




## *Mabea dalyana* (Euphorbiaceae-Hippomaneae): a new subshrub with xylopodia endemic to the savannas of the Brazilian Amazon

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### ABSTRACT

During fieldwork in the Campos Amazônicos National Park, Amazonas state, Brazil, a new endemic species of *Mabea* was collected in savanna areas. Field collections and specimens in RON, MG, and HRCB were analyzed. To understand the species distribution and verify possible areas of occurrence, niche modeling was conducted using the sdm package in R. *Mabea dalyana*, the new species is a subshrub with xylopodia and reduced size (less than 1 m height) and small, yellow thyrses. There are several allopatric species of *Mabea* growing in Amazonian savannas, some widespread but others locally restricted, such as *M. uleana* from central Amazonia that has some superficial resemblance in leaves and inflorescences but can be distinguished from *M. dalyana* by pubescent adaxial leaf surface (*vs.* glabrous), 12-21 submarginal glands (*vs.* 10 submarginal glands), thyrse brownish to red (*vs.* yellow thyrse) and conspicuous caruncle (*vs.* caruncle inconspicuous). *M. dalyana* is endemic to hyperseasonal savanna, very well adapted to savanna, and fire tolerant. It has notable characteristics, such as a subshrub habit, a xylopodium, glabrous leaves, and sepals noticeably larger than the ovary.

**Keywords:** campos amazônicos, fire tolerance, *Mabea* sect. *Mabea*, niche modelling, taxonomy

## Introduction

*Mabea* is a genus of Euphorbiaceae with ca. 40 species, and the largest and most diverse genus in the tribe Hippomaneae (Esser 1993; 1994; 2001). The number of species could even be higher because of several still undescribed taxa (Esser 1994; 2012). Currently, 25 species are recorded for Brazil,

of which five are endemic to the country (Esser 1994; 2000; Cordeiro *et al.* 2020).

According to Esser (1994; 2012), *Mabea* is characterized by brownish to reddish dendritic trichomes, in particular on the densely tomentose ovaries and fruits, pistillate flowers with usually six (rarely seemingly three when reduced) sepals and a distinct stylar columns, and staminate flowers with five fused sepals and a large number (sometimes up

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to ca. 100) of stamens. The genus is currently divided, by the morphological data, into two sections, *Mabea* sect. *Spiculigeræ*, with two species (*M. angustifolia* and *M. fistulifera*) and *Mabea* sect. *Mabea*, including all remaining species (Esser 1994; 2012). The species of *Mabea* can be distinguished by leaf glands, venation, pubescence, bracts, size of inflorescence, sepals, and fruit. Still, most of the species can be easily recognized by leaf characters (Esser 2012).

Here we present a taxonomic novelty of *Mabea*: the first species to be described in 20 years (Martínez Gordillo *et al.* 2000). This new species was found in Amazonian savanna in the southern part of the Amazonas state, Brazil. Also, the potential distribution and conservation status are analyzed and discussed, contributing to the spatial context of this Amazonian novelty.

## Materials and methods

### Study area

*Mabea dalyana* was discovered during four field expeditions between February 2018 and August 2019 to the Campos Amazônicos Savanna Enclave (CASE), a major enclave of savanna vegetation in the Brazilian Meridional Amazonian (Fig. 1A, B). The CASE has a total area of 4,342 km<sup>2</sup> almost entirely integrated as a protected area according to Brazilian laws, with 47 % belonging to the limits of Campos Amazônicos National Park (CANP), 46 % and 5 % in the Tenharim Marmelos Indigenous Land and Tenharim Igarapé Preto Indigenous Land, respectively (Fig. 1B). CASE is a continuous area of the predominance of savanna environments (Fig. 1C). It is located in a region dominated by rainforest vegetation, classified as Disjunct Amazonian Savanna, one of the seven provinces of Cerrado described by Ratter *et al.* (2003). The topography is composed of flat slopes, dominated by dystrophic soils (neosoils marked by the presence of plinthite in the B horizon) (ICMBio 2016). The regional climatic conditions are characterized by high medium annual temperatures (between 24 °C and 28 °C) and annual precipitation of ca. 2000 mm. Between November and March, it is characterized by distinct periods of rain, whereas May to September is a dry season; the months from October to April usually correspond to a transition period between these two seasons (Marengo *et al.* 2001).

