



Integrated Strategies for Tropical Flora Conservation and Sustainable Agriculture in the South of Lake Maracaibo Region, Venezuela

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ABSTRACT

The South of Lake Maracaibo in Venezuela is an ecological region that included a type of tropical humid forest that was deforested and transformed into a livestock system, currently leaving only 3% of the original ecosystem, restricted to small jungle relics that must be protected. To avoid the complete extinction of this ecosystem, the few conservation strategies that have been presented have attempted to include agricultural producers, highlighting the importance that these jungle relics may have for them in their agricultural developments as providers of ecosystem services. In this work, a bibliographic review is made of the conservation proposals and the foundations on which they are based. These proposals have focused on highlighting the importance of the Zingiberales order and the Araceae family as a source of genetic material in tropical floriculture and hosts of beneficial entomofauna for cocoa cultivation. It is important that future projects highlight the importance of forest fragments to address the climate crisis resulting from climate change.

KEYWORDS: Biodiversity, Ecosystem services, Conservation, Zingiberales, Jungle relics.

INTRODUCTION

Biodiversity refers to the variety of species in a given area and has a fundamental role in the functioning of ecosystems and in the environmental services that they can provide, which directly or indirectly benefit man, therefore, we must understand biodiversity as a beneficial resource for the well-being of the population.¹

Although the loss of biodiversity is a global problem, between 60 and 70% of the world's biodiversity is spread across a dozen countries, half of which are in Latin America, mainly due to their geographical location, its relief and history have allowed the development of an incalculable wealth of flora and fauna species¹. Within this context, Venezuela, considered a megadiverse country², needs to conserve this important wealth to guarantee true sustainable development.

Some authors point out that, in Latin American countries, due to the great diversity of species, complexity of ecosystems and the speed of their transformation, it is necessary to establish regional conservation strategies, and that is why one of the first challenges in Latin America is the incorporation of conservation as an economic and social priority for sustainable development.¹

The South of Lake Maracaibo is an Eco-region that included a type of tropical humid forest, with biodiversity, composed of a mixture of endemic Venezuelan floristic

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elements, with numerous elements of the Amazonian flora and the lowlands of Venezuelan Guayana, forming a sector of wide floristic diversity called “Refugio Catatumbo”.³ This eco-region was transformed and replaced by a livestock replacement system, leaving only 3% restricted to small jungle relics to date,^{4,5} making it necessary to study and preserve these remnants of the jungle that still remain.³

The region has several fauna reserves (Ciénagas de “Juan Manuel”, “Aguas Blancas” and “Aguas Negras”)³ and the national parks of Perijá and the Ciénagas del Catatumbo,⁶ in where authors such as defined mangrove communities important for their conservation, specifically at the mouth of the rivers that define the geographic area called Catatumbo Deltaic Complex. Even so, the loss of jungle and biodiversity has been notable.⁷

The South of Lake Maracaibo, in addition to being a livestock system, also cultivates plants, mainly musaceae, cocoa (*Theobroma cacao* L.) and oil palm (*Elaeis guineensis*), with the cultivation of criollo cocoa varieties being one of the most appreciated. and with greater potential, due to the high demand for fine cocoas in the world, this crop is a biodiverse agroforestry system with very complex management, which has recently had a significant boom and is presented as an opportunity to highlight the importance of the biodiversity of the jungle remnants, and encourage their conservation.

For this reason, for the conservation of biodiversity in the South of Lake Maracaibo in Venezuela, different strategies could be proposed to encourage the preservation of jungle relics, mainly highlighting their importance as providers of ecosystem services within farms and developments established agricultural lands and the benefits of their preservation to better address the climate crisis resulting from climate change.

