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Biogeographical distribution, conservation and local use of *Amburana acreana* (Ducke) A. C. Sm. in the Cacoal-Rondônia region, Brazil

Distribución biogeográfica, conservación y aprovechamiento local de *Amburana acreana* (Ducke) A. C. Sm. en la región de Cacoal-Rondônia, Brasil

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Abstract

Amburana acreana (Ducke) A. C. Sm., popularly known as "cerejeira" or emburana, is a tree belonging to the Fabaceae family (Leguminosae: Faboideae) and is included in the list of threatened and endangered species, according to Regulation No. 06 of the Brazilian Ministry of the Environment, dated 23 September 2008, standing out as one of the most vulnerable species. The objective of this study was to analyse the biogeographic distribution of *A. acreana* in the municipality of Cacoal, located in the Brazilian Amazon. The research was based on field data, complemented by herbarium records, databases, sampling and surveys of the local community to obtain information on the location and abundance of the species. The use of advanced tools such as DIVA-GIS 7.5® and Terra-i® made it possible to visualise the distribution of *A. acreana* in Brazil, both in its natural habitat (States of Acre, Mato Grosso and Rondônia) and in cultivated areas (Minas Gerais and Rio de Janeiro), extending also to Bolivia and Peru. In the municipality of Cacoal, the presence of the species was confirmed in ten localities, two of which hosted more than six adult individuals. The consideration of the microclimatic conditions of these localities proves to be a crucial element for proposing effective conservation strategies. The study not only provides a detailed overview of the distribution of *A. acreana*, but also highlights the need to address specific environmental conditions to ensure the long-term conservation of this threatened species in the Amazon region.

Resumen

Amburana acreana (Ducke) A. C. Sm., popularmente conocida como "cerejeira" o emburana, es un árbol perteneciente a la familia Fabaceae (Leguminosae: Faboideae) y se encuentra incluida en el listado de especies amenazadas y en peligro de extinción, según la Normativa No 06 del Ministerio del Medio Ambiente de Brasil, fechada el 23 de septiembre de 2008, destacándose como una de las especies más vulnerables. Este estudio se propuso analizar la distribución biogeográfica de *A. acreana* en el Municipio de Cacoal, ubicado en la Amazonia Brasileña. La investigación se basó en datos de campo, complementados con registros de herbarios, bases de datos, muestreo y encuestas a la comunidad local para obtener información sobre la ubicación y abundancia de la especie. La utilización de herramientas avanzadas como DIVA-GIS 7.5® y Terra-i® permitió visualizar la distribución de *A. acreana* en Brasil, tanto en su estado nativo (Estados de Acre, Mato Grosso y Rondônia) como en áreas cultivadas (Minas Gerais y Rio de Janeiro), extendiéndose también a Bolivia y Perú. En el Municipio de Cacoal, se identificó la presencia de la especie en diez localidades, dos de las cuales albergaban más de seis individuos adultos. La consideración de las condiciones microclimáticas en estas localidades se revela como un elemento crucial para proponer estrategias efectivas de conservación. El estudio no solo brinda una visión detallada de la distribución de *A. acreana*, sino que también destaca la necesidad de abordar las condiciones ambientales específicas para garantizar la preservación a largo plazo de esta especie amenazada en la región amazónica.

Introduction

Biodiversity can be defined as the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part [1]. The Amazon, according to the technical definition, is the largest biome of the planet Terra, distributed in 6.7 million km^2 between Bolivia, Brazil, Colombia, Ecuador, French Guyana, Suriname, Peru and Venezuela, known for its great biodiversity, highlighting in particular, more than 350 indigenous groups, more than 2500 species of fish and 40,000 species of plants in the forest [2]. However, deforestation threatens this diversity and, according to Silva et al. [3] the Brazilian Amazon deforestation rate in 2020 is the greatest of the decade, resulting in the destruction of habitats and the disappearance of species. One of these species catalogued as endangered is the "Cerejeira" or "Emburana" (*Amburana acreana* (Ducke) A. C. Sm.), according to Regulation No. 06 of the Brazilian Ministry of the Environment, published on 23 September 2008 [4], which describes a list of plant species threatened with extinction.