**Herbarium material and methods** - The specimens of this new species were studied in the field and in the herbaria RON and MG, acronyms following Thiers (2021, continuously updated). The collection of HRCB was analyzed from images sent by the curator. Specimens were hydrated and analyzed with a stereo microscope, which was connected to a camera.

**Niche modeling** - The potential distribution of *M. dalyana* was modeled over the natural savanna and grassland areas of Amazonia (derived from MAPBIOMAS 2020) using

the 'sdm' package (Naimi & Araújo 2016) in R. As input, 17 climatic and 24 soil variables were obtained from the Worldclim 2 (Fick & Hijmans 2017), and Soil Grids (Hengl *et al.* 2014) databases, all with a 1 km spatial resolution, and seven location points were used as current presence data (three from voucher collections and four from field inventories, see Tab. S1 in supplementary material), all of them within a distance greater than 2 km from each other (Fig. 1B). Variance inflation factor (VIF) analysis (Marquardt 1970) was used to avoid collinearity (using a threshold of 0.7), finally selecting nine variables (climate - Mean Diurnal Range Temperature, Isothermality, Temperature Seasonality, Precipitation of Wettest Month, and Precipitation of Driest Month; soil (for depths of 0-30 cm) - Available Soil Water Capacity, Weight Percentage of the Clay Particles, Volumetric Percentage of Coarse Fragments, and Weight Percentage of the Silt Particles). A presence-background model was configured using 100 pseudo-absence points, randomly assigned ('gRandom'), and 10 runs per method (Barbet-Massin *et al.* 2012). The suitability distribution map was derived from an ensemble of 3 different methods: generalized linear model - GLM (McCullagh & Nelder 1989), random forest - RF (Breiman 2001), and Support Vector Machine - SVM (Cortes & Vapnik 1995); all of them implemented in the 'sdm' package. Finally, the area under the curve (AUC) of the receiver operating characteristic (ROC) was used to assess the model, based on bootstrapping replications (Hastie *et al.* 2009), and Pearson correlation tests (*r*) were applied to explore the influence of the variables used in the final model.

**Conservation status and ecology** - We used the Geospatial Conservation Assessment Tool (GEOCAT) (Bachman *et al.* 2011) with a cell grid of 2 km<sup>2</sup>, providing information about the area of occupancy and the extent of occurrence of the new species. The conservation status was evaluated following the Red List criteria of the International Union for the Conservation of Nature (IUCN 2019). Complementary data on the history of forest fires of each locality visited were verified by the database of burnt areas of the CASE (Alves & Pérez-Cabello 2017), estimating possible influences on the recursion of these factors on the presence and distribution of the species.

## Results and discussion

### Taxonomic treatment

*Mabea dalyana* Bigio, Esser & Secco, **sp. nov.**

Type: BRAZIL, Amazonas: Manicoré, Parque Nacional dos Campos Amazônicos, 8°29'24" S, 61°30'25" W, 24 Aug. 2019, fl, fr, C.B. Anjos 200 (holotype: RON; isotype: MG). (Figs. 2, 3).

*Mabea dalyana* is a subshrub less than 1m height, with xylopodia elongate, blades ovate-elliptic, glabrous, abaxial

