UFSM

Ciência Florestal

ISSN 1980-5098
OPEN ACCESS

Ci. Fl., Santa Maria, v. 33, n. 4, e64546, p. 1-20, Oct./Dec. 2023 • https://doi.org/10.5902/1980509864546
Submitted: 2nd/03/2021 • Approved: 21st/09/2023 • Published: 24th/11/2023

Artigos

Agroclimatic referential for *Acrocomia aculeata* (Jacq.) Lodd. ex Mart. based on its diversity center in Minas Gerais, Brazil

Referencial agroclimático para *Acrocomia aculeata* (Jacq.) Lodd. ex Mart. baseado no seu centro de diversidade em Minas Gerais, Brasil

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ABSTRACT

The production chain of the macauba palm (*Acrocomia aculeata*) includes the cosmetics, food and bioenergy sectors, which highlights the relevance of defining bioclimatically favorable areas for the cultivation of this plant in the state of Minas Gerais, Brazil, the center of its origin. The mesoregions of this state were characterized according to the average annual temperature (AMT), annual precipitation (AP), precipitation in the driest quarter (PDQ), and aridity index (AI), following the Boolean logic. A total of 45.18% of the area of this state is bioclimatically favorable for the cultivation of *A. aculeata*, which facilitates the planning of farming activities, conservation, and management of this plant in other regions with conditions similar to those observed in this state. This palm can also be cultivated with irrigation in regions with adequate bioclimatic conditions, but without adequate rainfall pattern. This information can boost the rational and sustainable use of *A. aculeata* for the production of green vegetable oil.

Keywords: Productive chain; Climate; Boolean logic; Macaúba

RESUMO

A cadeia produtiva da palmeira macaúba (*Acrocomia aculeata*) inclui os setores de cosméticos, alimentos e bioenergia, aumentando a importância de se definir as áreas bioclimaticamente favoráveis para o cultivo dessa planta no estado de Minas Gerais, Brasil, centro de sua origem. As mesorregiões desse estado foram caracterizadas de acordo com a temperatura média anual (TMA), precipitação anual (PA), precipitação no trimestre mais seco (PTS) e índice de aridez (IA), seguindo a lógica booleana. Um total de 45,18% da área do estado de Minas Gerais é, bioclimaticamente, favorável ao cultivo da *A. aculeata*, facilitando o planejamento de atividades agropecuárias, conservação e manejo dessa planta. Essa palmeira pode, também, ser cultivada com irrigação em regiões com déficit de precipitação, mas com as outras condições bioclimáticas semelhantes às definidas nesse estado para essa planta. Essas informações aumentam as possibilidades do uso racional e sustentável de *A. aculeata* para produção de óleo vegetal verde.

Palavras-chave: Cadeia produtiva; Clima; Lógica booleana; Macaúba

1 INTRODUCTION

World production of vegetable oils for the 2023/2024 harvest is expected to reach around 222,78 million metric tons (mt). Soy (*Glycine max* L.), sunflower (*Helianthus annuus* L.), cotton (*Gossypium hirsutum* L.), peanut (*Arachis hypogaea* L.), castor beans (*Ricinus communis* L.), canola (*Brassica napus* L., *Brassica rapa* L., and *Brassica juncea*) and oil palm (*Elaeis guineensis* Jacq.) are the main oilseeds cultivated in Brazil (FAS, 2023) and produced 12,23 mt of oil, almost 6% (5,4897%) of world production.

Acrocomia aculeata (Jacq., Arecaceae) Lodd. ex Mart., known as macaúba and bocaiúva (Lorenzi; Pimentel; Paula; Negrelle; Paes, 2011), is an oil palm native to Neotropical America, which is found in the region from Mexico to Argentina, except in Peru and Ecuador (César; Almeida; Souza; Silva; Atabani, 2015). Little is known about the environmental conditions and bioclimatic features of the populations of this palm tree in the Brazilian territory (Coelho; Costa, Filho; Berton; Colombo, 2019). However, macaúba is widely distributed in the Cerrado biomes and open forests of the Atlantic Forest, under the dominance of the tropical climate, with dry winter (Aw) in the Southeast region of Brazil (Borges; Santos; Evaristo; Cunha; Veloso; Souza; Silva, 2021).

The *A. aculeata* production in crops can reach 24.000 kg of fruit and 4.000 to 6.000 kg of oil per hectare (Remape, 2014), which is ten times greater than that of soybeans (450 kg/ha). This palm tree can be cultivated in degraded areas, and its arboreal component adds ecological services to agroforestry systems (SAFs), by sequestering atmospheric CO_2 and mitigating climate change (Rosa; Souza; Pereira, 2019).

The state of Minas Gerais, the center of origin and diversity of *A. aculeata*, is a pioneer in studies, incentive policies, greenhouse nurseries, plantations and industrial enterprises related to *A. aculeata* (Lorenzi; Pimentel; Paula; Negrelle; Paes, 2011; Remape, 2014; Plath; Moser; Bailis; Brandt; Hirsch; Klein; Walmley; Wehrden, 2016). The expansion of commercial cultivation and the consolidation of the agro-industrial chain of this plant depend on knowledge of the bioclimatic requirements and the most suitable regions for its cultivation (Resende; Kuki; Corrêa; Zaidan; Mota; Telles; Gonzales; Motoike; Resende; Leite; Lorenzon, 2020).

Agroclimatic regionalization, based on air temperature and annual precipitation, contributes to the understanding of the spatial distribution and bioclimatic intervals by bioclimatic variable and the identification of mesoregions for *A. aculeata* cultivation. The present work aimed to determine the most favorable areas for the cultivation of *A. aculeata* in the state of Minas Gerais, Brazil, using the following bioclimatic variables: average annual temperature (AMT), annual precipitation (AP), precipitation in the driest quarter (PDQ) and index of aridity (AI).

