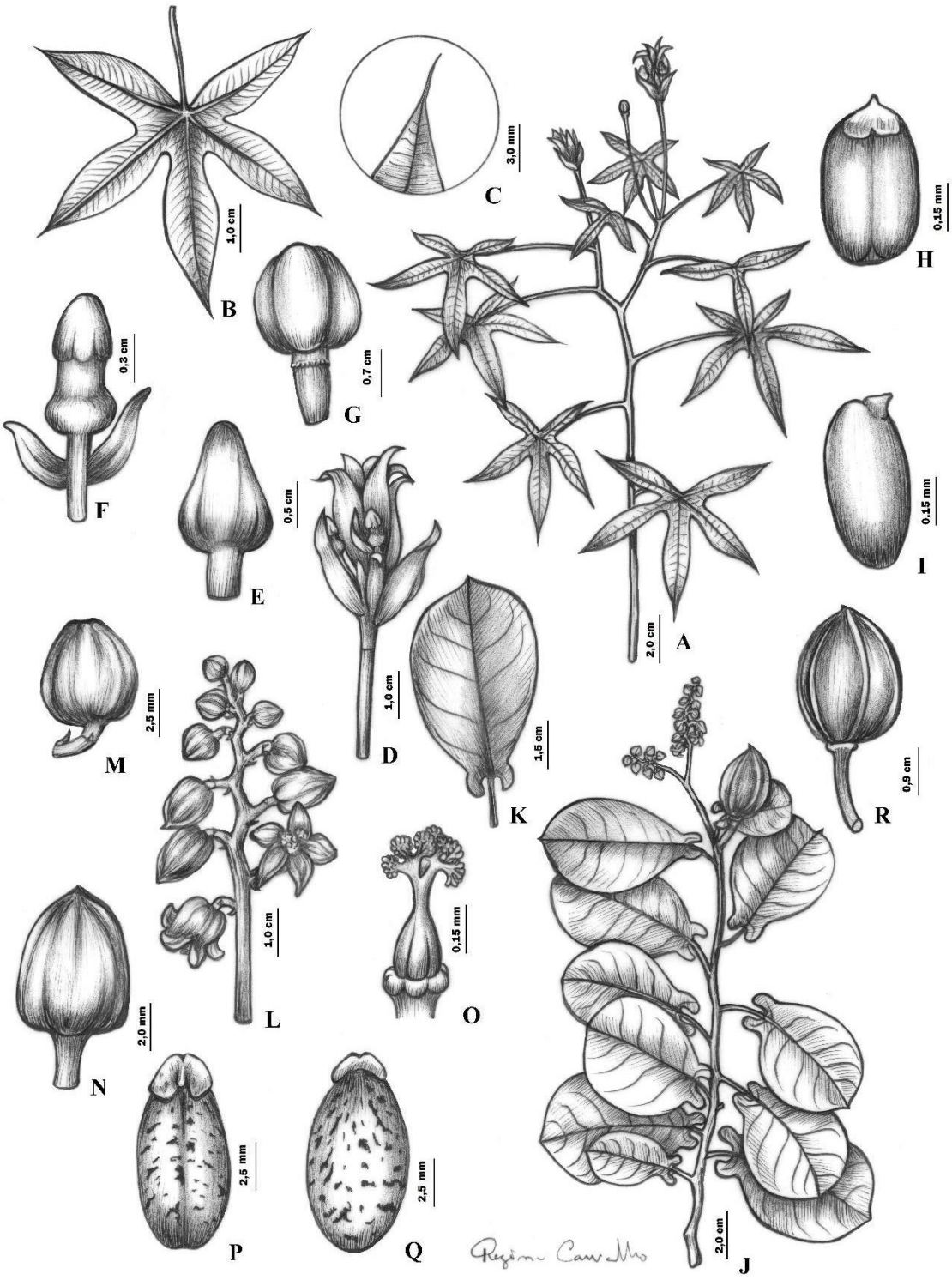


Figure 4. *Manihot bellidifolia* P. Carvalho & M. Martins, A. Fertile branch, B. Leaf, C. Detail of the apex, D. Inflorescence, E. Pistillate floral bud, F. Staminate floral bud, G. capsule, H-I Seed (Ganev, W. 1409 and Carneiro-Torres, D. 1334). *Manihot breviloba* P. Carvalho & M. Martins. J. Fertile branch, K. Leaf, L. Inflorescence, M. Staminate flower bud, N. Pistillate flower bud, O. Detail of the pistillate flower, P–Q. Seed, R. Capsule (Martins *et al.* 1800, Holotype).

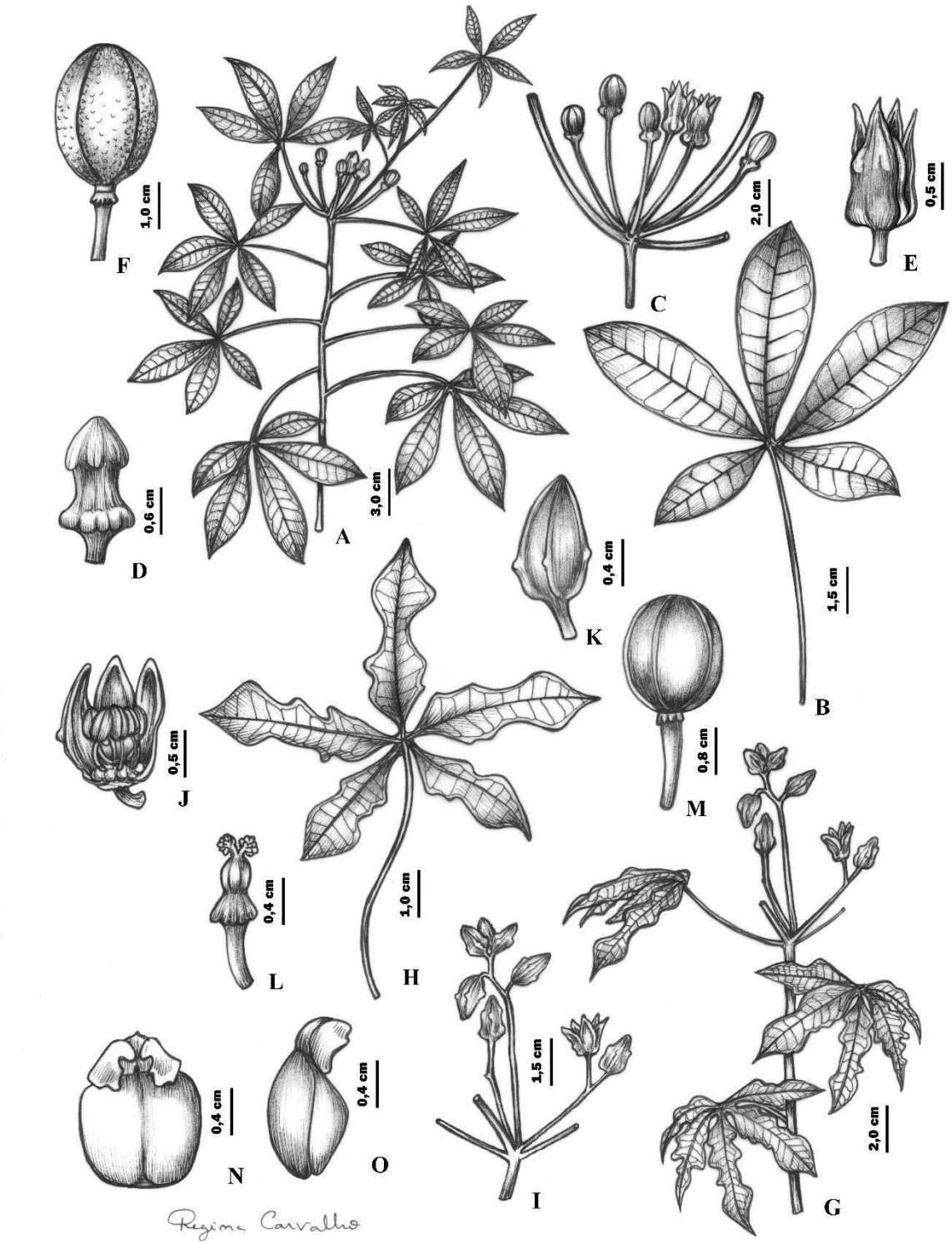


Figure 5. *Manihot compositifolia* Allem, A. Fertile branch, B. Leaf, C. Inflorescence (*Kulkamp 608*), D. Staminate flower bud, E. Detail of pistillate flower, F. Capsule (Martins *et al. 8472*). *Manihot diamantinensis* Allem. G. Fertile branch, H. Leaf, I. Inflorescence, J. Detail of staminate flower, K. Staminate floral bud, L. Detail of pistillate flower, M. Capsule, N–O. Seed (*Suarez et al. 7*).