In conservation strategies it is important to maintain and recover areas that provide refuge to a large number of organisms, promoting connections across the landscape, restoring and protecting riparian ecosystems that link fragments that facilitate the movement of species between the different jungle relics. This biodiversity can play an important role in agricultural systems such as cocoa, in which problems are reported due to low densities of pollinators and as a solution, different effective strategies are proposed to increase these populations (*Foripomyia* spp),⁸⁻¹⁰ but with the maintenance of more biodiverse surrounding areas it can also be a solution to consider.

Studies have shown that preserving forested areas of the landscape increases the abundance of pollinators, which leads to greater pollination success. Crop pollination services consist of beneficial organisms migrating from forests to adjacent agroforestry systems and increase the abundance of insects, likewise, these decrease when nearby forest patches are missing,^{11,12} and by forest fragmentation.¹³ In Costa Rica, some authors observed that pollinators quickly colonize cocoa crops adjacent to forest remains, since they provide the necessary food resources and breeding sites for their optimal development, demonstrating that forest conservation is necessary to improve the abundance of pollinators.¹⁴ It is also reported that forest patches close to cocoa cultivation improve the quantities of pollinators, nutrients in the soil and make them more resilient to climate change.¹⁵

For the conservation of biodiversity in the South of Lake Maracaibo, in a first step, they planned to establish collections of tropical flowers of native live plants, one belonging to the order Zingiberales¹⁶ and another from the Araceae family, mainly to highlight the potential uses that these may have within tropical floriculture and in the cocoa and coffee agroecosystems by serving as a host for beneficial entomofauna in the phytotelmata systems that can be established in their inflorescences,¹⁷ as well as there are some species in these botanical groups that need attention because they are currently in a vulnerable state or threatened with extinction.

This study, highlights the main characteristics taken into account in the plant groups selected as a flag to establish *ex situ* living plant collections and discusses the importance of the conservation of these botanical families in the preservation of the biodiversity of the South of Lake Maracaibo of Venezuela, highlighting the conservation of forest remnants as providers of ecosystem services.

STUDY AREA

The south of Lake Maracaibo is an eco-region made up of about 795,000 hectares of the states: Mérida, Táchira and Zulia, it constitutes the foothills of the Mérida Mountain Range, alluvial plains and swamps of Lake Maracaibo of Venezuela,⁴ ecologically it constitutes a Macrothermal Humid Forest called the Maracaibo Lake Depression, made up of colluvio-alluvial plains dissected by the courses of rivers coming from the Perijá Mountain Range and the Andes, southwest of the Zulia state and northeast of the Mérida state; The combination of floristic elements endemic to Venezuela, the Amazon and Guyana makes it a unique ecosystem³ (Figure 1).

Of this original ecosystem, only small forest remnants remain, located mainly on the farms of agricultural producers in the area, who are unaware of the importance these remnants can have in the conservation of biodiversity, in the provision of ecosystem services, and in addressing the challenge of climate change (Figure 2).

MATERIALS AND METHODS

This review primarily presents the results of the flora conservation program in the Southern Lake Maracaibo region, which has been carried out for approximately ten years, it includes a discussion of the articles available on Google Scholar, covering the main plant groups, proposals for biodiversity conservation, and the integration of agricultural production with conservation criteria, sustainable agriculture, and climate resilience.

The most relevant characteristics for selecting the main plant groups for conservation in the southern Maracaibo Lake region were established. Subsequently, specimens were collected from the forest remnants for propagation in nurseries and later planted in the field.

For the establishment of a collection of tropical flowers native to the South of Lake Maracaibo, the Order Zingiberales and the Araceae family were chosen. The selection criterion of these two plant groups was mainly due to the interest that exists among the residents of the South of Lake Maracaibo for its flowers and foliage, who practice extraction floriculture.



Figure 1. South of Lake Maracaibo. Venezuela



Figure 2. Remnant of the original forest, located within a cattle ranch in the Southern Lake Maracaibo. Venezuela.