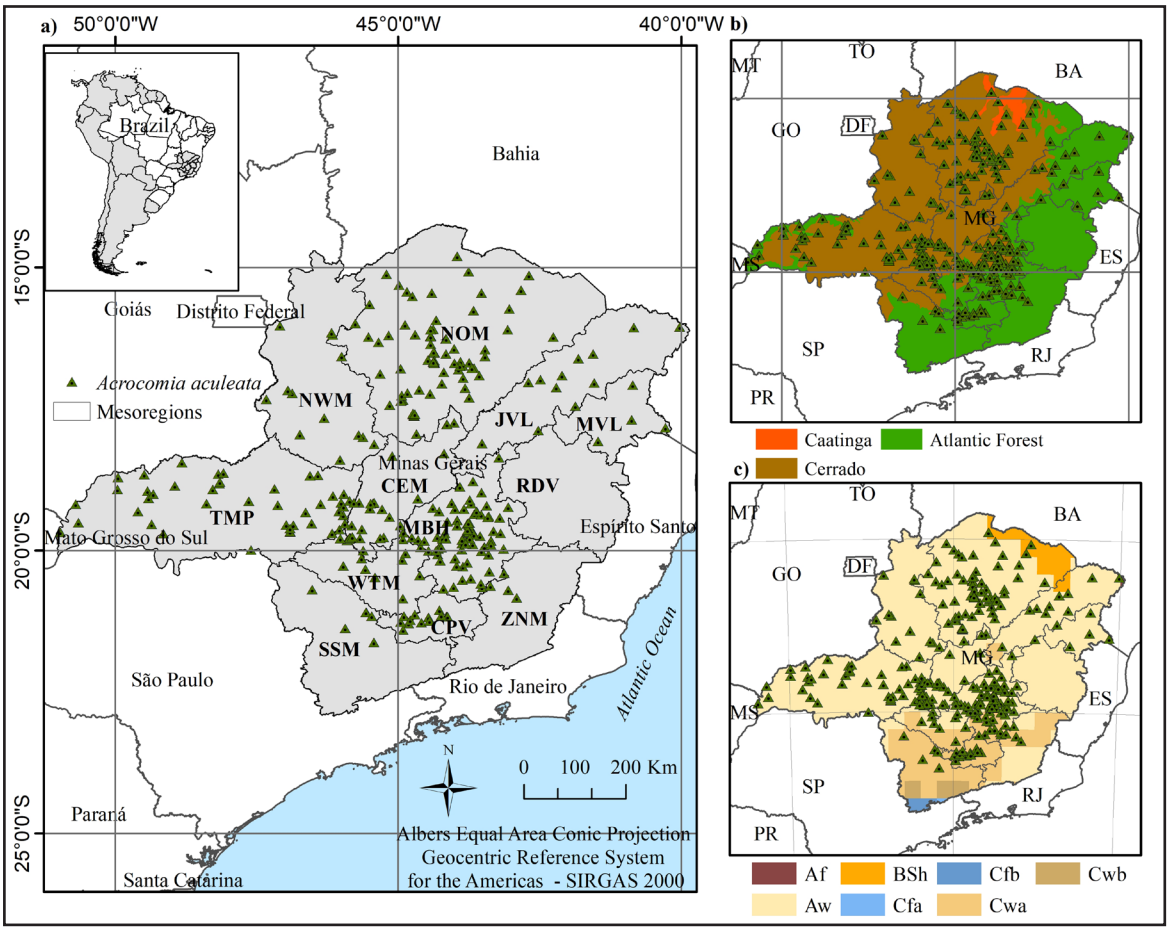
2 MATERIALS AND METHODS

2.1 Characterization of the study area

Minas Gerais (MG) is the 4th largest Brazilian state, with 586,528.28 km^2 (14°13'58"S to 22°54'00"S and 39°51'32" to 51°02'35"W), which borders the states of Bahia, Espírito Santo, Goiás, Mato Grosso do Sul, Rio de Janeiro and São Paulo (Figure 1ª). It is divided into 12 geographic mesoregions: Campos das Vertentes (CPV), Central

Mineira (CEM), Metropolitana de Belo Horizonte (MBH), Noroeste de Minas (NEM), Norte de Minas (NOM), Oeste de Minas (OTM), Vale do Jequitinhonha (JQA), Vale do Mucuri (VLM), Vale do Rio Doce (VRD), Sul e Sudoeste de Minas (SSM), Triângulo Mineiro/Alto Paranaíba (TMP) and Zona da Mata (ZNM) (Figura 1a). The vegetation cover of this state is associated with the biomes Cerrado (54%) in the Central-West region, Atlantic Forest (40%) in the east, and Caatinga (6%) in the North region (Drummond; Martins; Machado; Sebaio; Antonini, 2005; IEF, 2019) (Figure 1b).

Figure 1 – Map with the distribution of *Acrocomia aculeata* individuals by mesoregion (a), biome (b) and climate (c) in the state of Minas Gerais, Brazil



Source: Authors (2020)

In where: CPV = Campos das Vertentes; CEM = Central Mineira; MBH = Metropolitana de Belo Horizonte; NEM = Noroeste de Minas; NOM = Norte de Minas; OTM = Oeste de Minas; JQA = Vale do Jequitinhonha; VLM = Vale do Mucuri; VRD = Vale do Rio Doce; SSM = Sul e Sudoeste de Minas; TMP = Triângulo Mineiro/ Alto Paranaíba; ZNM = Zona da Mata.