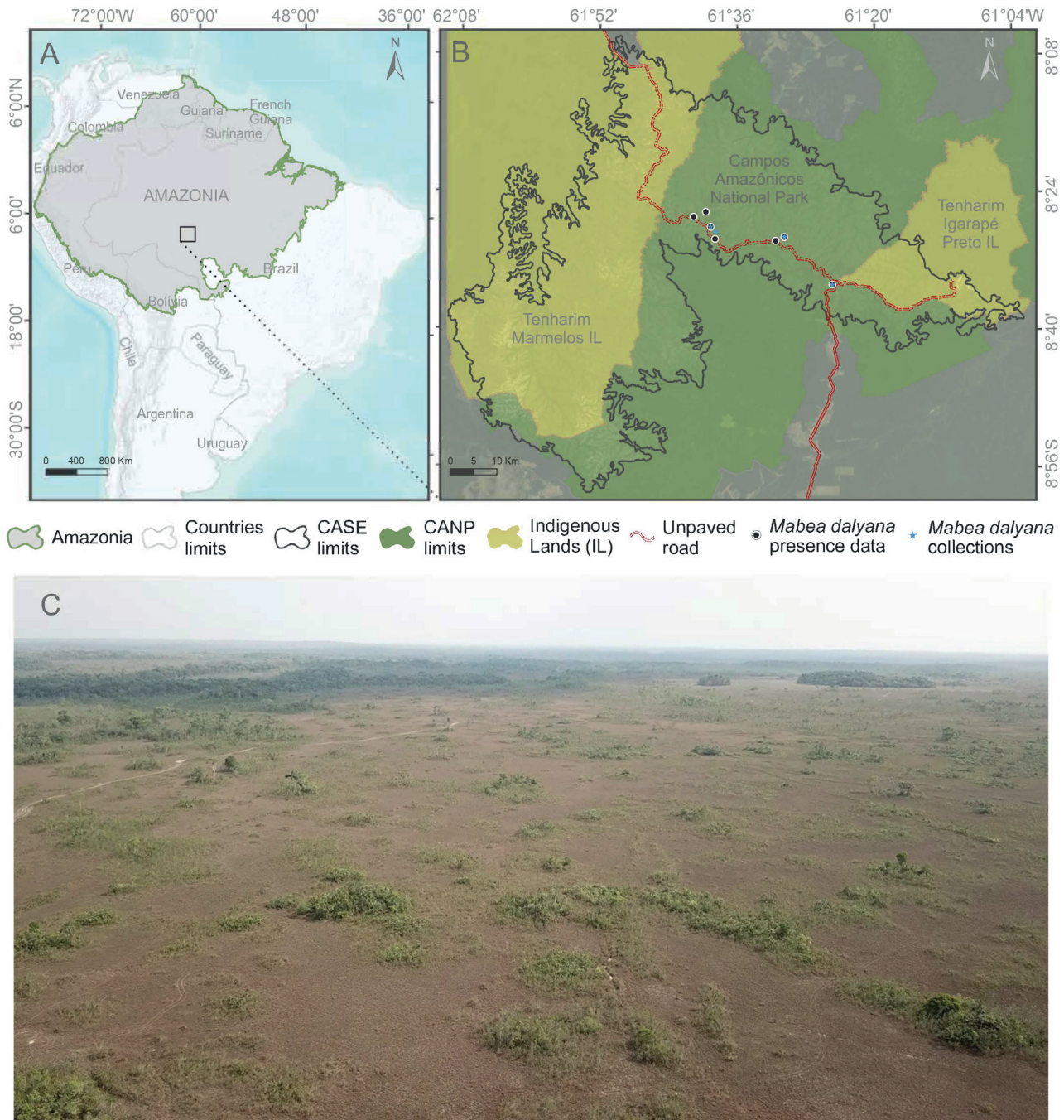


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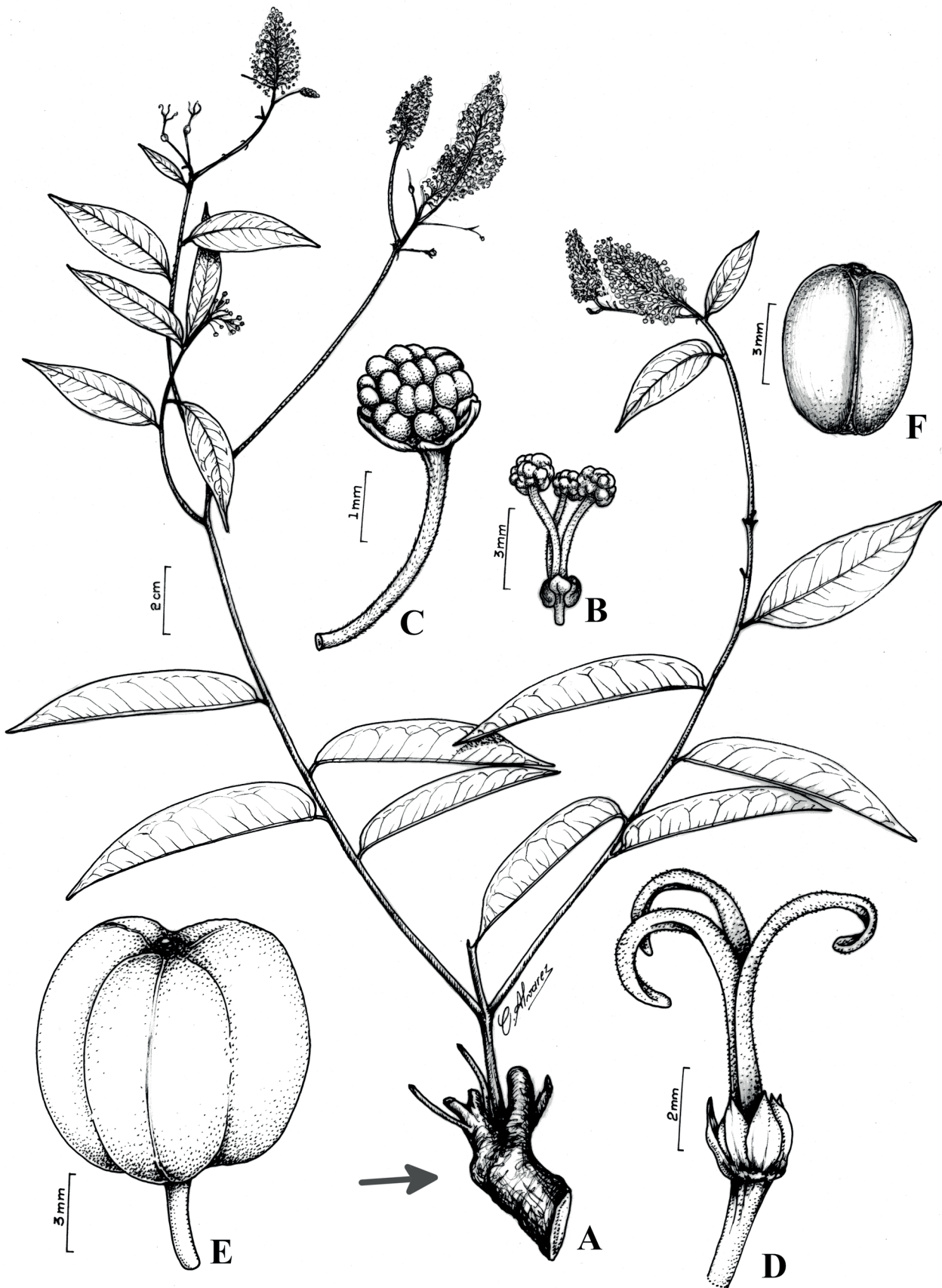
surface with 3-6 (10) submarginal glands. Staminate bracts cymules with a pair of stipitate glands; pistillate sepals 1.3-2 mm long, longer than the ovary.

**Subshrub** up to 45 cm tall; xylopodia elongate, cylindric, with longitudinal striations. **Branches** cylindric, glabrous, with longitudinal striations. **Leaves** alternate, blades ovate-elliptic, 4.0-8.2 × 1.7-3.6 cm, chartaceous to slightly

coriaceous, base rounded to obtuse, margin almost entire, but serrulate towards the apex, slightly revolute, apex acute to acuminate, glabrous on both surfaces, secondary veins in 6-9 pairs, brochidodromous, well visible on both surfaces; abaxial submarginal glands 3-6 (10), ca. 0.25-0.3 mm in diameter and separated from the margin by ca. their own diameter; **petiole** 2-4 mm long, glabrous, adaxially

