Threats to the Vegetation of the Colombian Orinoquia: A Novel Approach for Its Assessment

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Article

Threats to the Vegetation of the Colombian Orinoquia: A Novel Approach for Its Assessment

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Abstract: In the Colombian Orinoquia, the principal threats to flora and vegetation stem from selective logging and land-use changes. To assess these threats, an ordinal classification was performed based on the conservation urgency of phytosociological alliances and their characteristic flora. A multicriteria model was developed using the Analytical Hierarchy Process (AHP), incorporating data from IUCN Threatened Species lists, field surveys detailing local plant species uses, species geographical distribution, and habitat quality observations. A total of 281 vegetation surveys were carried out in grasslands and 178 in forests. In the grasslands, 258 angiosperm species were recorded, with 13 classified as highly threatened, and one phytosociological alliance categorized as critically threatened. In the forest plots, 546 angiosperm species were identified, with three phytosociological alliances considered highly threatened. Although the use of IUCN categories aids in comparing species' conservation statuses, these categories do not explicitly reflect the specific threats faced by vegetation types. Therefore, we propose that multicriteria models for threat assessment provide a more nuanced understanding of the threat and conservation status of each vegetation type, offering a more comprehensive framework for conservation efforts.

Keywords: Neotropical savannas; Colombian Orinoquian region; Vegetation types of Colombia; Threatened flora and vegetation of Colombia; Analytical Hierarchy Process (AHP)

1. Introduction

In recent decades, the assessment of threats to biodiversity has been guided by the criteria established by the IUCN [1]. The loss of vegetation cover and fragmentation present substantial risks to the geographic range and the integrity of many original habitats [2]. The qualitative and quantitative characterization of land use and biodiversity, combined with an understanding of the levels of human exploitation, provide critical inputs for the development of new methods for territorial zoning [3,4].

The Colombian-Venezuelan Llanos, encompassing approximately 532,000 km² (254,000 km² in Colombia and 278,000 km² in Venezuela), represent the second-largest expanse of neotropical savannas on the continent [5,6]. This region is particularly notable for the diversity and floristic composition of its phytocenoses, as well as for its intricate ecological processes [7]. Additionally, in Colombia the area is home to four National Natural Parks (PNN El Tuparro, PNN Serranía del Manacacías, PNN Tinigua, and PNN Sierra de La Macarena), one Integrated Management District (DMI Cinaruco), and two areas in the process of protection (Arauca Wetlands and Transitional Forests of Cumaribo).

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However, the biodiversity of this region is increasingly threatened by various anthropogenic activities, including deforestation, mining, livestock farming, and the establishment of monocultures, among others. These activities have significant impacts on the region's flora and, consequently, on the extent and structure of its plant communities and ecosystems [2,3,4]. Since the latter half of the 20th century, developmental processes have notably altered the physical conditions of the region's natural environment. The expansion of agricultural and livestock frontiers, along with government-issued licenses for oil and mineral extraction, has resulted in the fragmentation of vegetation types and the alteration of distribution areas for many taxa [8,9,10]. In this context, evaluating and assessing the threats faced by the region's vegetation is crucial for ensuring the conservation of its biodiversity and preserving its landscape value.

Rangel-Ch. [11], Minorta-Cely & Rangel-Ch. [9]), Rátiva et al. [12,13,14], and Niño [2,3,4], observed that the criteria proposed for assigning categories were, in some cases, difficult to apply due to a lack of sufficient field data on populations and their distribution areas. Moreover, reliable ecological estimates of abundance, dominance, and density—derived from vegetation inventories—were frequently overlooked in the evaluation process. Consequently, they proposed the inclusion of additional criteria, such as the overuse of the species, the representativeness of the species' distribution within the geographical area (number of collection sites), biological distinctiveness (endemism), past habitat transformation due to human activities, and potential impacts from infrastructure projects, including roads and civil works, which could affect the original conditions. This integrative approach offers a robust framework for assessing threats to vegetation. In the analysis of vegetation types, the conservation status of vegetation (forests, shrublands, and grasslands) and the surrounding environment (habitat) were considered, alongside the representativeness (distribution) or extent of the vegetation type within the study area. In cases where forest or shrubland fragments were present, the type of matrix in which these fragments were embedded—whether natural, agricultural, or livestock-based—was recorded.

The aim of this article is to propose a new model for evaluating the threats faced by the vegetation of the Colombian Orinoquia (grasslands and forests). In doing so, we integrate the IUCN guidelines with observations on the habitat in which the vegetation is established, as well as the potential uses of the species characteristic of each described phytocenoses by local human populations. Our approach is based on the following hypotheses: threats to vegetation types will increase when: I) Among its characteristic species there is flora reported as threatened according to IUCN; II) At least one of their characteristic species demonstrates significant versatility (i.e., a greater number of uses), any of their characteristic or dominant species are associated with logging or the significant extraction of their parts; and III) as habitat fragmentation or degradation intensifies. Thus, we propose that the development of multicriteria models for threat assessment offers a more comprehensive understanding of the current threat status and, consequently, the conservation status of each vegetation type.

2. Materials and Methods

2.1. Study Area

The Colombian Orinoquia is in the eastern plains of the country and includes the localities of the Arauca, Casanare, Meta, and Vichada departments. Geographically, it extends from the foothills of the Eastern Cordillera in the west to the Orinoco River in the east, and from the Guaviare River in the south to the Arauca and Meta rivers on the northern border with Venezuela. Four physiographic units are recognized: the foothills (referred to as *piedemonte*), alluvial plains, high plains, and the La Macarena Mountain Range [15-18]. Based on drainage characteristics and geomorphological processes, the region can be divided into two distinct units exhibiting different relief patterns: the well-drained Orinoquia (eastern Meta River, and the Meta and Vichada departments), characterized by high plains that are variously dissected, low hills, and different levels of terraces; and the poorly

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drained Orinoquia (western Meta River, and the Casanare and Arauca departments), characterized by alluvial fans and either alluvial or eolic plains [19].