The genus Amburana Schwacke & Taub. in South America, comprises three species distinguished by stem colour, number of leaflets per leaf, leaflet shape, inflorescence size, colour and size of the standard petal, presence or absence of a papillary wing surrounding the seed formed by the developed endocarp, and seed colour [5]. *A. acreana* occurs in the Bolivian, Brazilian and Peruvian Amazon. *A. cearensis* (Allemão) A.C.Sm. is widespread in Argentina, Bolivia, Brazil and Paraguay. *A. erythrosperma* Seleme is endemic to the south of the Chapada Diamantina, in the state of Bahia, Brazil [5-7].

A. acreana is a deciduous tree of the Fabaceae family (Leguminosae: Faboideae) that can reach 40 m in height and 150 cm DBH (diameter at breast height) as an adult. Stem up to 25 m long. Stem straight to slightly sinuous. Casca presents a thin rhytidome up to 5 mm thick. The surface of the outer peel has a reddish-ferruginous colouring, which becomes a smooth rósea colouring when detached in large slabs [5]. Composite leaves, with 17 to 25 membranous, glabrous, ovate or ovate-lanceolate leaflets, 6 cm long and 3 cm wide; subacute apex; rounded base; hairy petioles, 2 mm long. [5,7].

The flowers of *A. acreana* are white. The fruit consists of a dehiscent pod with 1 or 2 winged seeds, aromatic, containing 4% coumarin. The dispersal of fruits and seeds is anemochorous (by wind), falling far from the mother plant. The species is monoecious, mainly pollinated by bees [8]. *A. acreana* flowers in May on bare branches and bears fruit in July in the state of Acre, from August to September in the state of Mato Grosso and from August to October in the state of Rondônia, Brazil [9].

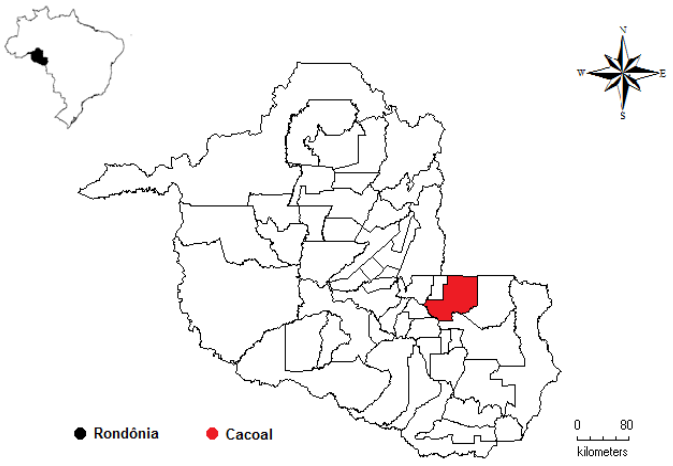
Given the vulnerability of the species, the aim of this study was to determine the biogeographical distribution of *A. acreana* in the Cacoal region of the western Brazilian Amazon, and to formulate strategies for local valuation and/or exploitation that would also constitute a conservation strategy.

Methods

Study area

The study area comprises the municipality of Cacoal, Brazil, located at 11º26'19" S and 61º26'50" W, at an altitude of 200 m.a.s.l. (Figure 1), in the State of Rondônia, Brazilian Amazon [10].

Figure 1. Map of the Municipality of Cacoal, State of Rondônia, Brazil



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The average annual temperature is 25°C [10]. The natural vegetation was described by Veloso et al. [11] as FOABSV - Foresta Ombrófila Abierta Bosque Siempre Verde (Open Evergreen Forest), including savannah patches ("Cerrado"). However, much of the current vegetation is secondary. The soil types present in Cacoal

are divided into five classes: Argisols, Latosols, Neosols, Podizolic and Cambisols [12].

Data collection sites

The sites for collecting data on the occurrence of *A. acreana* in the municipality of Cacoal, were identified through sampling and field records, as well as through interviews with the local community on the location and abundance of the species. In addition, a data set of herbarium records was collected, either in person or virtually, the most representative for the region being the herbaria of the Universidade Federal de Rondônia (UNIR; RON), the Instituto Nacional de Pesquisas Amazônicas (INPA; Herbarium INPA) and the Universidade Federal do Acre (UFAC; UFACPZ), all in Brazil. Table 1 lists the herbaria consulted. The records were systematised to form a database.

Table 1. Herbaria consulted for records of *A. acreana*. V= virtual consultation; P= on-site consultation.