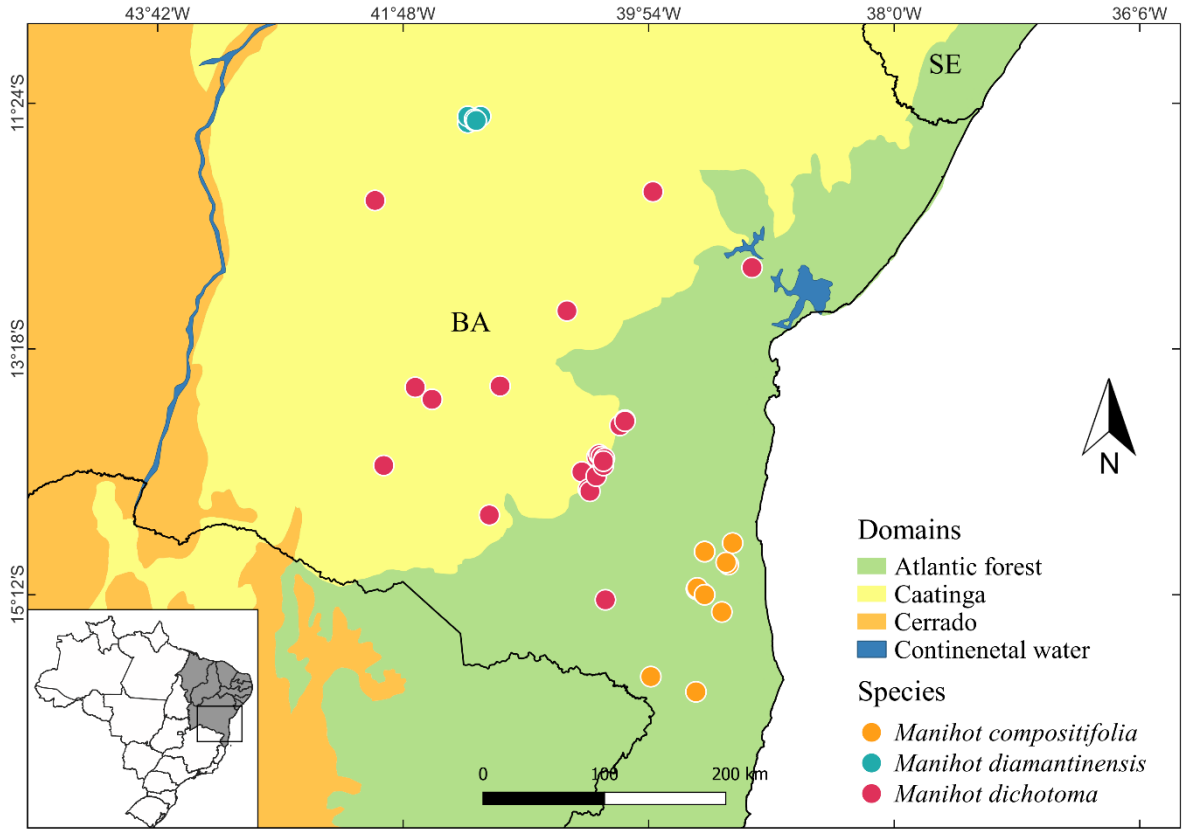


Figure 6. Distribution map of *Manihot compositifolia* Allem, *Manihot diamantinensis* Allem and *Manihot dichotoma* Ule, species endemic to Northeast Brazil.

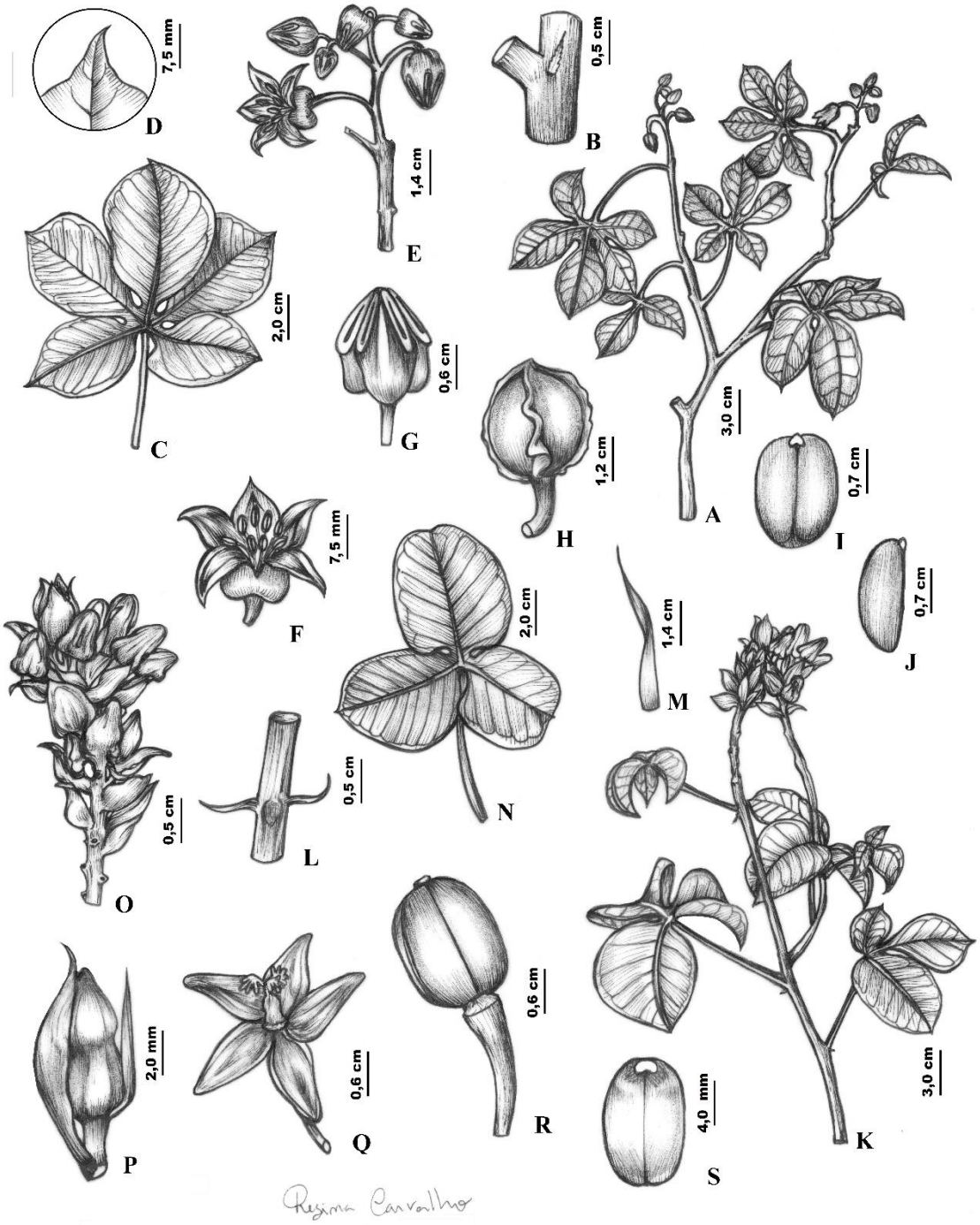


Figure 7. *Manihot dichotoma* Ule, A. Fertile branch, B. Stipules, C. Leaf, D. Detail of the apex, E. Inflorescence, F. Staminate flower, G. Staminate flower bud, H. capsule, I-J. Seed (*Suarez* et al. *15*). *Manihot jacobinensis* Mull.Arg., K. Fertile branch, L-M. Stipule, N. Leaf, O. Inflorescence, P. Staminate flower bud, Q. Pistillate flower, R. Capsule, S. Seed (*Suarez* et al. *2, 3*).

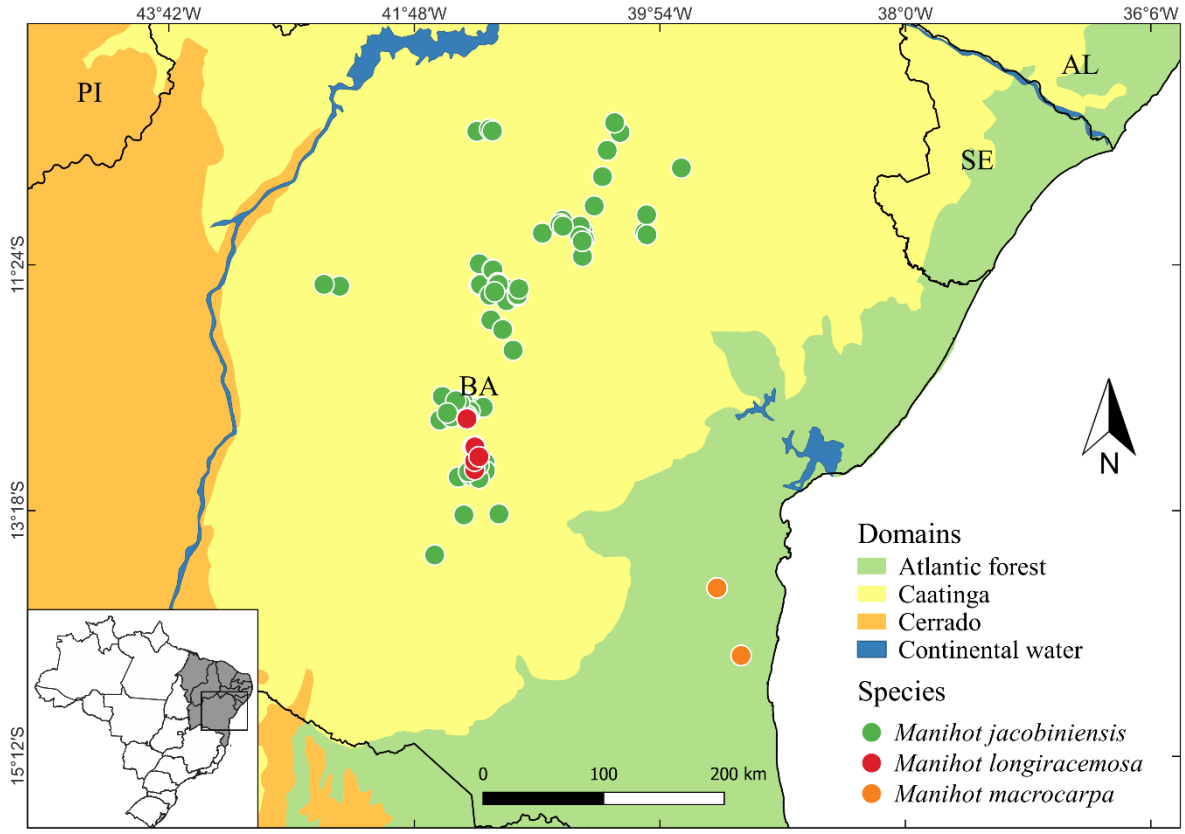


Figure 8. Distribution map of *Manihot jacobinensis* Müll. Arg., *M. longiracemosa* P.Carvalho & M.Martins and *M. macrocarpa* P.Carvalho & M.Martins, species endemic to Northeast Brazil.