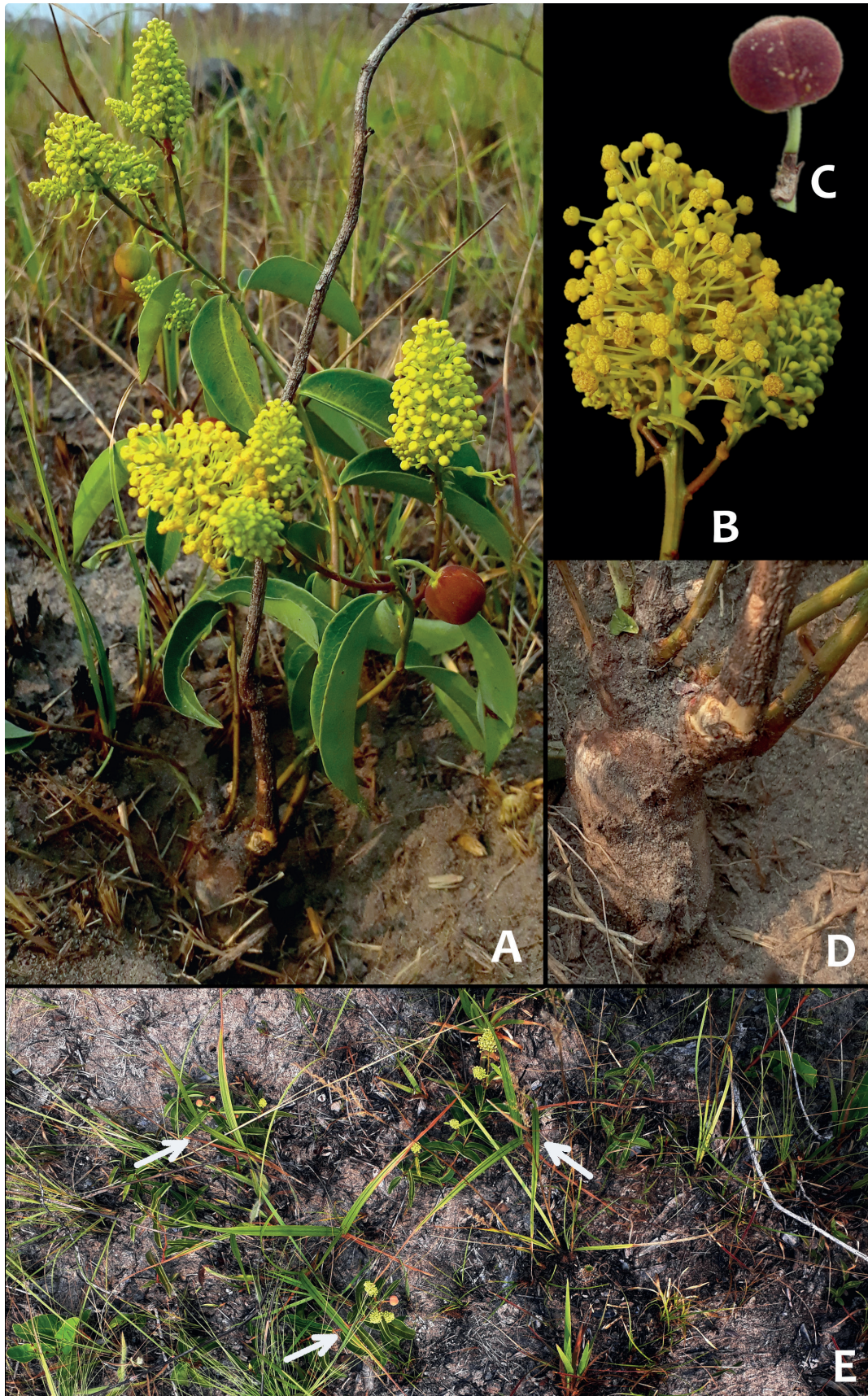


**Figure 1.** Campos Amazônicos National Park (CANP). **A.** Amazonia limits with the indication of CANP. **B.** Location of the collection points of *Mabea dalyana* in the south of the Brazilian Amazon, inside the Campos Amazônicos Savanna Enclave (CASE). **C.** Typical landscape of the Amazonian savanna inside the CANP. Grasslands and savanna predominate in almost all areas where *Mabea dalyana* occurs, while forests are mainly found in water bodies' proximity. **A** and **B** Background image: ©Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, Swisstopo, and the GIS User Community. **C** Photo: D. B. Alves in August 2019.



**Figure 2.** *Mabea dalyana* (Anjos 200): **A.** Habit; black arrow indicates part of the xylopodium. **B.** Staminate cymule. **C.** Staminate flower. **D.** Pistillate flower. **E.** Fruit. **F.** Seed with reduced caruncle.

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**Figure 3.** *Mabea dalyana* in the field (Anjos 200): **A.** Habit. **B.** Inflorescence. **C.** Fruit. **D.** Xylopodium. **E.** Habitat, white arrows point to three small individuals of *M. dalyana*. E. from Campos Amazônicos National Park. Photo C.B. Anjos in August 2019.