Acronym	Herbarium	Institution	Consultation
CEN	CENARGEN	Embrapa Recursos Genéticos e Biotecnologia	V
CEPEC	CEPLAC	Centro de Pesquisas do Cacau – CEPLAC	V
CGMS	UFMT	Universidade Federal do Mato Grosso – UFMT	P
CNMT	Centro-Norte Mato Grossense	Universidade Federal do Mato Grosso UFMT	P
HUEFS	UEFS	Universidade Estadual de Feira de Santana - UEFS	V
IBt	Instituto de Botânica (IBt)	Departamento de Botânica do Estado de São Paulo	V
INPA	INPA	Instituto Nacional de Pesquisa da Amazônia - INPA	P
IPT	Xiloteca Dr. Calvino Mainieri	Instituto de Pesquisa Tecnológica do Estado de São Paulo	V
KEW	Kew - Herbarium Specimens K	Kew - Royal Botanic Gardens	V
MBM	Museu Botânico Municipal	Jardim Botânico de Curitiba, Paraná	P
MOBOT	MO Herbarium	Missouri Botanical Garden MO	V
NYBG	NY Herbarium - Vascular Plant Collection	The New York Botanical Garden	V
RON	Rondoniensis	Universidade Federal de Rondônia – UNIR	P
SP	Maria Eneyda P. Kaufmann Fidalgo	Estado de São Paulo	V
UFACPZ	UFAC	Universidade Federal do Acre - UFAC	P

Methodological tools

The software DIVA-GIS 7.5®, Tierra-i® and ArcView® were used to scale the location of the individualised sites and to generate the maps. The dataset we sought to compile, based on the recognition of an endangered species in the region (*A. acreana*), consisted of herbarium records, sampling and field records, as well as interviews with the local community about the location and abundance of the species.

Geographical coordinates were obtained from herbarium specimen labels, public domain gazetteers and topographic maps (Google Earth™). Data were recorded for each specimen, including locality name, elevation, geographic coordinates using GPS, status (wild, cultivated) and ethnobotanical information. These data, once recorded, were tabulated for analysis using the DIVA-GIS 7.5® software to determine the distribution of adhesions collected and observed during the collection expedition or data collection. Specific and random sampling and observations were carried out in the region. This was complemented by an analysis of its potential occurrence in the region, based on Ocampo et al. [13].

Another tool used, *Terra-i®, detects changes in soil use due to human activities in nearly real time, producing updates every 16 days for every 250 m^2 of soil [14]. This procedure was used for the 15 rural properties evaluated in this study. The system is based on the premise that natural vegetation follows a predictable pattern of changes in greenness from one date to the next, caused by site-specific soil and climatic conditions over the same period [15].

For *A. acreana*, documentation of local uses was carried out, both forestry (timber forest products, PFM) and other types, highlighting medicinal and food uses (non-timber forest products, NTFP), taken from the ethnobotanical data inventoried on each farm. evaluated. Based on the data collection, the implementation of a harvesting and conservation strategy for *A. acreana* was proposed. Figure 2 shows a juvenile specimen, details of the stem and leaves.

Figure 2. *Amburana acreana* a) Tree; b) Trunk or stem with detail of bark; c) Leaf composed of leaflets