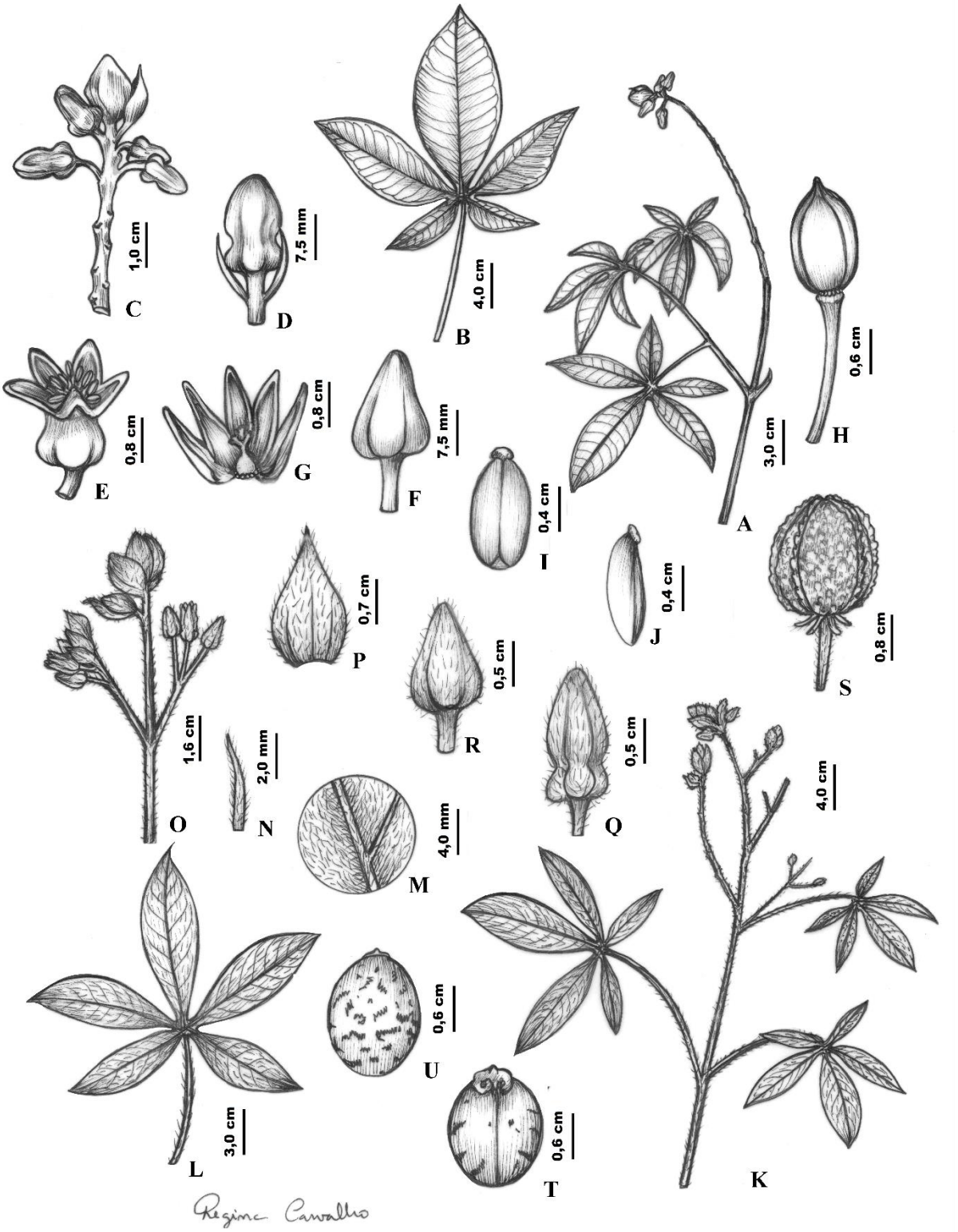


Figure 9. *Manihot longiracemosa* P. Carvalho & M. Martins, A. Fertile branch, B. Leaf, C. Inflorescence, D. Staminate flower bud, E. Staminate flower, F. Pistillate flower bud, G. Pistillate flower, H. Capsule, I-J. Seed (*Suarez* et al. *17*). *Manihot maracasensis* Ule, K. Fertile branch, L. Leaf, M. Leaf detail, N. Stipule. O. Inflorescence, P. Bract, Q-R. Staminate flower bud, S. Capsule, T-U. Seed (C. Allem *141148*).

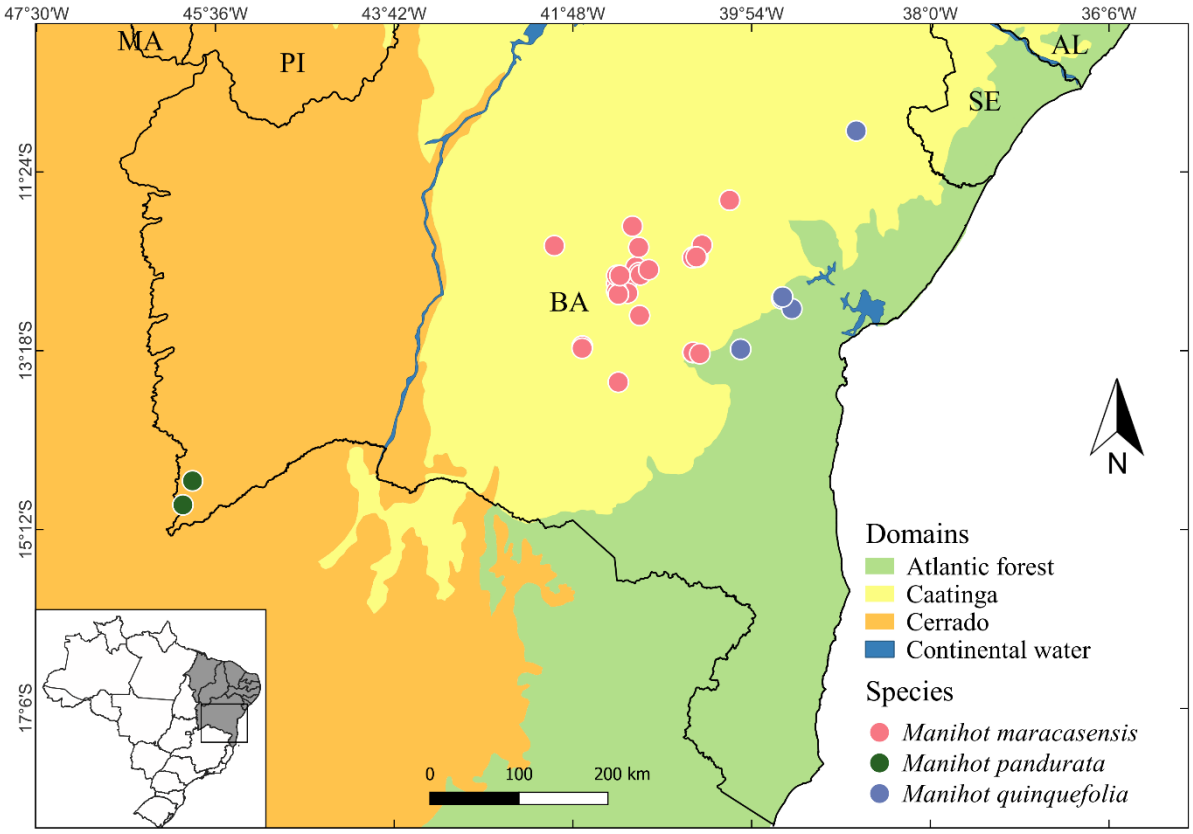


Figure 10. Distribution map of *Manihot maracasensis* Ule, *Manihot pandurata* M. Martins & M. Mend. and *Manihot quinquefolia* Pohl, species endemic to Northeast Brazil.

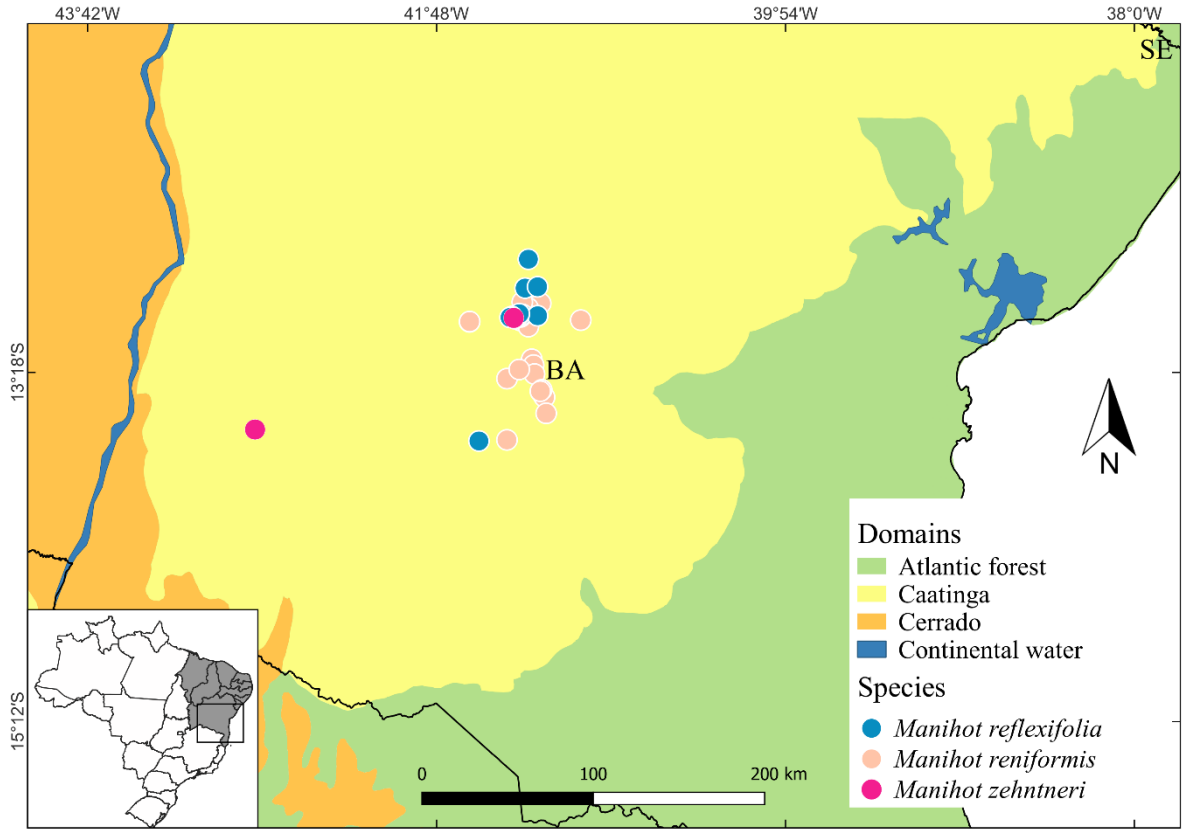


Figure 11. Distribution map of *Manihot reflexifolia* P. Carvalho & M.Martins, *Manihot reniformis* Pohl and *Manihot zehntneri* Ule.