canaliculate; **stipules** 2.5–3 × 0.8–1 mm, deltoid, glabrous. **Inflorescences** yellow thyrses, unbranched or sometimes compound with usually 2–3 branches, but then only one branch flowering at any given time; central axes glabrous, each branch with the staminate part 1–5 × 0.7–2 cm, **bracts** of staminate cymules 0.8–1.2 mm long, base obtuse and apex acuminate, with a pair of stipitate glands 0.8–1.5 mm long; at base with (1–)2 pistillate flowers, bracts with 2 basal glands, 0.1–0.3 mm long. **Staminate flowers** 2–3 per cymule; pedicel pubescent, 3–7 mm long, free; calyx with deltoid lobes 1.0–1.2 mm long; **stamens** 15–20 per flower. **Pistillate flowers** solitary, pedicel 5–8 mm long, enlarging in fruit to 12 mm long; calyx 6, free, eglandular; sepals, lanceolate-ovate, 1.3–2 mm long, base obtuse, apex acuminate, longer than the ovary; **ovary** 0.8–1.3 mm long, globose, tomentose, stylar column 2–3 mm long, pubescent, stigmas 5–6 mm long, recurved. **Fruits** subglobose, reddish-brown, 0.8–1 × 0.8–1.2 cm, tomentose, slightly sulcate, smooth. **Seeds** 7 × 5 × 3 mm, caruncle inconspicuous, the transversal hilum dark brown.

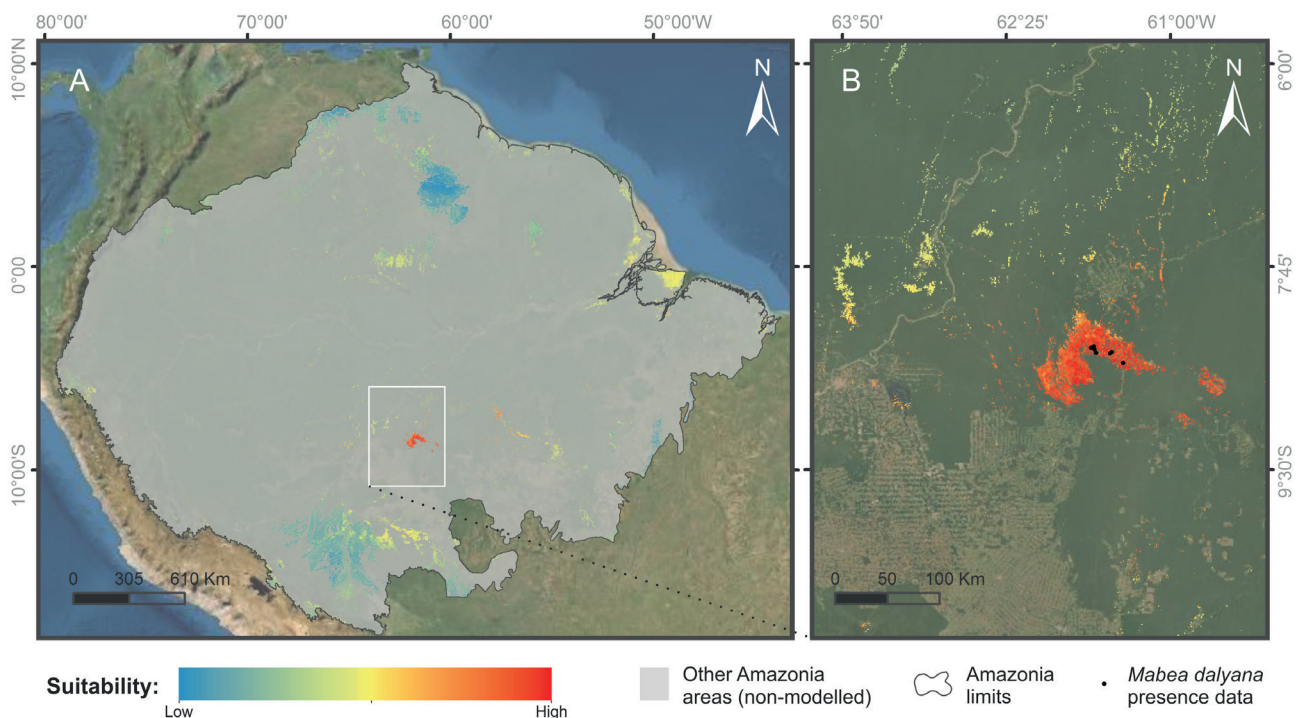
**Distribution and niche modeling** – *Mabea dalyana* has been observed in seven different locations inside CANP, in the municipalities of Manicoré and Novo Aripuanã (Amazonas state). Based on climatic and edaphic datasets and the observed characteristics at the known presence data points, a potential distribution of *M. dalyana* was modeled over all natural savanna and grasslands areas of Amazonia (Fig. 4A, B). Available soil water capacity ( $r = 0.71$ ) and temperature seasonality variations ( $r = -0.42$ )

were the variables that most influenced the final model, suggesting the existence of specific regional edaphic-climatic combinations that favour the presence of the species.