Results

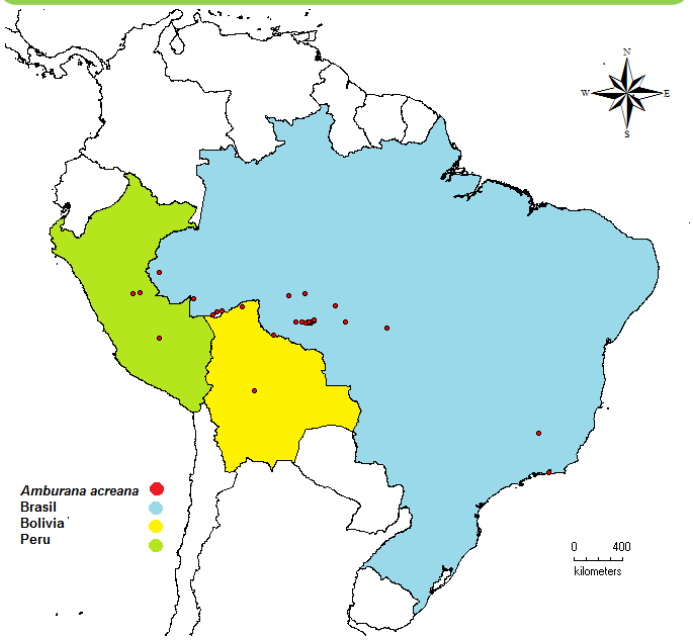
Herbarium records and databases

26 records for *A. acreana* were found in both physical and virtual herbarium sources. These records were distributed over three countries: Bolivia with three records, Brazil with 18 and Peru with five. Altitudinal data showed that the species thrives in a range from 150 to 1320 m.a.s.l. from a latitude of 7ºS in Acre, Brazil, to 16ºS in Cochabamba, Bolivia. The distribution of the species in Brazil is documented in databases and herbarium for the States of Acre, Amazonas, Mato Grosso and Rondônia in its native form (similarly for Bolivia and Peru), while it is recorded as cultivated in the States of Minas Gerais and Rio de Janeiro, at latitudes of 19ºS and 22ºS, respectively. Figure 3 shows the geographical distribution map of *A. acreana* in the three countries of occurrence, both in its native and cultivated forms (the latter in the south-eastern region of Brazil).

Field collection records

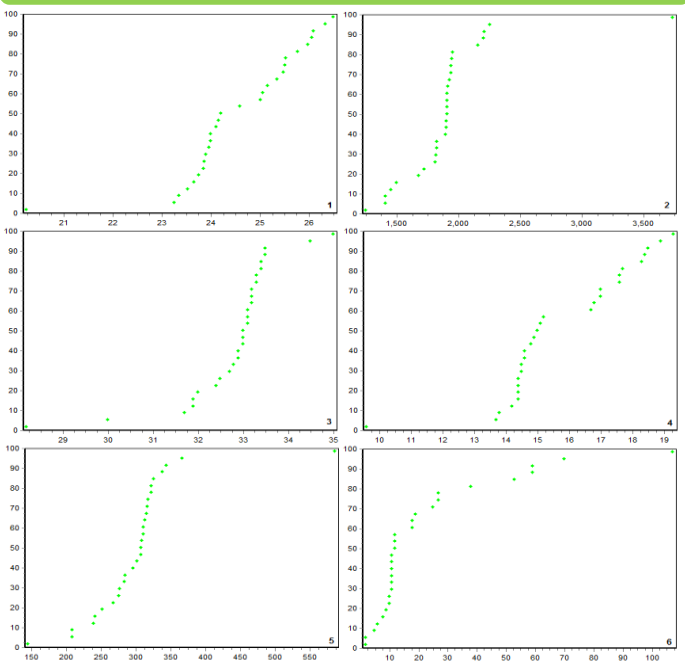
During the field data collection, the presence of the species *A. Acreana* in its native form, was recorded at ten locations in the municipality of Cacoal, Brazil. In two of these locations (-11.384037ºS, -61.533862ºW; -11.462199ºS, -61.71871ºW), more than six adult individuals were observed within a radius of less than 500 m. Figure 4, shows the temperature and rainfall ranges in which *A. acreana* occurs, compiled from all sources. The mean annual temperature varies from 23 to 27°C, while the annual rainfall ranges from 1450 to 2400 mm. The average maximum temperature during the warmest period recorded was between 28 and 35°C, and the average minimum temperature during the coldest period was between 13 and 19°C. Rainfall during the wettest period ranged from 150 to 370 mm and during the driest period from 0 to 70 mm.

Figure 3. Biogeographical distribution of *A. Acreana* on a map of altitude (m.s.n.m.) in Bolivia, Brazil and Peru