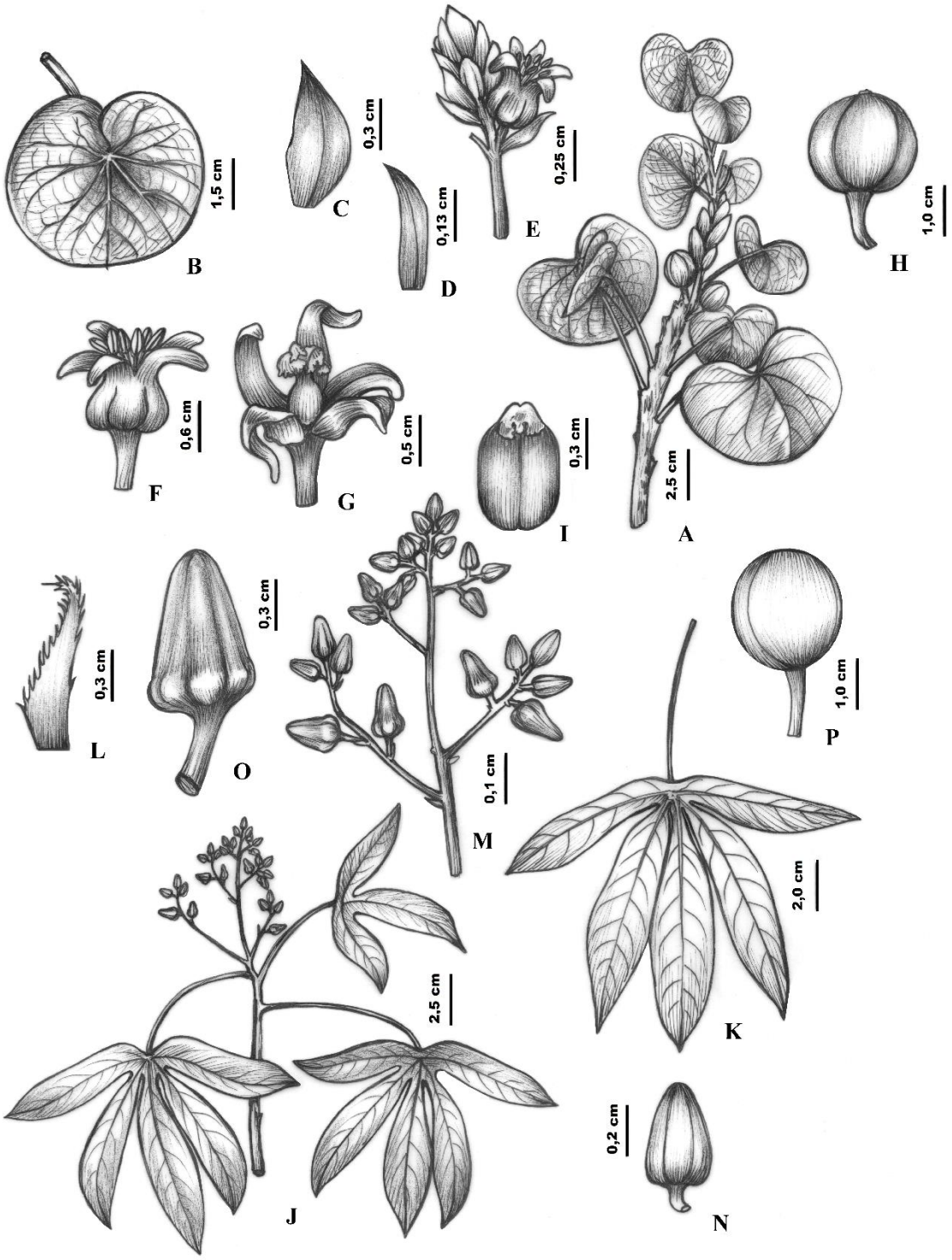


Figure 12. *Manihot reniformis* Pohl, A. Fertile branch, B. Leaf, C. Bract, D. Bracteole, E. Inflorescence, F. Staminate flower, G. Pistillate flower, H. Capsule, I. Seed (*Suarez K. 10, 1*). *Manihot zehntneri* Ule, J. Fertile branch, K. Leaf, L. Stipule, M. Inflorescence, N. Staminate flower bud, O. Pistillate flower bud, P. Capsule (*Martins M.L.L. 2114, Zehntner 598*).

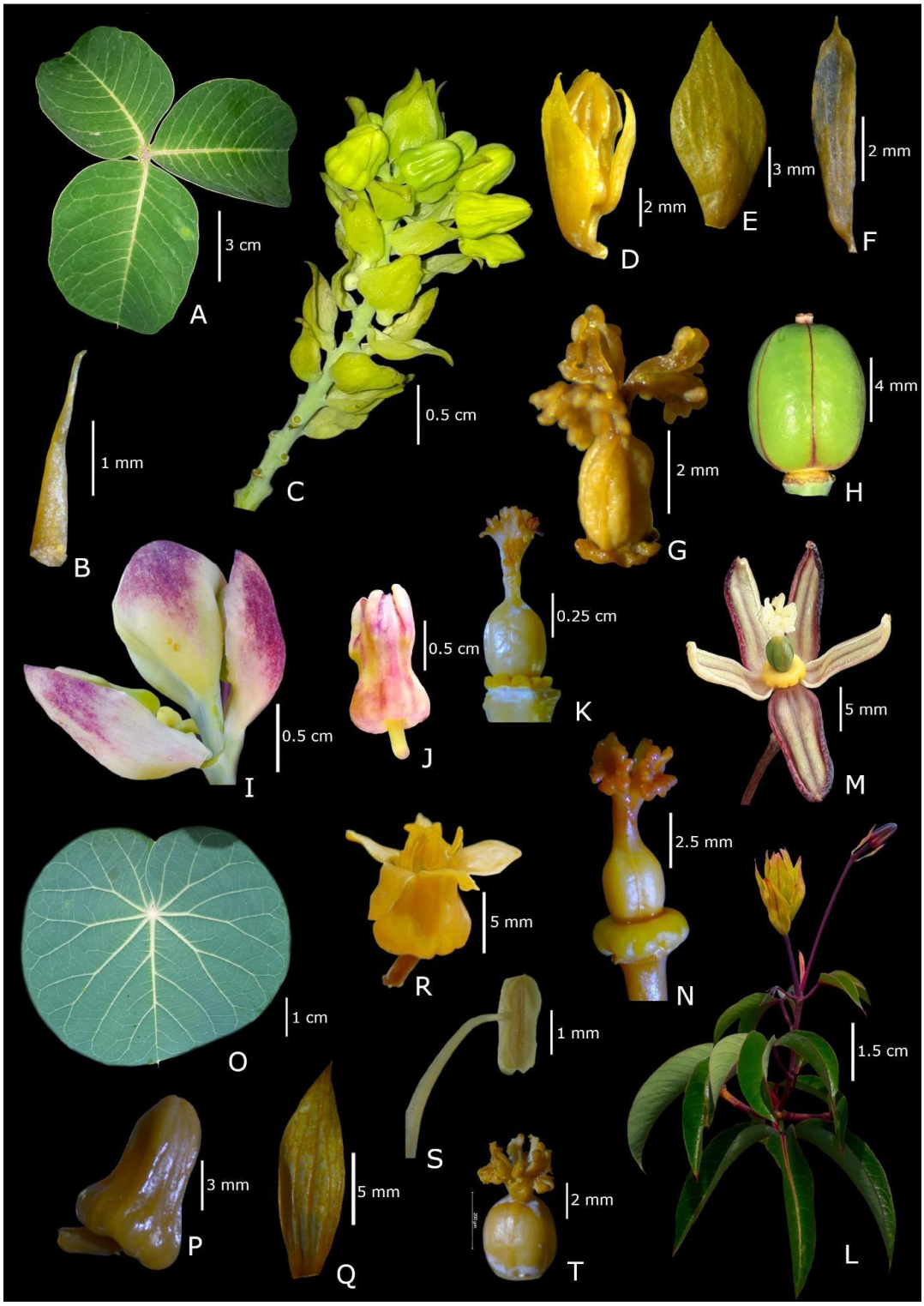
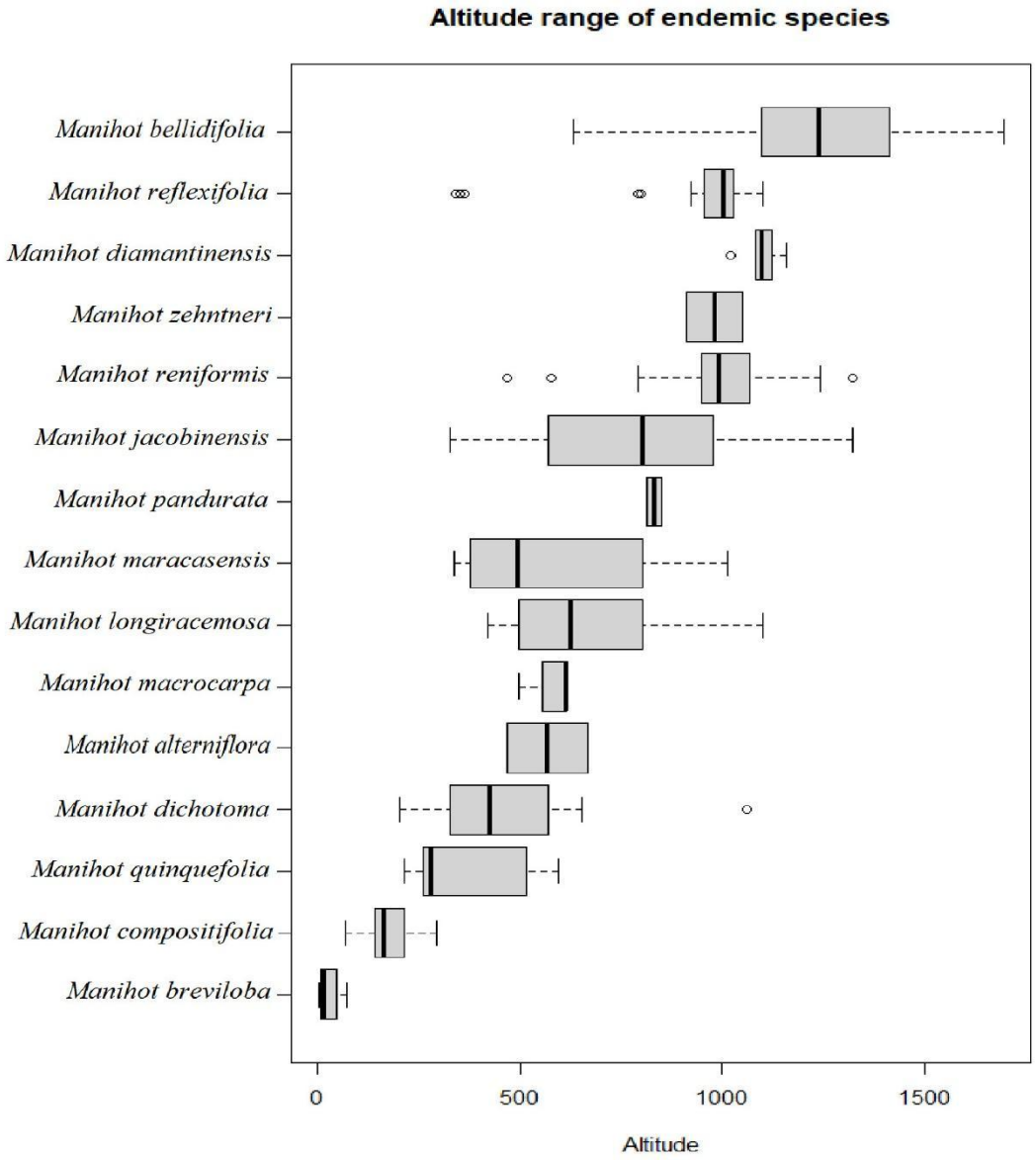