2.2. Species Richness Patterns

The records include 4347 species of flowering plants from 1347 genera and 184 families [20, 21], with the most diversified families being Rubiaceae (716 spp.), Fabaceae (503 spp.), Poaceae (292 spp.), Melastomataceae (234 spp.), and Asteraceae (156 spp.).

In the alluvial plain, 1131 species from 491 genera and 110 families were recorded, with the most diversified families being Fabaceae, Poaceae, Cyperaceae, Rubiaceae, and Melastomataceae. In the forests, a total of 642 species were identified, with the families Fabaceae (s. l.), Rubiaceae, Malvaceae (s. l.), Sapindaceae, and Poaceae dominating. In the grasslands, 371 species were recorded, with the richest families being Poaceae, Cyperaceae, Fabaceae (s. l.), Melastomataceae, and Malvaceae (s. l.) [22].

In the northern part of the high plain, in the Serranía de Manacacías region (Meta), 2368 species from 896 genera and 146 families were recorded, with the most diversified families being Fabaceae, Poaceae, Rubiaceae, Cyperaceae, and Melastomataceae. In the forests, 611 species were recorded, with dominance by the families Fabaceae, Melastomataceae, Rubiaceae, Euphorbiaceae, and Annonaceae. In the grasslands, 573 species were recorded, with the richest families being Poaceae, Fabaceae, Cyperaceae, and Melastomataceae [23].

In the southern part of the highland landscapes (altillanura) in the Cumaribo region (Vichada), 1657 species from 648 genera and 128 families were recorded, with the most diversified families being Fabaceae, Rubiaceae, Poaceae, Melastomataceae, and Apocynaceae. In the forests, 1276 species were identified, with the families Fabaceae, Rubiaceae, Melastomataceae, and Apocynaceae predominating. In the grasslands, 523 species were recorded, with the richest families being Poaceae, Fabaceae, Rubiaceae, and Cyperaceae [24].

2.3. Vegetation

Alliances are units with a floristic component, defined by their characteristic-dominant species and the associated soil and climate conditions (with humidity being clearly distinguished). The concept of alliances has been employed in various integrated studies of biota and biodiversity in Colombia as a reference point for defining ecosystems [25,26]. Some of the initial studies on the vegetation of the Orinoquia region of Colombia include those by [27,28,29]. In the past decade, more detailed characterizations using a phytosociological approach (i.e., classes, orders, alliances, associations) have been conducted, allowing for the integration of floristic composition and structural aspects. These studies were carried out by [30]. More recently, the alliance has served as the fundamental unit in the preparation of cartography (maps at various scales) of Colombia's natural vegetation [31]. For these reasons, we have chosen this level (alliances) as the reference unit for threat assessment.

The recent phytosociological classification of the grasslands in the Orinoquia region of Colombia comprises one class, three orders, nineteen alliances. The class *Schizachyrio sanguinei - Trachypogonetea spicati* is widely distributed across the geographic subregions of Orinoquia, primarily in the high plains ("altillanura"), along the banks of the alluvial plain, scattered in the eolic plain, and occasionally in the fringes of the foothills. This class is represented by three orders: *Axonopodo purpusi - Paspaletalia pectinati*, with seven alliances; *Schyzachyrio brevifoli-Trachypogonetalia spicati*, with five alliances; and *Axonopodo purpusi - Andropogonetalia virgati*, with seven alliances [32].

In the forests, three classes were defined: *Maquiro coriaceae-Copaiferetea pubiflorae*, which includes the order *Brosimo lactescentis-Oenocarpetalia minoris* with three alliances; the order *Iryanthero laevis-Oenocarpetalia batauae* with two alliances; the order *Alchorneo discoloris-Protietalia llanori* with five alliances; the order *Alibertio edulis-Mabeetalia trianae* with two alliances; and the order *Ocoteo bofo-Mabeetalia trianae* with three alliances. The second class, *Brosimo lactescentis-Eschweileretea subglandulosae*, includes the order *Mabeo nitidae-Mespilodaphnetalia cymbari* with two alliances and the

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order *Phenakospermo guianensis-Minquartietalia guianensis* with one alliance. The final class, *Jacarando copaiae-Luehetea seemani*, includes the order *Pouterio stipitatae-Terminalietalia amazoniae* with two alliances [33].

2.4. Threatened Flora

A previous study on the threatened flora of the Colombian Orinoquia [9] indicated that of the 4,347 species present in the region, 992 species were classified as being under some degree of threat. The category of Least Concern (LC) encompassed the largest number of species (693). Of the remaining species, 282 were classified as Vulnerable (VU), 10 as Endangered (EN), 4 as Near Threatened (NT), and 3 as Critically Endangered (CR). The families with the highest number of threatened species were Fabaceae (94 species; 41 VU), Rubiaceae (44 species; 13 VU, 1 EN, 1 CR), Poaceae (36 species; 3 VU), and Chrysobalanaceae (35 species; 6 VU). In Arecaceae, 21 threatened species were classified (8 VU, 2 EN). Subsequent contributions [12-14] provide detailed information, based on general collections (all taxa), regarding the threats to flora and vegetation in various localities across the subregions of the Orinoquia, including the alluvial plain, highlands, and piedmont or foothills. In summary, the global pattern indicates that the families with the greatest number of threatened species are Fabaceae, Poaceae, Cyperaceae, Arecaceae, and Chrysobalanaceae.