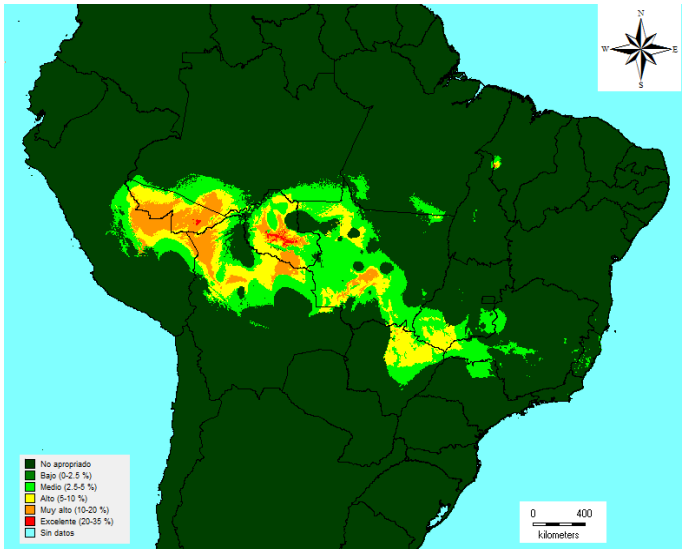
The analysis of the potential distribution of the species showed that the central region of the State of Rondônia (with the largest area) and the south-eastern region of the State of Acre (hot spots) had the highest percentage of probability of occurrence, followed by other parts of Acre, Rondônia, Mato Grosso (Brazil) and northern Bolivia and south-eastern Peru with lower probability of occurrence (Figure 5). The analysis of the potential distribution of *A. acreana* for the state of Rondônia only showed that it partially coincides with areas of indigenous reserves and Brazilian Environmental Conservation Units (UCAB), where native vegetation is preserved, such as the lands of the Uru-Eu-Wau-Wau indigenous group and the Pacaá Novos National Park. However, the other part, with the highest probability of occurrence of the species, corresponds to unprotected areas that are already undergoing advanced deforestation (Figure 6).

Figure 4. Average temperature and rainfall data for *A. acreana* habitats



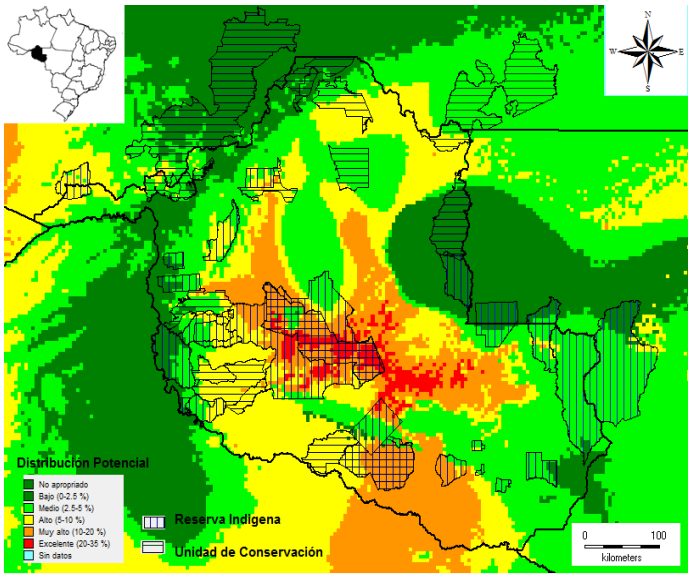
1) Mean annual temperature; 2) Annual rainfall; 3) Mean maximum temperature of the warmest period; 4) Mean minimum temperature of the coldest period; 5) Rainfall of the wettest period; 6) rainfall of the driest period (*temperature in °C; annual rainfall in mm).

Figure 5. Potential distribution of *A. acreana* for Brazil, Bolivia, and Peru



The points of highest probability of occurrence are observed in the States of Rondônia and Acre, in the Amazon region of Brazil.

Figure 6. Potential distribution of *A. acreana* and location of indigenous reserves and conservation units for the State of Rondônia. Brazil



The local use of *A. acreana* products

As noted in the ethnobotanical inventory, the uses of *A. acreana* reported by the local community and found in literature are as follows:

- **Human consumption**. In the state of Acre, the seeds of the Amazon cherry are eaten roasted. They are also used as a condiment in the preparation of dishes. When added to cachaça, they enhance the taste of this popular drink.
- **Medicinal**. The bark and seeds are used regionally in-home medicine to treat headaches, toothaches and flu, as an expectorant and even for anaemia. The seeds are used to make rapé, which is used to relieve nasal congestion. It is also used to perfume tobacco and clothing. The aroma is due to the presence of 4% coumarin in the seeds [16].
- **Lumber and maple**. The wood of this species, somewhat similar to that of the European oak (*Quercus petraea* subsp. pinnatiloba (K.Koch) Menitsky), is smooth and aesthetically pleasing, classified as "excellent" in civil construction and highly sought after, especially by the national luxury furniture industry, which uses it in the form of sawn and veneered wood (decorative load-bearing panels). In fact, *A. acreana* is also used in the building

industry for interior finishes such as skirting boards, frames, mouldings, consoles, doors, door frames, turned parts, etc.