Figure 13. *Manihot jacobinensis* Mull.Arg., A. Leaf, B. Stipule, C. Inflorescence, D Staminate flower bud with bract and bracteole, E. Detail of bract, F. Detail of bracteole, G. Detail of pistillate flower, H. Capsule. *Manihot longiracemosa* P. Carvalho & M. Martins, I. Inflorescence, J. Staminate flower bud, K. Detail of pistillate flower. *Manihot reflexifolia* P. Carvalho & M.Martins, L. Fertile branch, M. Pistillate flower, N. Detail of pistillate flower. *Manihot reniformis* Pohl, O. Leaf, P. Staminate flower bud, Q. Bract, R. Staminate flower, S. Detail of anther, T. detail of pistillate flower.



Supplementary material (SI). Altitude range of *Manihot* species endemic to Northeast Brazil.

2. CAPITULO II

POTENTIAL EFFECTS OF CLIMATE CHANGE ON THE GEOGRAPHIC DISTRIBUTION OF ENDEMIC SPECIES OF *MANIHOT* AT THE NORTHEAST OF BRAZIL

To be submitted to: Perspectives in Ecology and Conservation

Title: POTENTIAL EFFECTS OF CLIMATE CHANGE ON THE GEOGRAPHIC DISTRIBUTION OF ENDEMIC SPECIES OF *MANIHOT* AT THE NORTHEAST OF BRAZIL

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POTENTIAL EFFECTS OF CLIMATE CHANGE ON THE GEOGRAPHIC DISTRIBUTION OF ENDEMIC SPECIES OF *MANIHOT* AT THE NORTHEAST OF BRAZIL

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Abstract

The aims of this paper were to evaluate the potential effects of climate change on the geographic distribution of endemic species of *Manihot* in the Northeast of Brazil and confirm the presence of the suitability area in protected areas in the future. As a result, we present the ecological niche modeling results of 11 endemic species, of which we predict the current and future geographic distribution for the year 2100 using three different general circulation models (CNRM, MIROC, and MRI) and two climate change scenarios (SSP 245 and SSP 585). We found that 45% and 54% of species could have a partial reduction in their total range potential by the year 2100 in an optimistic and pessimistic scenario, respectively. While some other

species will increase their distribution. The suitable area for most species will be preserved by some protected area. However, species that currently have restricted distribution and whose potential range will be reduced in both the optimistic and pessimistic scenarios need to be prioritized for conservation. This study provides valuable information about the future distribution of endemic species of *Manihot* and shows that climate change can have a potential positive or negative effect on the geographic distribution of species. They also help to understand the distribution of species and can provide subsidies for actions to develop public policies for the conservation of taxa and phytogeographic domains, especially those that are seriously threatened.

Key words: Climate change, Euphorbiaceae, Ecological Niche Models, Future scenarios, Maxent

Highlights

- Climate change can have a potential positive or negative effect on species distribution.
- 36% of the endemic species of the genus *Manihot* in the Northeast of Brazil will completely lose their potential distribution areas by 2100.
- Although most species suffer reductions in their suitability area, some species will gain new climatically suitable areas in the future.

Introduction

Climate change causes physicochemical changes in the atmosphere, resulting in cycles of warming and cooling (De Oliveira et al., 2017; Simões et al., 2019). These changes are natural but, intensified by human actions after the Industrial Revolution in the late 18th century have increased concentrations of greenhouse gasses in the atmosphere, causing global climate change and disruptions in natural climate cycles (Ghini et al., 2008; Karki and Gc 2020). These changes have impacts on biodiversity, changing the geographic distribution and increasing the extinction rate of many species in the world (Jump and Penuelas, 2005; Ravenscroft et al., 2015; Garza et al., 2020), especially in areas with high species richness or endemism (Simões et al., 2019).

The distribution of the plants can be modified by the increase in temperatures during the warmer months and the decrease in rainfall. It is predicted that the species will move towards higher elevations and latitudes to find places with the most suitable climatic conditions to face these changes (Walther et al., 2002; Walther, 2003; Parmesan and Yohe, 2003). Some species may persist within their original distribution range due to acclimatization and phenotypic plasticity or they can migrate to new areas (Silva et al., 2019: Sosa et al., 2019). For plants that are endemic, that survive in fragmented areas or have low dispersal distances, it is difficult to adapt to these changes because they are more quickly affected and more susceptible, increasing the chances of extinction (Isik, 2011; Zuber and Villamil, 2016; Rocha et al., 2020; Garza et al., 2020).

One of the useful tools to determine the role of environmental factors in distribution patterns is Ecological Niche Models (ENM). This tool use occurrence records and environmental variables (Pulliam, 2000; Phillips et al., 2006; Farias et al., 2017; De Lima et al., 2020; Garza et al., 2020) to make mathematical approximations on specie's climatic niche and can contribute to map areas with environmental conditions potentially suitable for species

occurrence (Guisan and Zimmermann, 2000; Loiselle et al., 2003; Araújo and Guisan, 2006; Siqueira and Durigan, 2007).

The ENM has been used by several authors to evaluate the effectiveness of protected areas in the conservation of species in the present and to calculate the loss of areas of occupation of the species in the future (Coetzee et al., 2009; Araújo et al., 2011; Qin et al., 2017; D'Arrigo et al., 2020; Ferreira et al., 2022). Furthermore, ENM provide information that help in reserve design, ecological restoration (Taylor et al., 2017; Jinga and Ashley, 2019), invasive species management (Barbet-Massin et al., 2018), species reintroductions (Sanchez et al., 2010) and predicting the potential impacts of global environmental change on biogeographical patterns.

The genus *Manihot* Mill., includes around 150 species that are distributed exclusively in the Neotropics, with the Amazon as its probable center of origin (Simon et al., 2022). *Manihot* and can be characterized by having a shrub, subshrub, arboreal or, lianescent habit, presence of latex, simple, alternate leaves, sometimes peltate, entire to lobed, unisexual flowers, with nectariferous disk, capsular fruits and carunculated seeds (Müller, 1866; Rogers and Appan, 1973). *Manihot* is an emblematic group due to the cultivable species *Manihot esculenta* Crantz, which is one of the main sources of starch in the world (Hershey, 2008). The cultivated taxa are considered resilient to the effects of aggravation of climatic changes because have physiological, morphological and anatomical traits that enable them to tolerate stress in hot and dry climates, contrary to wild species specially the endemic, that are being negatively affected with consequent reduction in population size (Duputié et al., 2007; Pushpalatha and Gangadharan, 2020). To exemplify, Garza et al. (2020) evaluated the potential effects of climate change on the distribution of *M. walkerae* Croizat in the U.S.A. and in Mexico and showed a potential reduction in the geographic distribution of the species. They also evaluated the usefulness of protected natural areas in the future conservation of the species. As a result, they found several protected areas potentially suitable for *M. walkerae* in the U.S.A., while in Mexico there are no protected areas within the suitability habitat of the species.