2.5. Input Data

In this contribution, plant threat category assessments are based on records of taxa found in each of the inventories (vegetation surveys or study plots) for grassland formations and forests. The tables presenting richness patterns include figures on the species listed in the regional floristic inventory and their respective threats, along with those found in the inventories.

2.6. Analytic Hierarchical Process (AHP) Model

The methodological guidelines and theoretical considerations for this study are based on the methods recommended by [2, 34-36]. The AHP methodology unfolded in three steps: first, modeling or structuring the relevant variables for the evaluation to ensure a comprehensive consideration of pertinent factors; second, assessing or incorporating the evaluators' preferences through established judgments in a matrix of paired comparisons, allowing a systematic evaluation of criteria based on their importance; and third, prioritizing or calculating the weight vector of the criteria considered in the evaluation. This weight vector was then integrated with the criteria to calculate the threat level [37-40].

2.7. Model Criteria

For this analysis, we utilized input data from IUCN threat categories [1] and threat characterizations described by [12-14]. Additionally, the model incorporated information regarding species uses by local human communities, an estimated threat category derived from field observations on the prevalence of natural or fragmented vegetation cover, as well as the species' geographical distribution and commercial value (if applicable). Information on the degree of exploitation and habitat quality was also integrated into the model [9,12-14]. The threat criteria and their relative importance were aligned with the registered threat levels and assigned standard ordinal values ranging from zero to one, according to the degree of threat (Table 1). The final assessment for versatile species (where versatility refers to the number of use types associated with a species—the higher the number, the greater the versatility) was derived from the sum of points assigned to the different registered uses of the species.

2.8. Criteria Weights

A square matrix was constructed using paired comparisons to establish a correspondence scale linking qualitative assessments to numerical values [34-35]. This matrix of relative priorities

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incorporates ascending categories from the IUCN Red List, species uses, and field observations. Furthermore, a standard matrix was computed to estimate the weight vector for the criteria included in the anthropogenic classification of threats (Table 1).

2.9. Criteria Integration and Threat Level Classification

The weighting of each criterion was applied according to the assigned weights. The resulting score is the product of these values for each of the proposed alternatives or threat levels for each species. A weighted linear sum was calculated, resulting in a single threat score derived from the sum of the weighted criteria. This value was determined based on the weight assigned to each species and the total threats to species within their syntaxonomic categories. Finally, these values were classified using the natural breakout method [2-4]. This methodology grouped the data based on its inherent characteristics, identifying ranges of similar values and maximizing the differences between categories.

Table 1. Criteria for the Categorization of Threats to Target Species assessment and normalized priority matrix.

Initial weight	Criterium	Alternative	Designed value	Use	IUCN	Weights	Assessment	λ
5	IUCN	Critically endangered (CR)	1	3	1	0,633	1,946	3,072
		Endangered (EN)	0,8					
		Vulnerable (VU)	0,6					
		Near threatened (NT)	0,4					
		Least concern (LC)	0,2					
		Data deficient (DD)	0					
3	Uses	Timber	0,99	1	0,333	0,26	0,79	3,033
		Ornamental	0,83					
		Medicinal	0,66					
		Forage	0,49					
		Edible	0,33					
		Protective	0,16					
		Data deficient (DD)	0					
1	Field assessment	Endangered (EP)	0,99	0,333	0,2	0,106	0,32	3,011
		Near threatened (CA)	0,66					
		Least concern (PM)	0,33					
		Data deficient (DD)	0					

3. Results

3.1. Model Fit and Validity

The degree of inconsistency in the decision-making judgments was assessed using the Consistency Index. The average eigenvalue λ (3039) indicated a stable assessment within the standard priority matrix, meaning that the values were close to, and never less than, the number of criteria (3). The calculated Consistency Index was 0.019, which was derived from the Consistency Reason calculation using a Random Consistency Index of 0.5245. This value was obtained by generating 500,000 random matrices for three criteria [36]. The Consistency Ratio was 0.037. In this study, the weight vector was considered to have an acceptable inconsistency ratio of >0.1 (Table 1).

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3.2. Richness Patterns in Grasslands

The analysis is based on inventories from 281 plots, which documented 258 species across 156 genera and 62 families of flowering plants (Table 2). The families exhibiting the highest richness in genera and species are Poaceae (25 genera/50 species), Fabaceae (13/24), Cyperaceae (6/23), Melastomataceae (7/16), and Rubiaceae (11/14). These findings align closely with the richness pattern previously observed for the entire Orinoquia. Other families, such as Eriocaulaceae, Lythraceae, Orobanchaceae, and Convolvulaceae, are well-represented in the inventories but do not appear prominently in the regional richness pattern. Conversely, families like Apocynaceae, Araceae, Acanthaceae, Gentianaceae, and Solanaceae, though underrepresented in the inventories, display significant representation in the regional pattern across the entire region. In grasslands, at the genus level, the genera richest at the regional level are similarly represented in the inventories. However, some of the richest genera at the regional level, such as *Scleria*, *Panicum*, *Spermacoce* (s.l.), *Palicourea*, and *Bulbostylis*, do not exhibit the same prominence in the inventories (Table 2).

Table 2. Richness floristic patterns of the Colombian Orinoquia grassland.