These two plant groups are of great importance within tropical floriculture as cut flowers, landscaping, foliage^{18,19} and a potential use within cocoa and coffee agroforestry systems¹⁷ due to the presence of phytotelmata systems,^{20,21} which allow the development of hosts for beneficial entomofauna.²²

Order Zingiberales

The order Zingiberales encompasses a group of tropical monocotyledons made up of eight families: Musaceae, Strelitziaceae, Lowiaceae, Heliconiaceae, Zingiberaceae, Costaceae, Cannaceae and Marantaceae. Two of them, Musaceae and Lowiaceae, are not native

to the Neotropics, while Heliconiaceae and Cannaceae are exclusive to the American tropics,²³ although there is a group made up of eight species of Heliconiaceae that are found in the South Pacific.²⁴

The botanical order Zingiberales, in addition to its importance within tropical floriculture, can be a source of dyes.²⁵ Specifically in the South of Lake Maracaibo, some native species of the Heliconiaceae family, such as: *Heliconia bibai* L. and *Heliconia lathysphata* Benth., are used as cut flowers and landscaping, as is the case with some Costaceae such as: *Costus malortieanus* H. Wendl. and *Costus spiralis* (Jacq.) Roscoe, while the Marantaceae *Thalia geniculata* L. and *Calathea lutea* (Aubl.) E. Mey. Former Schult., they are appreciated for their

foliage. This last species is used to make craft objects from its fiber and also to wrap hallacas, a typical dish of Venezuelan cuisine.¹⁶

After Colombia and Ecuador, Venezuela is the most biodiverse country in Heliconias²⁶ these have bracts with exotic structures and showy colors that constitute their main ornamental attraction.¹⁸ These bracts in species that have erect inflorescences contain a fluid that is frequently secreted by the plant and is enriched with rainwater;²⁷ they also accumulate organic matter, forming microecosystems called phytotelmata, which house a large amount of invertebrate and vertebrate fauna, similar to those of bromeliads.^{20,28}

The plant *Heliconia bibai*, (Figure 3) was proposed as a species that has great potential among the native Heliconiaceae

to be used as a host for entomofauna in cocoa agroforestry systems in the South of Lake Maracaibo. Due to its erect inflorescence, the size and number of bracts that, when accumulating water, establish Phytotelmata systems that can play a very important role for the biology of beneficial entomofauna such as that of cocoa pollinators, whose low population constitutes one of the main limitations in production.¹⁵



Figure 3. *H. bibai* inflorescence with bracts that allows establishing phytotelmata systems. located in a jungle remnant south of Lake Maracaibo. Venezuela.

Family Araceae

The South of Lake Maracaibo in the foothills of the Mérida Mountain Range, next to the foothills of the Sierra de Perijá, constitutes one of the seven floristic regions of araceae diversity in Venezuela.²⁹ Some researchers point out that among these regions the richest area per unit area is the Cordillera de Mérida, mainly due to the different elevations and habitats.³⁰

Precisely in the foothills of the Mérida Mountain Range, two endemic species from the south of Lake Maracaibo have been reported: *Philodendron mesae*^{30,3} and *Syngonium meridense*,³⁰ which can be in danger of extinction due to the disappearance of its natural ecosystem.

Within the Araceae family, the Anthurium genus is one of the most important in global tropical floriculture. This genus consists of about 1100 Neotropical species and its center of diversity is the northern Andes between Colombia and Venezuela, reported for the latter country seventy species.^{29,31}

RESULTS

Establishment of a Collection *Ex situ* Living Plant Collections of Native Flowers from the South of Lake Maracaibo

Biodiversity conservation can be carried out in two ways: *in situ* and *ex situ*. *In situ* conservation refers to complete ecosystems, while *ex situ* conservation keeps germplasm outside their natural environments³² and complements *in situ* conservation in many ways, it also allows the study of plant groups of interest and provides propagules for ecological restoration, research and educational programs.³³

With these collections, we are providing users from the scientific community, students, producers and the community in general, with activities of interest that promote conservation and are the basis for conducting education and public awareness projects regarding the importance of biodiversity and its conservation.