Eight of the nine climate classes of Thornthwaite Humidity Index (Carvalho; Alves; Oliveira; Vianello; SE/ediyama; Dantas; Neto, 2006; Sampaio; Alves; Carvalho; Alves, 2011) were identified in Minas Gerais, according to the Köppen-Geiger classification (Figure 1c), namely, Af climates (humid tropical), Aw (tropical savannah with dry winter season), BSh (dry and hot semiarid), Cfa (humid temperate with hot summer), Cfb (humid temperate with temperate summer), Cwa (humid temperate with dry winter and hot summer) and Cwb (humid temperate with dry winter and warm summer).

2.2 Database

The regionalization of Minas Gerais for the cultivation of *A. aculeata* was based on the bioclimatic variables Mean Annual Air Temperature (AMT), annual precipitation (AP), Precipitation in the Driest Quarter (PDQ) and the Global Aridity Index (AI).

Data on air temperature (°C), annual precipitation and the driest quarter (mm) were obtained from the WorldClim climate database version 2, in "raster" format, historical series from 1970-2000 (Fick; Hijmans, 2017). The aridity index (ratio between the Average Annual Precipitation and the Average Annual Potential Evapotranspiration) was obtained from the Global-PET-Global-Aridez database, at a resolution of 30 seconds of arc (~ 1km at the equator), referring to the series historical period of 1950-2000, ranging from <0.03 to >0.65 worldwide (Hijmans; Cameron; Parra; Jones; Jarvis, 2004) (Table 1).

Table 1 – Reference values and climate class of the aridity index

Value	**<0.03**	**0.03 – 0.2**	**0.2 – 0.5**	**0.5 – 0.65**	**> 0.65**
Climatic class	Hiper arid	Arid	Semi-arid	Dry	Wet

Source: Authors (2020)

2.3 Occurrence of *Acrocomia acuelata* in Minas Gerais

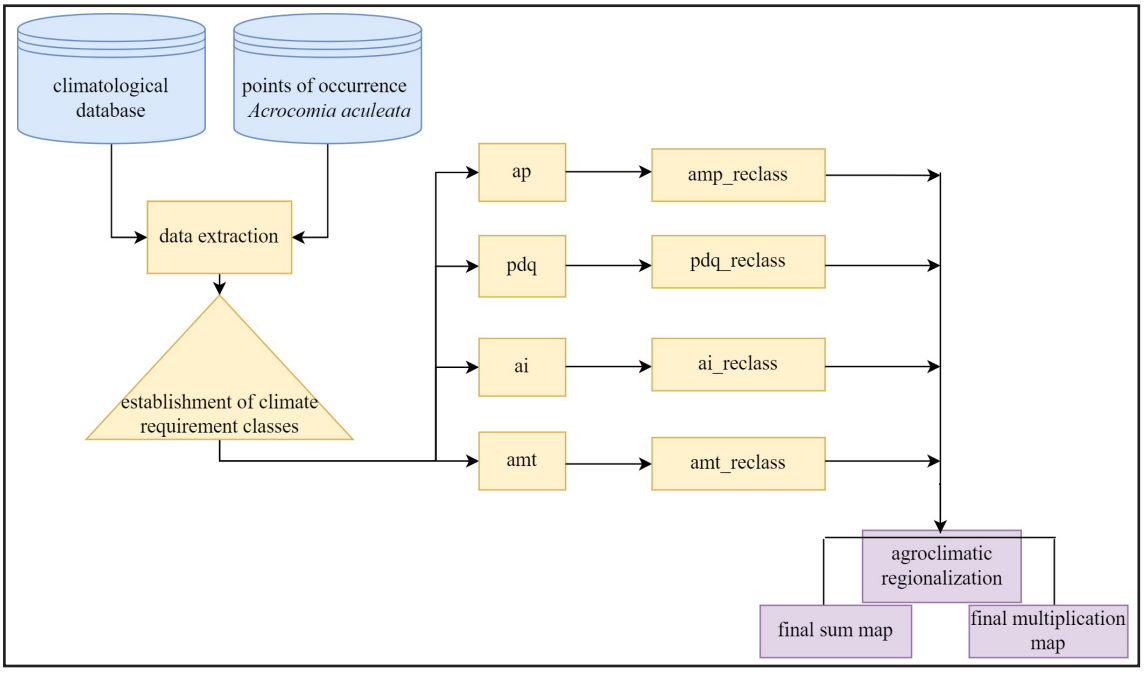
The records of *A. aculeata* in Minas Gerais were obtained from a bibliographical

review, from the virtual herbarium (Specieslink network - http://splink.cria.org.br), which is linked to the Macaúba Network for Technology and Research Development (REMAPE), coordinated by the Universidade Federal de Viçosa (UFV) and the company Acrotech Sementes e Reflorestamentos. The records are units of palm trees geolocated in different regions of the state of Minas Gerais (Figure 1).

2.4 Agroclimatic regionalization methodology

The georeferenced points were standardized and tabulated in an electronic spreadsheet. The regionalization steps were carried out in ArcGIS.10.6 ESRI (2018), and the points of natural occurrence of *A. aculeata* were plotted on maps, which allowed the extraction of their most frequent intervals by the bioclimatic variable analyzed and obtaining the classes of climatic requirements favorable this plant (Figure 2).

Figure 2 – Methodological flowchart divided into work stages for the agroclimatic regionalization of *Acrocomia aculeata* in the state of Minas Gerais, Brazil



Source: Authors (2020)

The maps were reclassified by bioclimatic variable, following the Boolean logic 0

and 1. The most frequent intervals for average annual temperature, annual precipitation, precipitation in the driest quarter and aridity index favorable to the survival of *A. aculeata* were classified as class one (1) and the others, outside the favorable ranges, as class zero (0). The reclassified variables were summed and multiplied using the raster calculator tool in ArcGIS.10.6, to generate the final agroclimatic regionalization maps for *A. aculeata,* in the state of Minas Gerais. The map resulting from the sum, by generating several numerical combinations, was standardized into numerical codes for better identification of climatic variables by mesoregion.