A. Families			**B. Genera**		
Family	**Plots vegetation**	**All Orinoquia**	**Genera**	**Plots vegetation**	**All Orinoquia**
	Gen #/Spp #	**Gen #/Spp #**		**Spp #**	**Spp #**
Poaceae	25/50	60/169	*Paspalum*	12	29
Fabaceae	13/24	46/120	*Rhynchospora*	8	24
Cyperaceae	6/23	13/88	*Andropogon*	6	9
Melastomataceae	7/16	20/51	*Crotalaria*	5	6
Rubiaceae	11/14	27/64	*Eleocharis*	5	8
Asteraceae	8/8	29/38	*Hyptis*	5	12
Malvaceae	5/8	10/21	*Miconia*	5	20
Euphorbiaceae	6/7	8/18	*Axonopus*	4	10
Lamiaceae	2/6	4/15	*Cuphea*	4	7
Eriocaulaceae	4/5	4/10	*Ludwigia*	4	12
Lythraceae	2/5	2/9	*Acisanthera*	3	4
Malpighiaceae	2/4	5/11	*Aeschynomene*	3	6
Onagraceae	1/4	1/12	*Buchnera*	3	4
Orobanchaceae	2/4	3/6	*Byrsonima*	3	6
Convolvulaceae	1/3	3/4	*Chamaecrista*	3	9
Count from 15 richest families	**96/181**	**235/636**	**Sum from 15 richest genera**	**73**	**166**
Other families	60/77	221/384	Other genera	185	854
Total	**156/258**	**456/1020**	**Total**	**258**	**1020**

Plots vegetation: [30].

3.3. Richness Patterns in Forests

The analysis was based on inventories from 178 plots, which documented 700 species of flowering plants across 272 genera and 79 families (Table 3). The families exhibiting the highest richness in genera and species are Fabaceae (37 genera/87 species), Rubiaceae (20/40), Arecaceae (11/35), Moraceae (9/34), and Annonaceae (6/33), which shows considerable alignment with the regional pattern observed across the Orinoquía. Other families, such as Burseraceae,

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Chrysobalanaceae, Myrtaceae, and Salicaceae, are well-represented in the inventories but do not align with the regional richness pattern. Conversely, families like Poaceae, Asteraceae, Cyperaceae, Orchidaceae, Sapindaceae, Araceae, and Piperaceae, although underrepresented in the inventories, are more prominent in the regional pattern across the entire region. These differences are most likely due to variations in sampling methodologies and the condition of the selected sites. In our approach, it is essential to select sites based on physiognomic homogeneity and good conservation status, ensuring they are not subject to selection, logging, or other anthropogenic disturbances. At the genus level, the analysis revealed a consistent pattern of richness for *Protium*, *Inga*, *Ficus*, *Miconia*, and *Pouteria* (Table 3). However, genera that are species-rich at the regional level, such as *Psychotria* (s.l.), *Palicourea*, *Paspalum*, *Solanum*, and *Clusia*, do not exhibit the same richness in the plots or inventories.

Table 3. Richness floristic patterns of the Colombian Orinoquia forests.

A. Families			**B. Genera**		
Family	**Plots vegetation**	**All Orinoquia**	**Genera**	**Plots vegetation**	**All Orinoquia**
	Gen #/Spp #	**Gen #/Spp #**		**Species #**	**Species #**
Fabaceae	37/87	112/475	*Protium*	11	30
Rubiaceae	20/40	107/693	*Inga*	10	45
Arecaceae	11/35	22/59	*Ficus*	9	26
Moraceae	9/34	17/65	*Bactris*	8	11
Annonaceae	6/33	17/72	*Casearia*	8	18
Melastomataceae	7/29	33/223	*Miconia*	8	117
Apocynaceae	10/26	35/98	*Ocotea*	8	17
Burseraceae	6/25	7/50	*Xylopia*	8	14
Euphorbiaceae	12/25	32/88	*Guatteria*	7	16
Bignoniaceae	12/21	27/83	*Virola*	7	10
Chrysobalanaceae	7/21	9/46	*Cordia*	6	19
Lauraceae	5/21	10/61	*Eschweilera*	6	11
Malvaceae	11/17	37/129	*Hirtella*	6	13
Myrtaceae	6/16	11/52	*Pouteria*	6	27
Salicaceae	4/14	9/31	*Tabernaemontana*	6	10
Count from 15 richest families	**163/442**	**485/2225**	**Sum from 15 richest genera**	**114**	**384**
Other families	109/258	815/2553	Other genera	432	4394
Total	**272/700**	**1300/4778**	**Total**	**546**	**4778**

Plots vegetation: [30].

3.4. Target Species Threats classification

In grasslands, 212 species were selected for the assessment of their threat categories. The families with the highest number of threatened species were Poaceae (50 species), Fabaceae (24), Cyperaceae (23), Melastomataceae (16), Rubiaceae (14), and Asteraceae (8). Two species were classified under the "very high" threat category: *Paspalum conjugatum* in the Serranía de Manacacías and Cumaribo, and *Miconia albicans* in the Serranía de Manacacías, the wetlands of Arauca, and Cumaribo [29-31]. In

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comparison to the regional pattern, there is alignment with the classification of the families Fabaceae, Poaceae, Rubiaceae, Cyperaceae, and Asteraceae. However, families such as Bromeliaceae, Chrysobalanaceae, and Melastomataceae, which contain a high number of species with some degree of threat, do not exhibit the same level of representation in the grasslands.