Understanding the potential effects of climate change in the distribution patterns of the endemic taxa of the genus can help prevent the reduction of their natural populations and the genetic erosion of the group. In this context, spatial analyzes such as the ENM prove to be essential tools for assessing the conservation status of species in different climate scenarios (Simões et al., 2019), especially for endemic taxa of *Manihot* in the Northeast of Brazil, of which 80 % are within some category of threat. The aims of this paper were to evaluate the potential effects of climate change on the geographic distribution of endemic species of the genus *Manihot* in the Northeast of Brazil and confirm the presence of the suitability area in protected areas in the future. We hypothesize that the aggravation of climate change in the Northeast could result in a variation in the area of occurrence of endemic taxa of *Manihot* in the region.

Methods

Occurrence points

We obtained 428 occurrence records of 11 species endemic to Northeast of Brazil (Table 1) through the following databases: Global Biodiversity Information Facility (GBIF: http://www.gbif.org); speciesLink (http://www.splink.org.br/) and Reflora Virtual Herbarium (http://reflora.jbrj.gov.br/). We also consulted the collections of the following herbaria: ALCB, ASE, BAH, BHCB, CEN, CEPEC, CPAP, EAC, ESA, F, FLOR, FUEL, FURB, G, HBR, HDJF, HEPH, HRCB, HTSA, HUEFS, HUESB, HUFSJ, HUNEB, HURB, HVASF, HVC, IAC, IAN, INPA, IPA, JPB, MAC, MBM, MG, MO, MOSS, NY, P, PEUFR, R, RON, SP, SPF, UB, UEC, UFP, US, VIC, VIES and HST (not indexed), including the type specimens (acronyms according to Thiers 2012). Field expeditions were carried out between 2010 and 2022 in different regions of the Northeast Brazil. In species with less than four occurrence records were excluded from the study, due to the statistical impossibility of performing ENM.

We filtered the records of each species to obtain the maximum number of occurrences that were at least 1,5 km apart using the "spThin" package (Aiello-Lammens et al., 2015).

Climate data

We obtained a set of 19 bioclimatic variables through WorldClim database 1.4 (Fick and Hijmans, 2017) with a spatial resolution of 2.5 arc minutes. We calculated a correlation matrix,using Pearson's correlation coefficients with a cut-off value of 75% to reduce problems with collinearity. Then, we evaluated each variable considering its biological relevance for interest species and selected those with Pearson's correlation below 75%. We considered six variables as predictors: BIO1 (Annual Mean Temperature), BIO2 (Mean Diurnal Range (max temp -min temp), BIO3 (Isothermality), BIO12 (Annual Precipitation), BIO13 (Precipitation of Wettest Month) and BIO14 (Precipitation of Driest Month).

Ecological niche modeling

We build Ecological Niche Models (ENM) relating the known occurrences of the species and bioclimatic variables using the MaxEnt algorithm (version 3.4.1, Phillips et al., 2017). To model the distribution of species, this algorithm uses the maximum entropy method using presence data and environmental variables (Phillips et al., 2017). The calibration area was given by the minimum convex polygon (MCP), based on 100% of the species occurrence points, surrounded by a 1.5° buffer.

We used the ENMwizardpackage (Heming et al., 2019) to define the calibration area for each species by creating a minimum convex polygon around all occurrences based on 100% of the species occurrence points, surrounded by a 1.5° buffer. This approach was used to improve MaxEnt predictive power given that the buffer represents areas potentially accessible for the species and increases variable heterogeneity, therefore, performing more realistic niche estimations (Anderson and Raza, 2010; Barve et al., 2011; Mota et al., 2022).

This procedure reduces sampling bias and improves model performance (Boria et al., 2014). We used ENMevaluate_bfunction from ENMwizard package (Heming et al., 2019). For model cross-validation, we used the "block" partitioning method that improves spatial and temporal transferability (Hijmans, 2012; Veloz, 2009) and "jackknife" for species with less than 15 records (Shcheglovitova and Anderson, 2013).

We optimized MaxEnt parameters using the ENMevalpackage (Muscarella et al., 2014)to give variable complexity to the models (0.5–5.0 with 0.5 intervals). The candidate models were adjusted using various options of Feature Classes (FC) and Regularization Multipliers (RMs). The models were built using all combinations of four feature classes : L, P, Q, H, LP, LQ, LH, PQ, PH, QH, LPQ, LPH, LQH, PQH, LPQH where "L" is linear, "P" is product, "Q" is quadratic, and "H" is hinge. To select the best model, we evaluated each candidate model according to the ecologically based pest management (EBPM), using the calib_model_b function of ENMwizard (Heming et al., 2019).

We selected three General Circulation Models: CNRM, MIROC and MRI to generate the future projections. We projected the climate models using two Shared Socioeconomic Pathways (SSPs): SSP245, considered an optimistic scenario for the emission of greenhouse gasses and SSP585, considered a pessimistic scenario. The projection area was defined as the extension limits of the Northeastern with a buffer of 1.5°.

Richness and protected areas

To evaluate species Richness patterns we used we used the models in the the function "common_spatial_metric" from package ENMwizard (Heming et al., 2019). Finally, we estimated the percentageof climatically suitable areas covered by protected areas for each species and for each scenario. To do this, we used the function "mask_thr_projs_mscn_b" from package ENMwizard (Heming et al., 2019). The shapefile of spatial distribution of protected areas was obtained through the databases UNEP-WCMC and IUCN (UNEP-WCMC and IUCN

2023). All analyses were carried out in R software version 4.2.2 (RStudio, 2022) and maps were generated in QGIS software v3.28.2 (QGIS Development Team, 2022).

Results

Of the 15 species reported as endemic to northeastern Brazil (Suarez et al., 2023 in preparation), 11 have the minimum number of records required to perform ENM (Table 1). One hundred and fifteen models were generated for each species of which 15 models had omission rates that moderately approximated their theoretical expected values, and they had acceptable and statistically significant partial ROC values—all partial ROC values>1 with P = 0.

Table 1. Number of initial occurrence records of endemic species of *Manihot* to northeastern Brazil, and number of the maximum number of occurrences that were at least 1,5 km apart using the "spThin" package.

Species	Occurrence records	Final occurrence records
Manihot alterniflora P. Carvalho & M. Martins	2	-
Manihot bellidifolia P. Carvalho & M. Martins	18	13
Manihot breviloba P. Carvalho & M. Martins	31	16
Manihot compositifolia Allem	19	10
Manihot diamantinensis Allem	9	5
Manihot dichotoma Ule	29	22
Manihot jacobinensis Mull.Arg.	174	78
Manihot longiracemosa P. Carvalho & M. Martins	10	7
Manihot macrocarpa P. Carvalho & M. Martins	4	-
Manihot maracasensis Ule	37	25
Manihot pandurata M. Martins & M. Mend.	2	-
Manihot quinquefolia Pohl	8	5
Manihot reflexifolia P. Carvalho & M. Martins	44	12
Manihot reniformis Pohl	46	26
Manihot zehntneri Ule.	2	-

Geographic projections of ecological niche models identified a suitables areas for Manihot endemicity of Northeast of Brazil, associated with the Espinhaço Range and "Chapada Diamantina " in Bahia state. The present geographic distribution consensus modelwas used to compare the percent change of geographic distribution with the future climatic models. Most species show a projected reduction or total loss in their potential distribution projected for 2100. Considering the pessimistic scenario, 36% of the species will totally lose their area and 18% will decrease (e.g. *M. longiracemosa, M. maracasensis*) (Table 2). In the optimistic scenario, 36% of the species will lose their area completely (*M. bellidifolia, M. breviloba, M. reflexifolia, M. reniformis*) and9% will decrease (e.g. *M. maracasensis*). Although most species suffer reductions in their suitability area, some species (*M. compositifolia, M. dichotoma, M. diamantinensis, M. jacobinensis, M. longiracemosa and M. quinquefoli*a) will gain new climatically suitable areas, especially in the south and southeast of Bahia in the future, 55% for the optimistic scenario and 46% for the pessimistic (Table 2).

Table 2. Area (km²) and percent of change of geographic distribution for *Manihot* between the current model and the future projected climate change model for the year 2100 (threshold ten percentile).

Species	Current (km²)	Climatic scenario, SSP_45 (km²)	% Change	Climatic scenario, SSP_85 (km²)	% Change
Manihot bellidifolia	83532.45	0	100	0	100
Manihot breviloba	662398.59	0	100	0	100
Manihot compositifolia	61313.11	104111.24	69,8	339587.21	453,9
Manihot diamantinensis	85640.46	1449613.80	345,0	1456452.69	383,1
Manihot dichotoma	168227.59	748551.54	1592,7	812628.32	1600,7
Manihot jacobinensis	981319.40	1423266.20	45,0	1270871.17	29,5
Manihot longiracemosa	814507.08	877991.24	7,8	798870.25	-1,9
Manihot maracasensis	1129233.45	862367.74	-23,6	682232.45	-39,6
Manihot quinquefolia	60209.77	311991.28	418,2	293455.91	387,4

Manihot relexifolia	154999.71	0	100	0	100
Manihot reniformis	115473.46	0	100	0	100

Comparing the different species studied, *M. maracasensis* currently has the largest suitability area, however this species will lose between 76% and 60% of its area by 2100 (Fig. 2), considering optimistic and pessimistic scenarios respectively. Currently, *M. jacobinensisis* the second species with the largest area of climatic suitability, while *M. diamantinensis* has one of the smallest areas at present. *Manihot diamantinensis* and *M. jacobinensis* are both predicted to expand their distribution by 2100 in both climatic scenarios (Figs. 1 M-O and 2 A-C). *Manihot bellidifolia, M. breviloba, M. reflexifolia and M. reniformis* will lose their entire suitability area in both optimistic and pessimistic climatic scenarios (Figs. 1 and 2).

The area with the highest predicted richness of endemic species of *Manihot* to northeastern Brazil is located in a south portion of Bahia state and a second area with high prediction of richness is located in the Chapada Diamantina, also in Bahia (Fig. 3A). Our study detected that endemic species richness for northeast will increase in the central and south portion of Bahia, in both the optimistic and pessimistic scenarios (Fig. 3B-C).