3 RESULTS

Three hundred and twenty-four points of occurrence of *A. aculeata* were found in 169 municipalities in the state of Minas Gerais, at an average altitude of 750 meters (m) and a maximum and minimum altitude of 1.331 m and 166 m, respectively.*A. aculeata* was detected in the following municipalities in the state of Minas Gerais: Abaeté, Acaiaca, Águas Formosas, Alfenas, Almenara, Araguari, Arapuá, Araxá, Araçuaí, Arcos, Arinos, Baldim, Bambuí, Barão de Cocais, Berilo, Betim, Boa Esperança, Bocaiúva, Bom Despacho, Bom Sucesso, Bonfinópolis de Minas, Bonito de Minas, Brasília de Minas, Brumadinho, Buenópolis, Buritizeiro, Cabeceira Grande, Cachoeira Dourada, Caeté, Campos Altos, Capelinha, Carlos Chagas, Carmópolis de Minas, Carneirinho, Catas Altas, Catas Altas da Noruega, Cedro do Abaeté, Chapada Gaúcha, Claro dos Poções, Comendador Gomes, Conceição da Barra de Minas, Conceição do Mato Dentro, Congonhas, Congonhas do Norte, Conquista**,** Coqueiral, Coração de Jesus, Córrego Danta, Curvelo, Diamantina, Divinópolis, Dores do Indaiá, Entre Rios de Minas**,** Esmeraldas, Estrela do Indaiá, Ferros, Formiga, Francisco Sá, Frei Gaspar, Gurinhatã, Ibiá, Ibiaí, Igarapé, Iguatama, Ijaci**,** Ingaí, Ipiaçu, Itabira, Itabirito, Itambé do Mato Dentro, Itaobim, Itinga, Ituiutaba**,** Itumirim, Jaticatubas, Januária, Jenipapo de Minas**,** Jequitaí, Jequitibá, João Pinheiro, Joaquim Felício**,** José Gonçalves de Minas, Juatuba, Juramento, Lagamar**,** Lagoa Formosa, Lagoa Santa, Lassance, Lavras**,** Limeira do Oeste, Lontra, Luislândia, Luz**,** Manga, Mariana, Martinho Campos, Mateus Leme**,** Matias Cardoso, Mato Verde, Matozinhos, Matutina**,** Mirabela, Moeda, Monte Alegre

de Minas, Montes Claros**,** Morro do Pilar, Nazareno, Nova Lima, Nova Ponte, Nova Serrana, Nova União, Novo Cruzeiro, Olhos D'Água, Onça de Pitangui, Ouro Branco, Ouro Preto, Padre Paraíso, Pará de Minas, Paracatu, Paraopeba, Passos, Patos de Minas, Patrocínio, Paula Cândido, Perdizes, Pintópolis, Piranga, Pirapora, Pitangui, Porteirinha, Porto Firme, Prudente de Minas, Quartel Geral, Riacho dos Machados, Rio Paranaíba, Rio Piracicaba, Ritápolis, Sabará, Salinas, Salto da Divisa, Santa Luzia, Santa Rosa da Serra, Santa Vitória, Santana de Pirapama, Santana do Riacho, Santo Antônio do Amparo, Santo Antônio do Retiro, Santo Hipólito, São Francisco, São Gonçalo do Abaeté, São Gonçalo do Pará, São Gonçalo do Rio Abaixo, São Gotardo, São João da Lagoa, São João da Ponte, São João del Rei, Serra Azul de Minas, Serra dos Aimorés, Taquaraçu de Minas, Tiradentes, Tiros, Três Marias, Tupaciguara, Uberlândia, Urucuia, Varginha, Varjão de Minas, Várzea da Palma and Verdelândia. The bioclimatic variables of the points of occurrence of this palm tree are described in (Table 2).

Table 2 – Bioclimatic variables annual precipitation (AP), precipitation in the driest quarter (PDQ), aridity index (AI) and average annual temperature (AMT) of the points of occurrence of Acrocomia aculea in the state of Minas Gerais, Brazil

Statistic	AP (mm)	PDQ (mm)	AI	AMT (°C)
Score:	324	324	324	324
Minimum:	783	4	0.41	17.25
Maximum:	1704	137	1.17	24.27
Sum:	427277	11576	260.20	6896.34
Average:	1318.76	35.73	0.80	21.29
Standard deviation:	205.58	18.44	0.15	1.29