In the high-threat category, 12 species were classified: Acroceras zizanioides, Caladium macrotites, Chamaecrista diphylla, Chamaecrista rotundifolia, Grona barbata, Eriosema simplicifolium, Ipomoea schomburgkii, Miconia rufescens, Pterogastra divaricata, Rhynchanthera bracteata, Ruellia geminiflora, and Xanthosoma striatipes. Among these, Acroceras zizanioides is particularly important as a dominant species in certain vegetation types, where it is listed as threatened in the wetlands of Arauca and the Serranía de Manacacías. Some species, such as Caladium macrotites, Ipomoea schomburgkii, and Rhynchanthera bracteata, were not previously listed as threatened in earlier studies. In the medium-threat category, 53 species were classified, including dominant species in vegetation types such as Cyperus haspan, Axonopus purpusii, Schizachyrium brevifolium, Eriocaulon humboldtii, Phyllanthus fluitans, and Tonina fluviatilis. Additional species in this category are provided in Appendix A1. In the low-threat category, 145 species were included, with dominant species such as Andropogon bicornis, Andropogon virgatus, Anthaenantia lanata, Blechum pyramidatum, Ichthyothere terminalis, Leersia hexandra, Rhynchanthera grandiflora, Rhynchospora nervosa, and Schizachyrium sanguineum. Further species in this category are listed in Appendix A2.

In forest, 494 species were selected to estimate their threat category. The families with the highest number of threatened species were Fabaceae (67), Rubiaceae (31), Arecaceae (27), Moraceae (26), and Annonaceae (24). Within the very high-threat category, 116 species were classified. The following species, dominant in certain vegetation types, have also been recognized in previous studies within the threat categories: *Mespilodaphne cymbarum* in Arauca, Manacacías, and Cumaribo; *Ocotea leptobotra* in Arauca and Manacacías; *Vitex capitata* in Arauca and Cumaribo; *Ceiba pentandra*, *Minquartia guianensis*, *Licania mollis*, and *Zygia cataractae* in Cumaribo; *Guatteria maypurensis*, *Inga nobilis*, and *Zygia inaequalis* in Manacacías; and *Annona jahnii* in Arauca. Additional species, also dominant in various vegetation types, include *Brosimum guianense*, *Brosimum lactescens*, *Brosimum utile*, *Calophyllum brasiliense*, *Cedrelinga cateniformis*, *Copaifera pubiflora*, *Duguetia quitarensis*, *Erythrina poeppigiana*, *Guarea guidonia*, *Himatanthus articulatus*, *Hymenaea oblongifolia*, *Inga vera*, *Mabea montana*, *Mabea nitida*, *Ocotea bofo*, *Protium aracouchini*, *Tapirira guianensis*, *Virola calophylla*, and *Vitex orinocensis*. Further species in this category are detailed in Appendix A3.

A total of 105 species are classified in the high-threat category, many of which are significant due to their dominance in vegetation types and have been identified as threatened in previous studies. These include *Mabea trianae* and *Protium calanense* in Arauca and Cumaribo; *Caraipa llanorum* in Cumaribo; and *Trattinnickia rhoifolia* in Arauca; as well as *Mauritia flexuosa* and *Aniba perutilis* in Manacacías, Arauca, and Cumaribo. Additionally, the following species are dominant across various vegetation types: *Chamaedorea pinnatifrons*, *Cochlospermum vitifolium*, *Guadua angustifolia*, *Jacaranda copaia*, *Maquira coriacea*, *Oenocarpus mapora*, *Protium heptaphyllum*, *Protium llanorum*, *Pseudolmedia laevigata*, *Pseudolmedia laevis*, *Trichilia martiana*, and *Zanthoxylum caribaeum*. Other species within this category are provided in Appendix A4.

A total of 152 species were classified in the medium-threat category, many of which are significant due to their dominance in vegetation types and have been identified as threatened in previous studies [9, 12-14]. These species include: *Attalea maripa*, *Bactris major*, *Euterpe precatoria*, *Oenocarpus minor*, *Socratea exorrhiza*, and *Syagrus orinocensis* in Arauca, Manacacías, and Cumaribo; *Astrocaryum acaule*, *Attalea butyracea*, *Desmoncus orthacanthos*, and *Spondias mombin* in Arauca and Cumaribo; *Enterolobium schomburgkii* and *Macrolobium acaciifolium* in Cumaribo; and *Attalea insignis* and *Oenocarpus bataua* in Manacacías.

The Arecaceae family includes a total of 22 species classified in this category. In addition to those previously mentioned, the following species are also listed: *Astrocaryum chambira*, *Astrocaryum jauari*, *Bactris bidentula*, *Bactris brongniartii*, *Bactris corossilla*, *Bactris guineensis*, *Bactris hirta*, *Bactris maraja*,

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Bactris simplicifrons, *Euterpe oleracea*, *Iriartella setigera*, and *Oenocarpus bacaba*. Several of these species are dominant in various vegetation types, including *Amphirrhox longifolia*, *Apeiba membranacea*, *Clusia minor*, *Couma macrocarpa*, *Dialium guianense*, *Guazuma ulmifolia*, *Elaeoluma glabrescens*, *Eschweilera subglandulosa*, *Pera arborea*, *Pourouma bicolor*, *Didymopanax morototoni*, *Symphonia globulifera*, *Terminalia amazonia*, *Protium rhoifolium*, and *Xylopia aromatica*. Additional species in this category are listed in Appendix A5. In the low-threat category, 121 species were classified, among which the following are dominant in vegetation: *Alibertia edulis*, *Coccoloba caracasana*, *Connarus venezuelanus*, *Dendropanax arboreus*, *Faramea occidentalis*, *Handroanthus ochraceus*, *Iryanthera laevis*, *Luehea seemannii*, *Myrsine guianensis*, and *Phenakospermum guyannense*. Other species in this category are listed in Appendix A6.