In general terms, the model evaluation presents a high value of AUC (0.93). The areas with the highest occurrence suitability are located in the southern Brazilian Amazon, closely associated with the region of collection points. These highest suitability levels (Fig. 4B) were observed in almost all savanna enclaves of CANP (08°27'24" S, 61°33'20" W), including the Indigenous Lands of Tenharim Marmelos and Tenharim Igarapé Preto in the vicinity.

Other areas with moderate-high suitability can be found in the surrounding regions, and well conserved areas, like the savanna ecotones of the Guariba Statal Park (08°45'79" S, 60°38'22" W), the Mapinguari National Park (07°51'00" S, 63°51'23" W) and the Ecology Station of Cuniã (08°11'46" S, 63°51'23" W); however, we did not find *M. dalyana* in these areas. The first one is near CANP and has higher suitability, and we still did not collect there. The others two conservation units we already made some expedition and we did not find it, probably because they have less suitability.

In other areas of Amazonia, the suitability is generally rated lower, where some specific areas can be highlighted as the portions of Marajó Island (49°04'10" W, 00°38'31" S), in the north of Brazil, and sectors of the National Park of Yapacaná (67°04'03" W, 03°55'33" N) in Venezuela, where, for instance, *M. frutescens* occurs. Even with some constraints related to the low number of collection points



**Figure 4.** Potential distribution of *Mabea dalyana* within the Amazonian savanna and grassland. **A.** Overview map with an indication of the habitat suitability for *M. dalyana* in the Amazon. **B.** Close-up of the modeled areas with the highest suitability levels of habitat suitability (orange to red) as well as the location of the *M. dalyana* collection points inside the CANP (black dots). Background image: ©Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, Swisstopo, and the GIS User Community.

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and his geographic concentration in terms of the Amazonia region, these potential distribution models can still guide new collection campaigns in other suitable areas.

**Habitat and ecology** – *Mabea dalyana* occurs along an environmental gradient from seasonal savannas, subjected to annual drought stress, to areas of hyperseasonal savannas *sensu* Batalha *et al.* (2005), that in addition to drought, are also subjected to regular flooding during the rainy season. *M. dalyana* seems to be well adapted to fire, drought, and inundation, as seen by the presence of xylopodia that allow the accumulation of nutrients for rapid growth after the loss of branches and leaves. Areas where *M. dalyana* were collected were subjected to different fire patterns during the last years (Alves & Pérez-Cabello 2017), suggesting that this species is adapted to diverse frequency of fires.

Three of these localities are included in permanent experimental plots to study the effects of fires in the savannas. Direct observations executed in these experimental plots suggest a significant percentage of individuals with inflorescences in plots recently burnt, in contrast, to control plots (not burnt), an issue that will be analyzed in more detail in future studies (Alves in prep.). Relationships between the influence of fires, the flowering of the plants, and the presence of xylopodia and other structures for nutrient storage, are also illustrated in other studies of plants the herbaceous layer in areas of tropical savannas (Miranda *et al.* 2004; Fidelis *et al.* 2019) and correspond to the patterns observed with *M. dalyana*.

**Phenology** – *Mabea dalyana* were collected with flowers and fruit in April, July and August.

**Etymology** – The name *Mabea dalyana* honours Dr. Douglas Charles Daly, botanist of The New York Botanical Garden, who contributed significantly to our knowledge of the Amazonian flora with undeviating energy, and invigorated our knowledge of the state of Rondônia, and who aided much in the education of new enthusiasts of the *Scientia amabilis*.

**IUCN conservation assessment** – *Mabea dalyana* has an area of occupancy (AOO) of 28 km<sup>2</sup>, and an extent of occurrence (EOO) of 130 km<sup>2</sup>, and has been recorded in

seven different localities within the CANP. These conditions indicate that the species can be classified as Endangered under Criterion B. The species has a restricted distribution, with dense subpopulations, and occurs in an extensive area of well-protected savanna vegetation with low current anthropogenic influences. Considering that the species depends on a protected area, it seems appropriate to assessed as Near Threatened (NT) regarding its distribution and number of locations, meeting the criteria B1a+B2a.