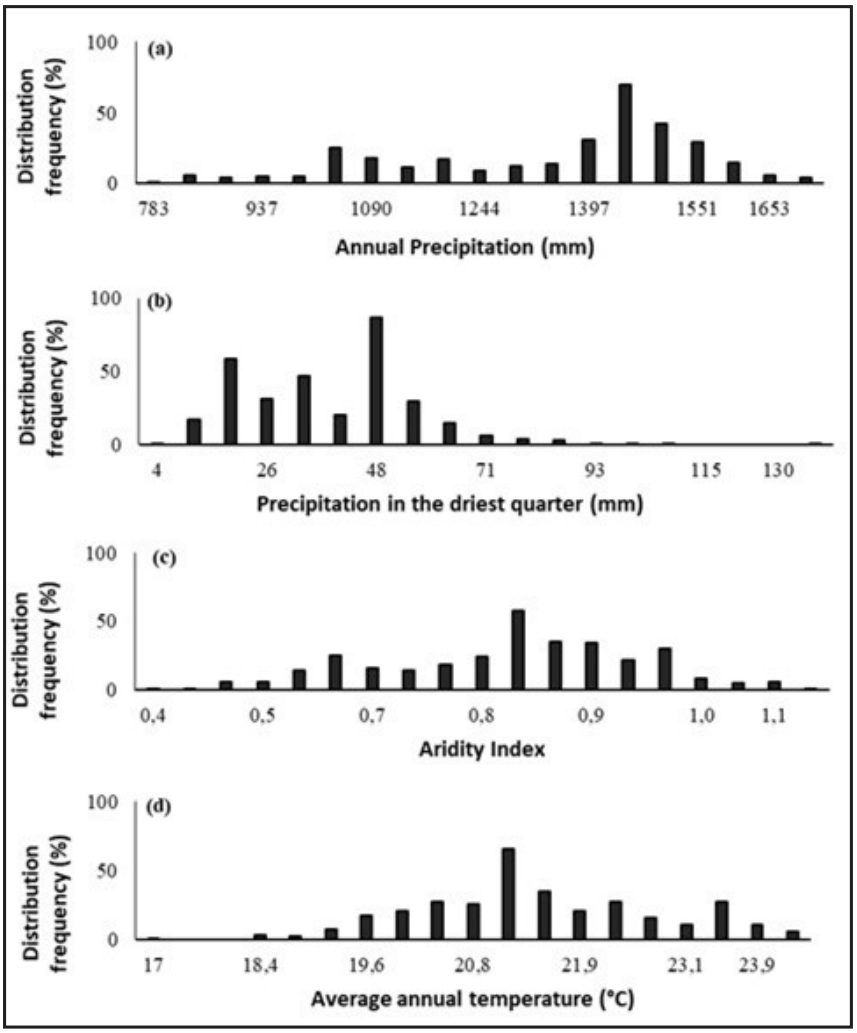
Source: Authors (2020)

The frequency of *A. aculeata* is higher in the mesoregions: Metropolitana de Belo Horizonte (MBH), Norte de Minas (NOM), Triângulo Mineiro/Alto Paranaíba (TMP) and part of Central Mineira (CEM). Scattered points in the westernmost part of Zona da Mata (ZNM), Campos das Vertentes (CPV) and northwest of the South/Southwest of Minas (SSM). Furthermore, sites with random distribution were found in Vale do Jequitinhonha (JQA), Vale do Mucuri (VLM), Oeste de Minas (OTM) and Noroeste de

Minas (NEM), while no points were identified in the Vale do Rio Doce mesoregion (VRD) (Figure 1a).

Most of the points with the occurrence of *A. aculeata*, plotted by the bioclimatic variable studied, are found in the domain of the Cerrado biome and the Semideciduous Seasonal Forest phytophysiognomy, in the transition region between the Cerrado and the Atlantic Forest (Figure 3).

Figure 3 - Distribution (%) of *Acrocomia aculeata* occurrence points in the state of Minas Gerais, Brazil



Source: Authors (2020)

Precipitation in the Driest Quarter (PDQ) favorable for the survival of *A. aculeata* is 11 to 79 mm per month, and annual precipitation (AP) is 990 to 1.516 mm (Table 3).

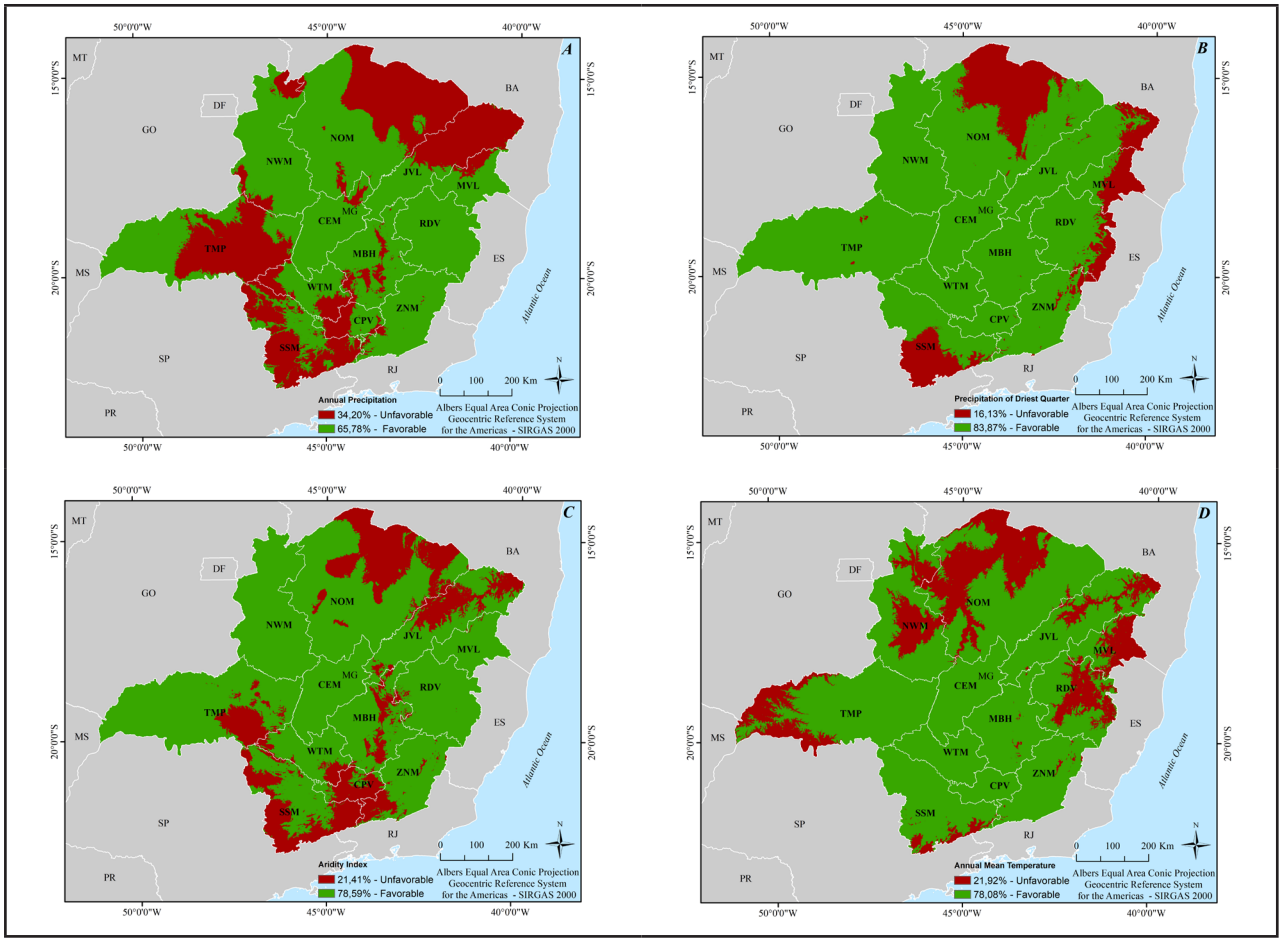
Water restrictions are lower in the South region of Minas Gerais, and greater in the lower altitudes of the NOM and NEM mesoregions of that state (Figures 4-A and 4-B).