3.5. Vegetation Threats Classification: Grassland Phytosociological Alliances (Table 5)

The very high threat category includes the grasslands of the *Paspalion carino-pectinati*, found in the high plains of the Serranía de Manacacías. The high threat category consists of various community types, which are grouped into the *Sipaneo pratensis-Axonopodion purpusi* and *Sacciolepio angustissimatis-Rhynchanterion bracteatae* in the highlands of the Serranía de Manacacías. Also classified in this category are vegetation types from the *Eleochario interstinctae-Rhynchosporion barbatae* in the Casanare plains and the *Rhynchosporo barbatae-Axonopodion ancepitis* in the floodplains of Arauca, both of which are located in the floodplain subregion or landscape. In the medium threat category, the *Axonopodo aurei-Trachypogonion spicati* and *Andropogono virgati-Axonopodion ancepitis*, found in the high plains of the Serranía de Manacacías, were classified. The low threat category includes vegetation types grouped into the *Hyptio confertae-Schizachyrion brevifoli*, *Schizachyrio brevifoli-Tibouchinion asperae*, and *Rhynchosporo corymbosae-Schyzachyrion brevifoli* in the high plains of the Serranía de Manacacías, as well as the *Steinchismo laxae-Andropogonion bicornis* in the floodplains of Arauca.

In comparison with previous assessments, several alliances considered in this study were assigned equivalent threat ratings, despite differences in the methodological approach. Consequently, the grasslands of the *Andropogono virgati-Axonopodion ancepitis* in Cravo Norte and Puerto Rondón, in the department of Arauca, were classified in the Vulnerable (VU) category, with a medium level of intervention. Similarly, the *Paspalion carino-pectinati* of the highlands and alluvial plains was also classified in the Vulnerable (VU) category, with a medium level of intervention.

3.6. Vegetation Threats Classification: Forest Phytosociological Alliances (Table 5)

The Very High Threat category in the subregion or landscape of the high plains includes various vegetation types grouped into the *Attaleo maripae-Iryantherion laevis* in Cumaribo, the *Guatterio metensis-Ingion cylindricae* in the Serranía de Manacacías, and the *Protio guianensis-Caraipetion llanori* in the Carimagua-Manacacías sector. The High Threat category includes the mixed palm groves of the *Protio aracouchinitis-Oenocarpion batauae* in the high plains of the Serranía de Manacacías, as well as forests of the *Copaifero pubiflorae-Protion guianensis*, *Spondiado mombinis-Viticion orinocensis*, and *Vitici orinocencis-Mabeetion trianae* in the flood plains of Arauca. The Medium Threat category includes the forests of the *Duguetio quitarensis-Amphirrhocion longifoliae* from the highlands of the Cumaribo sector, as well as the palm groves of the *Oenocarpo minoris-Attaleion maripae* in the Carimagua sector and the mixed palm groves of the *Siparuno guianensis-Maurition flexuosae* from the Serranía de Manacacías.

In the subregion of the floodplain, within the medium threat category, the forests of the *Coccolobo caracasanae-Tapiriretion guianensis* in Casanare and the forests of the *Ocoteo leptobotrae-Viticion orinocensis* in the floodplains of Arauca were also classified in the high threat category. The *Alchorneo triplinerviae-Maurition flexuosae* in the high plains of Carimagua and the *Protio heptaphylli-Jacarandion obtusifoliae* in the Arauca floodplains were classified as low threat.

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Table 4. Threat categories for grasslands and forests phytosociological alliances found in Colombian Orinoquian region.

Grasslands and meadows	**Threat Category**	**Distribution / Physiography**
Paspalion carino-pectinati	**Very high**	Manacacías / High plain
Sipaneo pratensis - Axonopodion purpusi	**High**	Manacacías / High plain
Sacciolepio angustissimatis-Rhynchanterion bracteatae		Manacacías / High plain
Eleochario interstinctae-Rhynchosporion barbatae		Plains of Casanare / Alluvial plain
Rhynchosporo barbatae-Axonopodion ancepitis		Wetlands of Arauca / Alluvial plain
Axonopodo aurei-Trachypogonion spicati	**Medium**	Manacacías / High plain
Caperonio palustris-Leersion hexandrae		Plains of Casanare / Alluvial plain
Andropogono virgati-Axonopodion ancepitis		Manacacías / High plain
Hyptio confertae-Schizachyrion brevifoli	**Low**	Manacacías / High plain
Paspalo pectinati-Axonopodion aurei		Manacacías / High plain
Schizachyrio brevifoli-Tibouchinion asperae		Manacacías / High plain
Rhynchosporo corymbosae-Schyzachyrion brevifoli		Manacacías / High plain
Steinchismo laxae-Andropogonion bicornis		Wetlands of Arauca / Alluvial plain
Forest type: forests, palm (p) and mixed palm forests (bp) of the alliances	**Threat Category**	**Distribution / Physiography**
Attaleo maripae-Iryantherion laevis (bp)	**Very high**	Cumaribo / High plains
Guatterio metensis-Ingion cylindricae		Manacacías / High plains
Protio guianensis-Caraipetion llanorum		Carimagua-Manacacías / High plains
Protio aracouchinitis - Oenocarpion batauae	**High**	Manacacías / High plains
Copaifero pubiflorae -Protion guianensis		Arauca wetlands / Alluvial plains
Spondiado mombinis-Viticion orinocensis		Arauca wetlands / Alluvial plains
Vitici orinocencis-Mabeetion trianae		Arauca wetlands / Alluvial plains
Duguetio quitarensis-Amphirrhocion longifoliae	**Medium**	Cumaribo / High plains
Coccolobo caracasanae-Tapiriretion guianensis		Casanare / Alluvial plains
Ocoteo leptobotrae-Viticion orinocensis		Arauca wetlands / Alluvial plains
Oenocarpo minoris-Attaleion maripae (p)		Carimagua / High plains
Phenakospermo guyannensis-Attaleetion maripae (p)		Arauca wetlands / Alluvial plains
Siparuno guianensis-Maurition flexuosae (bp)		Manacacías / High plains
Alchorneo triplinerviae-Maurition flexuosae (bp)	**Low**	Carimagua / High plains
Protio heptaphyllii-Jacarandion obtusifoliae (bp)		Arauca wetlands / Alluvial plains