**Comments** – *Mabea dalyana* belongs to *Mabea* sect. *Mabea* because of the absence of an apical awn on the leaf blade, the leaves being not papillate below, the sepals of mature pistillate flowers not imbricate, and in particular because of the 3-flowered staminate cymules with free pedicels. *Mabea dalyana* seems to be restricted to savannas of the southern parts of Amazonia (see the results of niche modeling) and exhibits some characters that are certainly adaptations to the peculiar habitat conditions (low growth, xylopodia). Similar characters are also found in few other species of white sand savannas north of the Amazon, *e.g.*, *M. frutescens*, occurring in Venezuela and Colombia. *Mabea dalyana* differs from the *M. frutescens* in acute-acuminate leaves and yellowish inflorescences, thyrses ca. 1-5 cm long and, pistillate flowers with sepals longer than ovary (*vs.* apically rounded-mucronate leaves and reddish-brownish thyrses ca. 6–10 cm long and, pistillate flowers with shorter sepals than ovary). These two species are probably not phylogenetics closely related. The morphological characteristics are probably parallel adaptations because of environmental factors, but the species relationships within the genus are mostly unsolved.

There are several allopatric species of *Mabea* growing in Amazonian savannas, some widespread but others locally restricted, such as *M. uleana* from central Amazonia that has some superficial resemblance in leaves and inflorescences but can be distinguished from *M. dalyana* by pubescent adaxial leaves (*vs.* glabrous leaves), 12-21 submarginal glands (*vs.* 10 submarginal glands), thyrses brownish to red (*vs.* yellow thyrses) and caruncle distinguished (*vs.* indistinctly caruncle). For other characters, see Table 1.

**Table 1.** Morphological comparison between *Mabea dalyana* and similar species.

	<i>M. dalyana</i> Bigio, Esser & Secco	<i>M. frutescens</i> Jabl.	<i>M. uleana</i> Pax & K. Hoffm.
<b>Habit</b>	Subshrub	Subshrub	Shrub
<b>Xilopodia</b>	Present	Present	Absent
<b>Leaf margin</b>	Almost entire, but serrulate toward the apex	Serrate	Entire/ciliate
<b>Adaxial leaf surface</b>	Glabrous	Glabrous	Pubescent
<b>Leaf glands number</b>	0-6(10)	ca. 10	12-21
<b>Leaf apex</b>	Acute-acuminate	Apically rounded-mucronate	Acuminate / sub acuminate
<b>Thyrses</b>	Yellow. Simple or compound	Reddish-brownish. Simple	Brownish to red. Simple
<b>Sepal length</b>	Larger than ovary	Smaller than ovary	Larger than ovary
<b>Caruncle</b>	Inconspicuous	Inconspicuous	Conspicuous
<b>Occurrence</b>	Savanna in South Amazon Brazil (Amazonas)	Savanna in the North Amazonia, Venezuela and Colombia	Amazonia Campinarana, Inundated Forest, Secondary vegetation in Brazil (Amazonas)



The collection *Anjos 73* shows some pistillate flowers with 4 or 5 stigmas, very probably only an aberrant specimen.

Note that *M. dalyana* was discovered after collections made within the fire monitoring project at CANP were made in the years 2018 and 2019. When we studied the material and checked other collections, we found the specimen *Lombardi 10046* made during the Park management plan in 2013. This discovery reinforces the need to make more collections in the Amazon and to have more taxonomists in the region to identify the plants (Sobral & Stehmann 2009; Miliken *et al.* 2010; Gasper *et al.* 2020).

#### **Additional material examined (paratype). BRAZIL.**

**Amazonas:** Mun. Manicoré, Parque Nacional dos Campos Amazônicos, 8°28'20" S, 61°38'53" W, 31 July 2018, fl, fr, C.B. *Anjos 73* (RON, MG); 8°28'37" S, 61°38'58" W, 02 Apr. 2018, fl, F. *Bonadeu 1082* (RON, MG); Nova Aripuanã, 8°34'55" S, 61°24'26" W, 29 July 2013, fl., J. *Lombardi 10046* (HRCB).

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