Table 3 – Annual precipitation (AP), precipitation in the driest quarter (PDQ), average annual temperature (AMT) and aridity index (AI) for the cultivation of Acrocomia aculeata based on bioclimatic variables

Climate	AP (mm)	PDQ (mm)	AMT (ºC)	AI
Favorable	990 – 1,516	11 – 79	17 – 23	0.55 – 1.00
Unfavorable	<990 and >1,516	<11 and <79	<17 and >23	<0.55 and >1.00

Source: Authors (2020)

Figure 4 – Maps of the bioclimatic variables for *Acrocomia aculeata* in the state of Minas Gerais, Brazil



Source: Authors (2020)

In where: Annual precipitation (A); Precipitation in the driest quarter (B); Aridity index (C); Mean annual temperature (D).

The average air temperature favorable for *A. aculeata* in most mesoregions of Minas Gerais is from 17 to 23ºC (Table 4; Figure 4-D). The inadequacy of the AP (34.20%) and PDQ (16.13%) variables for the survival of this palm tree was greater in the NOM, NEM and part of the Triângulo Mineiro mesoregions (Figures 4-A and 4-B). The areas favorable to the survival of *A. aculeata* include around 78% of the AMT and AI variables with adequate values (Table 4).

Table 4 – Areas (km^2) and percentage (%) of favorable or unfavorable areas for the cultivation of *Acrocomia aculeata* in the state of Minas Gerais

Climate Variables	Favorable		Unfavorable	
	Km²	%	Km²	%
AI	460,932.55	78.59	125,596.66	21.41
AP	385,818.57	65.78	200,713.06	34.22
PDQ	491,902.23	83.87	9,4633.63	16.13
AMT	457,960.91	78.08	128,575.33	21.92

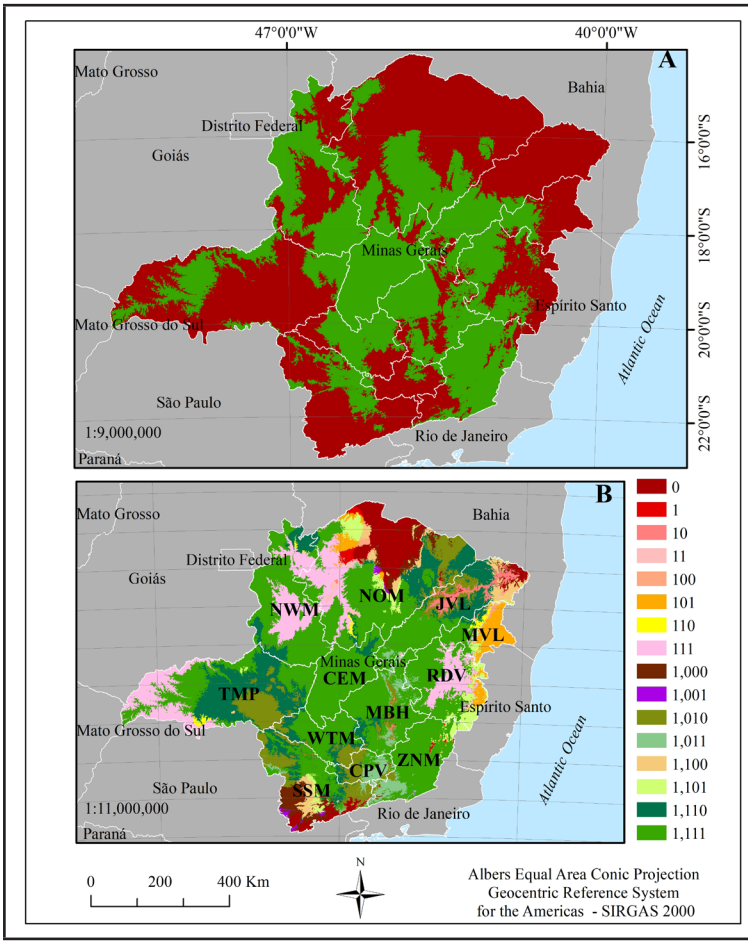
Source: Authors (2020)

In where: Based on the bioclimatic variables aridity index (AI); Annual precipitation (AP); Precipitation in the most recent quarter dry season (PDQ); Average annual temperature (AMT).