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4. Discussion

Authors should discuss the results and how they can be interpreted from the perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

It is clear that sole reliance on the categories and designations of the IUCN allows for comparisons and provides an understanding of the conservation status of species; however, when assessing vegetation types, these categories do not fully capture the specific threats faced by them. In this regard, it is necessary to design and implement comprehensive assessment and rating models that detail parameters associated with the characteristics of the natural environment (e.g., climatic factors, habitat quality and conditions, topographical features, ecogeographical considerations, etc.), as well as aspects such as the richness and floristic composition of vegetation types. These models should also incorporate territorial realities, ensuring the direct involvement of local residents and those who utilize protected areas for biodiversity conservation [41-44]. The assessment of threats to flora and vegetation is a critical input for defining zoning processes, territorial management plans, and the administration of protected areas. The integration of multi-criteria models, through the hierarchical characterization of vegetation, enhances the classification of threats to both biota and territory. In addition to planning and territorial development initiatives, the primary goal should be to promote the establishment of new protected areas. This approach will help conserve and protect species richness and beta diversity of vegetation types in the Orinoquian region.

Target Species: Floristic Analysis. The richness patterns at the family and genus levels in grasslands and forests closely resembled the regional patterns observed in the Orinoquia region of Colombia [45-47]. The 15 richest families accounted for over 50% of the total species. Dominant families such as Rubiaceae, Fabaceae, Poaceae, Melastomataceae, Asteraceae, and Cyperaceae have also been reported with similar patterns in the Amazon Basin [48-50], the Venezuelan Llanos [47], and the Bolivian plains in the Beni Department [51]. The genus richness pattern identified genera such as *Miconia*, *Psychotria* (s.l.), *Palicourea*, *Piper*, *Paspalum*, *Inga*, *Rhynchospora*, and *Solanum* as the most species-rich, a condition previously described by Cuatrecasas, who categorized them as eurythermal genera [52].

Threats of Phytosociological Alliances. In grasslands, 13 of the 18 characterized alliances for the Colombian Orinoquia [31] were classified as having some degree of threat. Most of them are located in the high plains (altillanura) sub-region, particularly the Serranía de Manacacías and surroundings regions. In forests, 17 alliances of the 31 characterized for the Orinoquia of Colombia [31] were classified as having some degree of threat. Most of them are located in the subregion of the floodplain (Arauca and surrounding areas). This result is consistent with the considerations related to the heavy logging and clearing processes that have occurred in this subregion.

Threats Categorization. The major threats to vegetation conservation in the study area are related to agriculture and extensive-to-very extensive cattle ranching. Additionally, illegal crops have a direct impact on vegetation, exerting high pressure through induced burns, selective logging, and land-use changes in the territory. Infrastructure construction, along with the extraction of hydrocarbons and minerals, also induces drastic changes in edaphic and hydrological conditions. All these anthropogenic activities are key drivers of the distribution and expression of species richness and floristic composition of vegetation [2-4].

Threat evaluations concerning vegetation habitat conditions and floristic composition are based on field surveys and careful observations. However, field results must be carefully reviewed, considering species' geographical distribution and ecology to adjust or reclassify species within specific categories. Such is the case for *Acroceras zizanioides*, *Paspalum conjugatum*, *Elephantopus mollis*, *Eriochrysis cayennensis*, *Sida glomerata*, *Heliotropium indicum*, *Kyllinga brevifolia*, and *Indigofera lespedezioides*. These taxa have broader geographical distributions and are typically categorized as "weeds." However, a finding of this study was that these species are now part of the floristic composition due to high replacement rates. This condition is a result of degradation and environmental alteration at a regional scale, which has occurred globally, especially in the

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Orinoquian region, over the past six decades. Similar replacement patterns are observed in aquatic vegetation types, where temporal water levels are critical factors for seedling establishment and individual survival, as seen in *Phyllanthus fluitans*, *Thalia geniculata*, *Leersia hexandra*, and *Montrichardia arborescens*. The presence of naturalized or widely domesticated species, such as *Eryngium foetidum*, *Sphenoclea zeylanica*, and *Vandellia diffusa*, denotes a high degree of vegetation transformation. Taxa replacements imply a near-complete functional reorganization of assemblages and new sets of ecosystem services and disservices, including those related to human-modified landscapes [53].

5. Conclusions

Our hypotheses were fully supported, indicating that more detailed analyses are required to better characterize the specific effects on the population dynamics of species that define or characterize phytocoenoses. This is essential for designing and implementing conservation strategies tailored to the socio-economic and cultural contexts of the territories. Furthermore, our model highlights the advantage of assigning differential weights to various sources of information (i.e., species and their local and regional ecology, habitats, and their conservation status). Consequently, the qualification process cannot be considered linear, as pressures on vegetation in any given territory are differential and will be primarily influenced by the history of land use. Other variables that affect vegetation include the socio-cultural context of the inhabitants, the development of various production systems, human population density, and deforestation. Furthermore, these conditions will impact the demand for goods and services directly associated with natural vegetation [2-4].