Finally, there are protected areas in Northeast that have high potential for the geographic distribution of most of the endemic *Manihot* species in the future and are expected to be unaffected by climate change (Table 3) like the environmental protection area Baía de Camamu, Lagoa Encantada and Marimbus/Iraquara, Serra Do Conduru and Morro do Chapéu state park and national park Chapada Diamantina. For some species like *M. bellidifolia, M. breviloba, M. maracasensis, M. reflexifolia* and *M. reniformis,* protected areas with high potential for their geographic distribution will decrease or disappear completely.

Table 3. Area of climate suitability for endemic species that is currently within a protected area at present and in the future, considering an optimistic and a pessimistic scenario.

Species	Current (km²)	Climatic scenario, SSP_45 (km²)	Climatic scenario, SSP_85 (km²)
Manihot bellidifolia	4682.69	0	0
Manihot breviloba	29830.45	0	0
Manihot compositifolia	1169.77	2287.46	8088.42
Manihot diamantinensis	4531.60	73235.27	73152.04
Manihot dichotoma	1048.96	24973.80	29086.38
Manihot jacobinensis	58070.08	71621.47	69164.92
Manihot longiracemosa	45616.73	48183.09	45648.40
Manihot maracasensis	67853.30	46165.95	37399.93
Manihot quinquefolia	6167.40	11552.60	11084.60
Manihot relexifolia	7434.47	0	0
Manihot reniformis	4470.91	0	0

Discussion

The models show that the potential geographic distribution for species of *Manihot* endemic to northeastern Brazil could be slightly reduced by 2100 because of climate change. About 45% (optimistic scenario) and 54% (pessimistic scenario) of the studied species will lose part or the total of their climatically suitable areas in response to climate change (e.g. *Manihot bellidifolia, Manihot breviloba, Manihot reflexifolia, Manihot reniformis)*. These species currently have a restricted distribution, and are surrounded by fragmented areas, which probably affects their future distribution. These restricted areas are associated with “Campos Rupestres” in the Bahia state *(Manihot bellidifolia, Manihot reflexifolia, Manihot reniformis*) and “Restinga” areas in the states of Sergipe and Alagoas *(Manihot breviloba)* (Suarez et al., 2023 in publication).

The ecosystem “Campos Rupestres” are a megadiverse, provide essential ecosystem services, harbor more than 5,000 species of vascular plants and have a high level of endemism

(Fernandes et al., 2018). Is mostly associated with the Espinhaco Range, at the ecotone of the Cerrado, Atlantic Forest, and Caatinga (Fernandes et al., 2020). This ecosystem is characterized by a mosaic of open vegetation types and occurs in mountains with ancient geological formations, where there are some "islands" that are isolated by a continuous matrix of lowland vegetation (De Bano et al., 1995; Mattos et al., 2019; Vasconcelos et al., 2020). This isolation facilitated allopatric speciation, which explains its high rates of endemism (40%). At the same time, the species have been exposed to environmental filters that have favored the establishment of slow-growing species, which have specialized strategies for the acquisition and conservation of resources, low fecundity and limited dispersal (Messias et al., 2012;Negreiros et al., 2014; Fernandes 2016; Oliveira et al., 2016; Dayrell et al., 2018; Le Stradic et al., 2018; Fernandes et al., 2020). However, despite hosting approximately 17% of the plant diversity of Brazil, its high rate of endemism and to harbor species with specific environmental requirements, Campos Rupestres are greatly underestimated and are being threatened by exploitation processes (Fernandes et al., 2018; Fernandes et al., 2020)

In the "Restinga" there are also plants that face extreme environmental conditions (Scarano, 2002; Marques et al., 2015) like *M. breviloba* and that are also seriously threatened since they are considered extremely vulnerable to climate change and highly exposed to deforestation and biological invasion (Zamith and Scarano, 2006; Inague et al., 2021). These threats could intensify the reduction or disappearance of these species in future climatic scenarios.

On the other hand, some species will have significant potential distribution increases in both climatic scenarios. This may be related to the great environmental tolerance that some *Manihot* species have, an ability that has been observed specially in cultivable species like *M. esculenta* (Pushpalatha and Gangadharan, 2020). These species currently have a wide distribution in the "Caatinga" and are adapted to dry and high temperature environments. Other studies have found similar results, where some endemic plants were affected positively by

climate change and expanded their distribution (Sosa, 2019; Garzaet al.,2020; Simões et al., 2019). These surviving species increase their ability to inhabit new places or persist where they are currently (Berg et al., 2010; Urban et al., 2013).

According to Pörtneret al., (2022), the temperature, concentrations of CO2, and ozone (O3) will continue to increase due to global warming by 2100. Precipitation patterns are also expected to differ because of climate change, with more frequent drought events predicted for regions that are already arid (Pörtneret al, 2022). In the northeast, an increase in temperature, consecutive dry days and a reduction in water resources are expected, which may explain future migrations of *Manihot* species to regions further south of the Northeast (Marengo, 2008; Da Silva, 2019).

Environmental stresses caused by climate change have diverse effects on different organs and tissues within a plant, responses can be molecular, cellular and morphological and vary between tissues and throughout the developmental life of a plant (Gray and Brady, 2016). The ability to change developmental processes in response to the environment is the key to plant success in these new habitats (Nicotra et al., 2010; Gray and Brady, 2016).

The temperature and precipitation directly affect the morphology and physiology of the plants, for example when the temperature increases it has been shown that the size of the leaves and their permanence time vary, the roots modify their length, the reproductive development is modified and causes heat damage (Gray and Brady, 2016). However, it is known that some species are not negatively influenced by these increases, for example the cultivable species *Manihot esculenta* can withstand high temperatures and high variability in rainfall (Pushpalatha and Gangadharan, 2020).

Currently, the "Chapada Diamantina" contains areas of greatest suitability of richness, which corresponds to the real existing richness of endemic species (Suarez et al., 2023 in publication). In the future, these areas will move towards the south of the study area, and the

"Chapada Diamantina" will continue to house the greatest areas of richness for the endemic species of *Manihot*. We also observe that currently, in the northwest region of the study area, there are also areas of wealth suitability. However, the models may overpredict the distribution of the species because the environmental conditions of a predicted ecological niche could be represented in multiple areas throughout a geographic space (Urbina and Loyola, 2008; Jetz et al., 2008). Nevertheless, this does not mean that the species can colonize these areas due to limited dispersal capacity or the presence of biological barriers (Mendez et al., 2020; Velasco et al., 2020).

The projected models show that there are some protected areas that could conserve some species in the future. For example, the National Park “Chapada Diamantina” has been recognized as a biodiversity hotspot registering a high presence of *Manihot* species, not only the endemic ones (Duputié et al. 2011; Martins 2013, Simon et al. 2022). This area presents topographical and environmental conditions that favor the establishment of these species, which explains its high degrees of endemism and diversity. However, we found that five species *(M. bellidifolia, M. breviloba, M. maracasensis, M. reflexifolia and M. reniformis*), which still need additional conservation areas to guarantee the protection of their potential distribution range, taking into account that they currently have a restricted distribution and that their potential distribution area will be reduced both in the optimistic and pessimistic scenario.

For other species, climate change does not seem to be an imminent threat, however, when considering other factors that threaten the species such as deforestation, fragmentation, urban expansion and the introduction of invasive species, the distribution of these species could decrease dramatically (Thomas et al., 2004; Oliver and Morecroft 2014).

This study provides valuable information on the future distribution of *Manihot endemic* species that can be used as a basis for the development of public policies for the conservation of these species and phytogeographic domains, especially those that are seriously threatened.

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Fig. 1. Consensus models of geographic distribution for *Manihot bellidifolia (A-C)*, *M. breviloba (D-F)*, *M. compositifolia (G-I)*, *M. diamantinensis* (J-L), *M. dichotoma* (M-O) in the present, future optimistic and future pessimistic scenarios until the year 2100. The blue colors represent regions with low climatic suitability, while the orange and red colors represent regions with high climatic suitability.