According to the aridity index, the limiting areas for the cultivation of *A. aculeata* were identified in the JQA, CPV, extreme North and extreme South mesoregions of the state of Minas Gerais (Figure 4-C). The aridity index (AI) of the *A. aculeata* occurrence sites ranged from dry (0.55) to humid (1.0), with isolated points in the semi-arid class (0.2-0.5) (Table 1).

The multiplication and sum of bioclimatic variables (AP, PDQ, AMT and AI) presented 45.18% favorable areas and 54.82% unfavorable areas for the cultivation of *A. aculeata,* in the state of Minas Gerais (Figure 5-A). The highest percentages of areas favorable to this plant were found for the mesoregions CEM (94,75%), ZNM (77,03%), MBH (75,40%), OTM (63,58%) and NEM (59,72%) of Minas Gerais; and the lowest, for CPV (76,54%), SSM (76,36%), VLM (72,64%), TMP (69,63%), NOM (68,52%) and JQA (67,29%) (Figure 5-B; Table 5). The Boolean logic (0) and (1) in figure 5-B can be observed in Table 6.

Figure 5 – Favorable (green) and unfavorable (red) areas for *Acrocomia aculeata* in the state of Minas Gerais



Code	Variable	
	Favorable	Unfavorable
0	**	ATM, AI, PDQ, AP
1	AP	ATM, AI, PDQ
10	PDQ	ATM, AI, AP
11	PDQ, AP	ATM, AI
100	AI	ATM, PDQ, AP
101	AI, AP	ATM, PDQ
110	AI, PDQ	ATM, AP
111	AI, PDQ, AP	ATM
1000	ATM	AI, PDQ, AP
1001	ATM, AP	AI, PDQ
1010	ATM, PDQ	AI, AP
1011	ATM, PDQ, AP	AI
1100	ATM, AI	PDQ, AP
1101	ATM, AI, AP	PDQ
1110	ATM, AI, PDQ	AP
1111	ATM, AI, PDQ, AP	**

Source: Authors (2020)

In where: CPV = Campos das Vertentes; CEM = Central Mineira; MBH = Metropolitana de Belo Horizonte; NEM = Noroeste de Minas; NOM = Norte de Minas; OTM = Oeste de Minas; JQA = Vale do Jequitinhonha; VLM = Vale do Mucuri; VRD = Vale do Rio Doce; SSM = Sul e Sudoeste de Minas; TMP = Triângulo Mineiro/ Alto Paranaíba; ZNM = Zona da Mata; Considering, together, annual precipitation (AP), precipitation in the dry quarter (PDQ), average annual temperature (AMT) and index aridity (AI), with canonical projection of climate restrictions in the mesoregions of this state (B).

Table 5 – Area (km²) and percentage per mesoregion favorable to the cultivation of *Acrocomia aculeata* in relation to the total area of the state of Minas Gerais, Brazil

Mesoregions-MG	Favorable		Unfavorable	
	Km²	%	Km²	%
Norte	40,409.16	31.48	87,940.13	68.52
Vale do Jequitinhonha	16,382.41	32.71	33,703.38	67.29
Vale do Mucuri	5,477.86	27.36	14,543.88	72.64
Vale do Rio Doce	20,717.06	49.75	20,929.26	50.25
Zona da Mata	27,396.84	77.03	8,171.91	22.97
Metropolitana Belo Horizonte	29,841.79	75.40	9,735.34	24.60
Campos das Vertentes	2,952.39	23.46	9,631.33	76.54
Sul/Sudoeste	11,687.10	23.64	37,760.40	76.36
Oeste	15,284.49	63.58	8,754.84	36.42
Triângulo Mineiro/Alto Paranaíba	27,433.74	30.37	62,891.78	69.63
Central Mineira	30,082.51	94.75	1,666.59	5.25
Noroeste	37,143.92	59.62	25,159.90	40.38

Source: Authors (2020)

4 DISCUSSIONS

The distribution of *A. aculeata* agrees with the reports of increased occurrence of this palm tree, mainly in the Metropolitan region of Belo Horizonte (MBH), Norte de Minas (NOM), Triângulo Mineiro/Alto Paranaíba (TMP) and part of Central Mineira (CEM). This plant was also reported in the North mesoregion in Montes Claros, Itacambira, Brasília de Minas, Mirabela and Grão Mogol and in the ZNM, CEM, TMP and South of Minas Gerais, Brazil (Motoike; Carvalho; Pimentel; Kuki; Paes; Dias; Sato, 2013). The highest occurrence of *A. aculeata* in southeastern Brazil is attributed to the great diversity of the genus *Acrocomia* (Lanes; Motoike; Kuki; Nick; Freitas, 2015).

Water scarcity, from February to October, in places in the North mesoregion, NOM, JQA and VLM, with rainfall between 650 mm and 900 mm per year, can reduce the establishment of *A. aculeata*, depending on the geographical position and relief and

reduce its cultivation (Aparecido; Batista; Moraes; Costa; Oliveira, 2019; Guimarães; Reis; Landau, 2010). The development and productivity of this oil palm may be appropriate in regions with rainfall rate from 500 to 3.000 mm per year (Ecocrop Fao, 2007). According to BRASIL (2014), the macaúba palm tree does not occur in regions with an excessively arid climate and rainfall less than 1.000 mm (BRASIL, 2014).