Threatened and Vulnerable Species

Among the native species of the order Zingiberales and the family Araceae of the South of Lake Maracaibo important for their conservation in these special *in situ* and *ex situ* programs, *Heliconia mariae* stands out, considered a vulnerable species (Figure 4), *Philodendron mesae*, an almost threatened species,³⁴ and *Syngonium meridense* are endemic species,³⁰ whose current status is unknown and surely, due to the high rate of deforestation, it is being subjected to high extinction pressure (Table 1).

Use of Native Plant Biodiversity

The species *H. bibai* (Figure 3), is proposed as a plant that can be used in cocoa agroforestry systems to increase pollinator population densities (Table 1), which is a major problem for producers in the South of Lake Maracaibo, although this still needs to be proven.¹⁷



Figure 4. *H. Mariae* species in vulnerable state. located in a jungle remnant south of Lake Maracaibo. Venezuela.

Table 1. Main species of Zingiberales and Araceae in the flora conservation programs of the southern Lake Maracaibo region, Venezuela.

Species	Importance of conservation
<i>Heliconia mariae</i>	Vulnerable species
<i>Philodendron mesae</i>	Almost threatened
<i>Syngonium meridense</i>	Status is unknown
<i>Heliconia bibai</i> L.	Proposed as a plant that can be used in cocoa agroforestry systems to increase pollinator population densities

Benefits of Preserving the Forest Remnants Found within Agricultural Estates

In the outreach programs conducted by the National Experimental University of Southern Lake (UNESUR), many agricultural producers have been involved, and they have been emphasized the importance of conserving the remaining patches of the original forest, as a source of biodiversity, such as the order Zingiberales and the Araceae family, as well as other ecosystem services, and resilience in the face of climate change.

Needs for Future Research

The biodiversity conservation proposals in the southern Lake Maracaibo region are based on many hypotheses or assumptions that need to be scientifically proven. It must be demonstrated whether Heliconias with erect inflorescences, such as *H. bibai*, can increase pollinator densities in cocoa agroecosystems.

It must also be demonstrated how forest remnants can benefit agricultural producers by providing ecosystem services, such as pollinators and regulating temperature fluctuations, given the high temperatures typical of the American Tropics, which have recently increased due to climate change.

Inclusion of Agricultural Producers in Conservation Programs

Agricultural producers, as owners of the lands where the forest remnants are located, must be included in the conservation program. To this end, it is important to demonstrate to them the importance of maintaining these forest remnants to address future environmental problems resulting from climate change, such as the high temperatures recorded primarily during the dry season, as well as their role in the production and regulation of the water cycle, since their dense vegetation and evapotranspiration contribute to atmospheric humidity and the maintenance of water sources.

This stage is important because, for an agricultural producer, a patch of forest is idle land, and it is more beneficial for them to clear it and establish pastures or highly profitable tropical crops.

CONCLUSION

The South of Lake Maracaibo, is a region where the original tropical humid forest ecosystem was transformed and replaced by a livestock system, leaving today some small jungle relicts, for which there is very little interest in preserving them, demonstrated by the limited

conservation work that has been carried out; an attempt has been made to highlight the importance of floristic biodiversity, especially of the botanical taxa of the order Zingiberales and the Araceae family present within the relicts, due to the fact that the inhabitants of the South of the Lake Maracaibo are identified with these, mainly because they are plants of great ornamental value, but currently with the boom that cocoa cultivation is having, it is proposed to address the problem of low pollination rates with the introduction of native heliconia plants within this agroforestry system. For the future, research must be done to determine and highlight the importance of relicts as providers of ecosystem services related to pollinators and also how they can help agroecosystems face problems related to climate change, making them more resilient. All this work must include agricultural producers, owners of the land, they must feel that they perceive some type of benefit from the presence of forest fragments and decide to maintain and protect them.

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CONFLICT OF INTEREST

No conflict of interest declared.

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