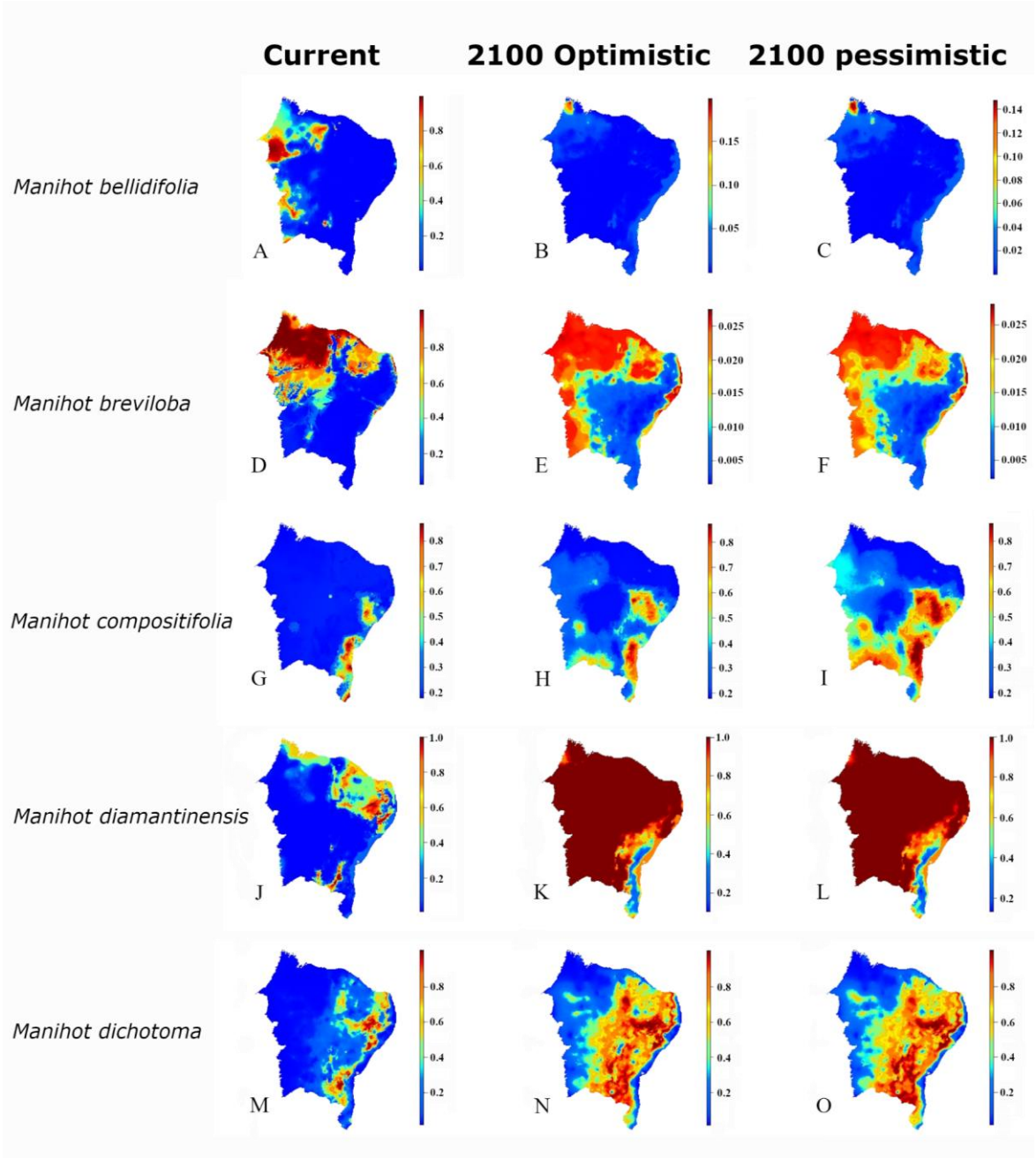


Fig. 2. Consensus models of geographic distribution for *M. jacobinensis (A-C)*, *M. longiracemosa (D-F)*, *M. maracasensis (G-I)*, *M. quinquefolia (J-L)*, *M. reflexifolia* (M-O), *M. reniformis* (P-R) in the present, future optimistic and future pessimistic scenarios until the year 2100. The blue colors represent regions with low climatic suitability, while the orange and red colors represent regions with high climatic suitability.

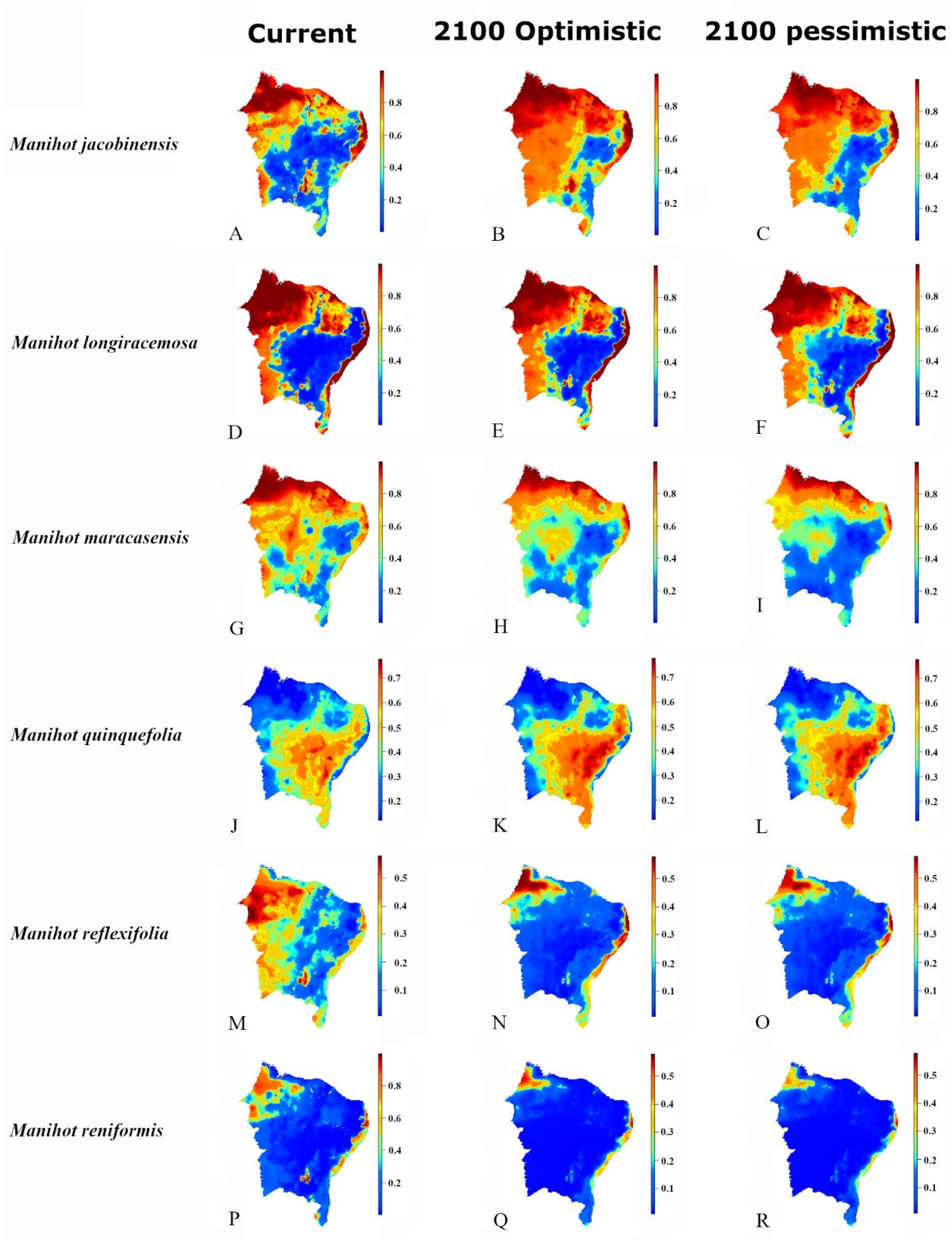
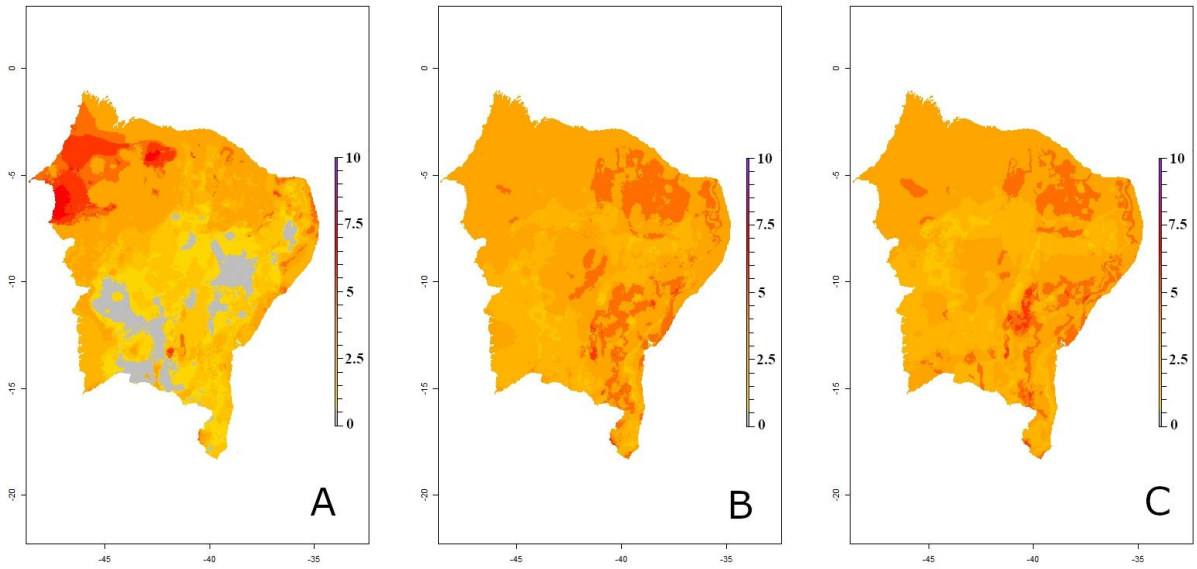


Fig. 3. Richness patterns of species reported as endemic to northeastern Brazil. (A) Current distribution, future distribution, in a (B) optimistic scenario and (C) pessimistic scenario for 2100. The gray and yellow colors represent regions where a smaller number of species were studied, while the orange and red colors represent the regions with the largest number of species studied.



CONSIDERAÇÕES FINAIS

Manihot é um gênero tropical com importância cultural, econômica e social para diversos países do mundo, especialmente, o Brasil. A realização deste trabalho permitiu confirmar 15 espécies endêmicas para o Nordeste do Brasil e obter avanços consideráveis na taxonomia dessas espécies (descrições detalhadas, ilustrações, chaves, dados de conservação, distribuição das espécies) e finalmente, resolver problemas de lectotipificação de cinco espécies.

Além disso, as análises espaciais associadas à modelagem do nicho ecológico dos táxons em diferentes cenários climáticos permitiram ter uma ideia sobre os possíveis efeitos que as mudanças climáticas podem ter sobre a distribuição geográfica das espécies endêmicas de *Manihot* registradas para o Nordeste do país.

Foi evidenciado que no Nordeste existem várias áreas protegidas potencialmente aptas para algumas espécies. No entanto, descobrimos que a área de aptidão de cinco espécies não será protegida no futuro. Para essas espécies, é importante implementar ações adicionais de conservação para garantir a proteção de sua potencial área de distribuição.

Este estudo fornece informações valiosas sobre a distribuição futura das espécies endêmicas de *Manihot* que podem servir de base para o desenvolvimento de políticas públicas para a conservação dessas espécies e domínios fitogeográficos, especialmente aqueles que estão seriamente ameaçados. Vale salientar que as inferências levantadas no presente trabalho precisam ser complementadas com outros fatores que afetam a distribuição das espécies como o desmatamento, expansão humana e introdução de espécies invasoras. Esperamos que esse trabalho sirva de base para outros estudos em *Manihot*, especialmente trabalhos envolvendo conservação das espécies e dos domínios fitogeográficos.