Defining the occurrence of *A. aculeata* is relevant, since this plant can be found in regions with average annual temperatures from 14 to 26ºC, with humid tropical climate, rainfall seasonality and climatic conditions typical of the Cerrado biome (Plath; Moser; Bailis; Brandt; Hirsch; Klein; Walmley; Wehrden, 2016). High temperatures can limit the survival of this palm tree (Khan; Hasan, 2020), but it can survive in dry regions, such as the North and Northwest mesoregions of the Minas Gerais state (Figure 1), in the Middle East and Australia with groundwater close to the soil surface (Salm; Salles; Alonso; Paim, 2007). Macaúba is native to regions with average temperatures ranging from 16.5ºC to 29ºC, which can be found in areas with humid tropical climate, such as the Amazon rainforest, and even in those with marked rainfall seasonality, including the Cerrado and the Cerrado-Caatinga transition area (Motoike; Carvalho; Pimentel; Kuki; Paes; Dias; Sato, 2013).

The reduced occurrence of *A. aculeata* in the South region of Minas Gerais, including Campos de Altitude, is due to low temperatures, high altitudes and sporadic frosts, as reported in coffee crops in the region (Sediyama; Junior; Santos; Ribeiro; Costa; Hamakawa; Costa; Costa, 2001). In general, palm trees are markers of hot and humid environments and, therefore, used as a model group in studies on evolution in tropical forests (Couvreur; Baker, 2013).

The variation in the TMA and the annual thermal amplitude for *A. aculeata* were similar to those reported for the Southeast region of Brazil, 16.5 and 22.6°C and 6°C, respectively (IEF, 2019). Populations of this palm tree in the state of Minas Gerais (Figure 1c) confirm its area of occurrence, mainly in the Aw climate types with rainy tropical climate, dry winter and average temperature above 18ºC, in the coldest month; and Cwa, a tropical high-altitude climate, with rain in the summer, drought in the winter

and average temperature of 22ºC, in the hottest month (Costa; Martins; Faria; Jorge; Leal, 2014).

The climatic transition zone between the Cerrado Biome and the Atlantic Forest, in the central part of Minas Gerais, with overlapping Cwa/Aw and Cwb climates, is favorable for the growth and development of A. aculeata plants and fruits (Resende, Kuki; Corrêa; Zaidan; Mota; Telles; Gonzales; Motoike; Resende; Leite; Lorenzon, 2020). However, long periods without rain and prolonged droughts (Correia; Kiill; Moura; Cunha; Júnior; Araújo, 2011), as observed in the Caatinga, are unfavorable for this palm tree (Fernandes, 2002; Resende, Kuki; Corrêa; Zaidan; Mota; Telles; Gonzales; Motoike; Resende; Leite; Lorenzon, 2020). The forest physiognomies of Central Brazil (Ratter; Bridgewater; Atkanson; Ribeiro, 1996), typically in the CEM, MBH and OTM mesoregions, which generally have Aw climate (Tropical with dry winter season) of Koopen-Geiger in the Cerrado biome, in Minas Gerais, are favorable to the occurrence of *A. aculeata.* However, this palm tree was also reported in the Pantanal biome (Calvani; Gonçalves; Silva; Oliveira; Marangoni; Reis; Cena, 2020). Macaúba masses naturally occur from Pará to Paraná, mainly in Cerrado areas and sub-deciduous forest environments (Motoike; Carvalho; Pimentel; Kuki; Paes; Dias; Sato, 2013).

The presence of *A. aculeata* in the ZNM and VRD mesoregions, in the Aw (tropical climate with dry winter) and Cwa (humid temperate with dry winter and hot summer) climate domains in the state of Minas Gerais is due to high precipitation and prolonged dry season in most of these points, called *Tropical Moist Deciduous Forest*, according to the FAO Global Ecological Zoning (FAO, 2001).

Bioclimatological studies on the prerequisites of *A. aculeata*, including agroclimatic classification systems, facilitate the sustainable expansion of this plant in crops and its conservation, thus reducing the risk of agricultural operations and attracting entrepreneurs and investments. The identification of these regions or areas, with favorable conditions for the introduction of plants, facilitates the extrapolation of the results obtained to regions with bioclimatic characteristics similar to those of this research, such as the Neotropical region (Falasca; Ulberich; Alvarez, 2016).

5 CONCLUSIONS

About half of the territory of the State of Minas Gerais, Brazil is favorable to the cultivation of *A. aculeata*.

The mesoregions Central Mineira (94,75%), Zona da Mata (77,03%), Metropolitana de Belo Horizonte (75,40%), Oeste (63,58%) and Noroeste (59,72%) are the most suitable for the cultivation of *A. aculeata*.

The following ranges of climatic variables are favorable to the cultivation of *A. aculeata*: average annual temperatures (AMT) from 17.0 to 23.0°C, annual precipitation (AP) from 990 to 1,516 mm, precipitation in the driest quarter (PDQ) from 11 to 79 mm and aridity index (AI) from 0.55 to 1.00.

ACKNOWLEDGMENTS

The authors are thankful to the Federal University of Viçosa for providing the physical structure for the conductance of this work. We also acknowledge the company Acrotech Sementes e Reflorestamento Ltda, for funding the research, and the Macaúba Network for Technology and Research Development – REMAPE, in particular, Professor Sérgio Motoike, for making Acrocomia aculeata points available in the Southeast region of Brazil.

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How to quote this article

SILVEIRA, V. A.; PAULA, H. B.; FRANCELINO, M. R.; FILPI, H. E. F. C. M.; KUKI, K. N.; ZANUNCIO, J. C.; IMBUZEIRO, H. M. A. Agroclimatic referential for *Acrocomia aculeata* (Jacq.) Lodd. ex mart. based on its diversity center in Minas Gerais, Brazil. **Ciência Florestal**, Santa Maria, v. 33, n. 4, e64546, p. 1-20, 2023. DOI 10.5902/1980509864546. Available from: https://doi.org/10.5902/1980509864546. Accessed in: day month abbr. year.