Discussion

Although *A. acreana* has a moderately wide potential distribution range in terms of altitude and latitude, from 150 to 1320 m.a.s.l. and from 7ºS in Acre (Brazil) to 16ºS in Cochabamba (Bolivia), for the State of Rondônia-Brazil, the limited number of specimens observed places this species in the "endangered" category, as described in the Regulation No. 06 of 2008 of the Ministry of the Environment of Brazil [4], which establishes a list of threatened plant species. The same vulnerability status was generally observed in the present study for the countries where the presence of *A. acreana* was recorded.

However, Barber et al. [17] argue that the “endangered” category does not apply to the state of Acre, as this species was present in all tree diameter classes analysed, with a wide distribution, in the forest management plans studied. The authors attribute this to the fact that the State of Acre has 46% of its territory designated as protected areas and indigenous lands, with 12% deforestation in the State of Acre and an annual growth rate of 1.05%, lower than that of the State of Rondônia, Brazil. This scenario may explain the non-inclusion of *A. acreana* in the “vulnerable” category [17].

One point to highlight regarding the potential distribution of *A. acreana* is the likelihood of its occurrence in the central area of the State of Rondônia-Brazil [18], which is one of the most deforested areas of the State. However, part of this area coincides with the Uru-Eu-Wau-Wau indigenous territory and the Pacaá Novos National Park, which were not included in this study and therefore have no records of *A. acreana*. These areas would be very suitable for searches. Conversely, Ocampo et al. [12] describe that, in some cases, species distribution data are related to the locations where searches have been carried out; for example, sites close to populated areas with universities have been more studied, as opposed to more remote areas with no roads or access routes [19].

The deforestation areas recorded in the municipality of Cacoal-Rondonia, Brazil, corresponded to private rural properties and the 7 de Setembro indigenous reserve [20, 21]. Among the factors involved are: *i*) the conversion of these areas to cattle or crops in the case of the private properties; *ii*) timber exploitation in the case of the indigenous reserve. The observed increase in pasture area may be due to degradation of pasture or increased grazing [22]. Inadequate management of established pastures has been identified as one of the main factors making these areas more vulnerable to degradation [23]. However, there are other related factors, such as the creation of inadequate pastures due to inappropriate soil preparation or the use of forage germplasm not adapted to the agroecological conditions of the Brazilian Amazon [24]. The decline in arable land may be due to fluctuating market prices, which may have led to a switch to cattle ranching, where prices are more stable [22,24].

In the 7 de Setembro Indigenous Reserve, located in Cacoal-Rondônia, Brazil, deforestation is also observed, but in this case, it is more related to timber exploitation [25]. Between 2004 and 2016, a loss of 5,403 ha was recorded for the entire area of the indigenous reserve [24,25]. According to Le Tourneau (2015), indigenous groups need to find new economic activities to access goods that are now part of their way of life (from basic tools to household items such as freezers, televisions and mobile phones) [26].

Sustainability in this context is a complex task, especially as many of Brazil's indigenous Amazonian groups are undergoing social and cultural changes that are increasingly moving them away from the image most people have of them as hunter-gatherers lost in the rainforest [27]. At the same time, the internal perceptions of Brazil's indigenous Amazonian communities continue to be shaped by their cultural histories and cosmologies, which now shape the way many groups negotiate relations with outsiders and their expectations [26].

The Floresta Nacional (FLONA) Bom Futuro, a protected area for sustainable use located in the municipalities of Ariquemes and Porto Velho in Rondônia and managed by the Chico Mendes Institute for Biodiversity Conservation (ICMBio), was created in 1988 with the aim of promoting the management of timber resources in the region. Illegal occupation and deforestation of the reserve led the Brazilian government to evict farmers and ranchers from the region. In fact, the rate of deforestation using the Terra-i methodology in Bom Futuro has been 10,188 $ha.yr^{-1}$ over the last 7.5 years (for a total conversion of 76,406 ha), compared to 6,337 $ha.yr^{-1}$ over the last 7.5 years in the Jaciparaná River (for a total conversion of 47,525 ha) [28].

Another study showed that 1,288,600 ha were lost in

2004, rising to 1,686,688 ha in 2011 (an increase of 31%). During this eight-year period, a total of 11,454,044 ha of natural vegetation cover was lost, with an average loss of 1,431,755 ha.yr^{-1}. The highest annual losses were recorded in the states of Pará and Mato Grosso, with losses of 478,038 and 457,055 ha.yr^{-1}, respectively. Both states and Rondônia, with an average deforestation rate of 253,018 ha.yr^{-1}, form the so-called deforestation are within the Brazilian legal Amazon [29].

The environmental services provided by the Amazon rainforest require compensation as a way of encouraging changes in deforestation behaviour. Keeping the forest intact can be done in two ways: *i*) inducing private landowners to conserve intact portions of native vegetation on their land, which can be achieved through motivation or government enforcement in strict compliance with existing legislation, by requiring a "legal reserve" on each property, or by payments for environmental services (PES) to the landowner and *ii*) creating reserves on public lands. This creation of conservation units consists in the fragmentation of large areas that were still in the public domain, that is, belonging to the Union or the State, since Brazil is a Federal Republic [30].

Conservation units and indigenous reserves are extremely important for the protection and conservation of species. Conservation Units are areas with relevant natural characteristics whose function is to ensure the representation of significant and ecologically viable samples of the different populations, habitats and ecosystems of the national territory and jurisdictional waters, preserving the existing biological heritage. CUs ensure the sustainable use of natural resources and even allow the communities involved to develop sustainable activities within or around them [31].

The proposal of the present study for the implementation of conservation strategies for *A. acreana* is based on the sustainable use (i.e. giving it a direct use value) of its non-timber forest products (NTFPs) by the local population itself, represented by traditional uses - food and medicine - and by the suppression of its use as NTFP, which implies the felling of trees. In the latter case, the same rigorous application of the Brazilian Ministry of the Environment's Normative Law No. 06 of 23 September, 2008 can protect the species [4]. Exploring the possibility of new uses for the species, such as better exploitation of its photochemical compounds (e.g. coumarin, present in its seeds), could confirm its potential as an Amazonian NTFP with high value on world markets.

One possible initiative to be considered at the municipal level is the establishment of a conservation programme inspired by the UC (Conservation Unit) or RPPN (Private Natural Heritage Reserve) models. This programme would cover both localities within the municipality of Cacoal in Rondônia, Brazil, as described in [29,32]. The selection of these specific areas is based on the documented presence of more than six adult individuals in a confined area. This observation is of great importance due to the favourable microclimatic conditions of these sites, which create an environment conducive to the natural development of the species. Furthermore, it is imperative that the ecosystem services provided by *A. acreana* are recognised and considered [5,7], particularly in light of its inherent value as a public good. Similarly, the introduction of the total economic value - use and non-use value [23], for Amazonian biodiversity could contribute to its conservation, in this case as far as the Brazilian Amazon is concerned.

Conclusion

The State of Rondônia, and in particular the municipality of Cacoal, located in the vast and ecologically significant western Brazilian Amazon, faces a critical challenge regarding the conservation of *A. acreana*, a species now classified as “vulnerable”. The need for sustainable development in the Amazon region requires a coherent, transboundary legal framework that transcends national boundaries. It is clear that the mere enactment of protective measures within the jurisdiction of a single country is not sufficient to ensure the comprehensive conservation and protection of a species such as *A. acreana.*

At the local level, effective conservation strategies for *A. acreana* must focus on the sustainable use of its non-timber forest products (NTFPs), particularly in the areas of food and medicine. In addition, these strategies should include a careful assessment of the ecosystem services provided by the species. There is also an urgent need to establish a special category of protected areas, such as a Unique Conservation Unit (UC), in regions with favourable microclimatic conditions for *A. acreana* populations to thrive. Finally, strict legal constraints need to be enforced to regulate the use of *A. acreana* as an NTFP, thereby limiting overexploitation and ensuring its long-term viability.

Consent for publication

The authors read and approved the final manuscript.

Competing interest

The authors declare no conflict of interest. This document only reflects their point of view and not that of the institution to which they belong.

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