Conservation implications. The proposed model can be highly useful for enriching and generating thematic maps of vegetation distribution areas (both current and potential), as well as for defining and prioritizing zones designated for conservation and their buffer zones. Based on the results obtained, with respect to grasslands, the *Paspalion carino-pectinati* alliance, which is preferentially distributed in the altillanura, and the forests *Attaleo maripae-Iryantherion laevis*, *Guatterio metensis-Ingion cylindricae*, and *Protio guianensis-Caraipetion llanorum*, which are circumscribed to the altillanura, should be considered for initiating active conservation and habitat protection programs. In this regard, the initial contributions of this study served as a baseline for the declaration of the Serranía del Manacacías Natural Park (altillanura of the Meta department), as well as for new protected areas such as the Arauca Wetlands Complex (floodplain, Arauca department) and the Transitional Forests of Cumaribo (Amazonia-Orinoquia Ecotone, altillanura of the Meta department).

The scope of the results from our proposed model for estimating threats is consistent with the previously established ratings for grasslands dominated by *Trachypogon spicatus*. This formation represents a type of grassland with an herbaceous matrix, characterized by species such as *Paspalum carinatum*, *Andropogon virgatus*, *Axonopus anceps*, *Eleocharis minima*, and *Andropogon bicornis*. Additionally, this community hosts notable grassland taxa, including *Schizachyrium brevifolium*, *Sipanea pratensis*, *Sacciolepis angustissima*, *Caperonia palustris*, and *Leersia hexandra*. In the forests, the proposed methodology corroborates the assessments of its characteristic species. For example, in the case of the *Copaifero pubiflorae -Protion guianensis* alliance (classified as high threat), the dominant species—*Protium guianense* (very high), *Spondias mombin* (very high), *Vitex orinocensis* (very high), *Mauritia flexuosa* (high), *Attalea maripa* (medium), and *Caraipa llanorum* (high)—are consistent with their threat classification.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Appendix A.1. Species Medium Category Threats Classification in Grasslands

Aristolochia nummularifolia, Axonopus compressus, Byrsonima crassifolia, Byrsonima verbascifolia, Miconia dependens, Miconia rubra, Clitoria guianensis, Crotalaria pilosa, Cuphea melvilla, Eleocharis geniculata, Eragrostis maypurensis, Eriosema crinitum, Heliconia psittacorum, Hyptis recurvata, Hyptis brachiata, Hyptis dilatata, Kyllinga odorata, Torenia crustacea, Miconia rubiginosa, Mimosa xanthocentra, Nymphoides indica, Panicum cayennense, Paspalum maculosum, Panicum rudgei, Paspalum repens, Rhynchospora candida, Rhynchospora corymbosa, Rotala mexicana, Sacciolepis angustissima, Scleria distans, Scleria reticularis, Setaria parviflora, Sida serrata, Sphenoclea zeylanica, Utricularia gibba, Utricularia subulata, Zornia diphylla, Bacopa reptans, Bacopa salzmannii, Caperonia palustris, Eriocaulon melanocephalum, Ludwigia sedioides, Paspalum carinatum, Sauvagesia deflexifolia, Sauvagesia erecta, Vandellia diffusa, Xyris savanensis.

Appendix A.2. Species in Low Threat Categories Grasslands and Shrubby Vegetation

Acanthospermum australe, Acisanthera limnobios, Acisanthera quadrata, Acisanthera uniflora, Acmella brachyglossa, Aeschynomene elegans, Aeschynomene evenia, Aeschynomene paniculata, Amaranthus dubius, Ambrosia peruviana, Andropogon hypogynus, Andropogon lateralis, Andropogon leucostachyus, Andropogon selloanus, Aristida capillacea, Aristida torta, Axonopus anceps, Axonopus aureus, Buchnera jacoborum, Buchnera palustris, Buchnera rosea, Bulbostylis junciformis, Bulbostylis lanata, Burmannia bicolor, Burmannia capitata, Byttneria genistella, Calea tolimana, Centrosema angustifolium, Chelonanthus alatus, Cipura paludosa, Coleataenia caricoides, Crotalaria incana, Crotalaria maypurensis, Crotalaria sagittalis, Crotalaria velutina, Ctenium concissum, Cuphea antisyphilitica, Cuphea odonellii, Cuphea repens, Curatella americana, Curtia tenuifolia, Cyperus aggregatus, Cyperus luzulae, Declieuxia fruticosa, Desmodium incanum, Desmoscelis villosa, Dioscorea amazonum, Dorstenia brasiliensis, Echinolaena inflexa, Eleocharis acutangula, Eleocharis filiculmis, Eleocharis interstincta, Eleocharis minima, Elephantopus mollis, Eriochrysis cayennensis, Eriochrysis laxa, Eriope crassipes, Eryngium foetidum, Galactia jussiaeana, Gymnopogon fastigiatus, Heliotropium indicum, Heteranthera limosa, Hibiscus sabdariffa, Hyptis conferta, Hyptis lantanifolia, Imperata brasiliensis, Indigofera lespedezioides, Ipomoea argentea, Kyllinga brevifolia, Larentia linearis, Limnosipanea spruceana, Ludwigia erecta, Ludwigia nervosa, Ludwigia rigida, Mandevilla scabra, Alectra stricta, Melochia nodiflora, Melochia spicata, Melochia villosa, Merremia aturensis, Miconia borjensis, Miconia rufa, Microstachys corniculata, Mikania congesta, Mimosa pellita, Murdannia nudiflora, Neanotis lancifolia, Panicum pilosum, Panicum trichoides, Paspalum lanciflorum,

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Paspalum melanospermum, Paspalum morichalense, Paspalum multicaule, Paspalum parviflorum, Paspalum pectinatum, Paspalum stellatum, Paspalum trinitense, Perama dichotoma, Philodice hoffmannseggii, Phyllanthus hyssopifolioides, Phyllanthus stipulatus, Piriqueta cistoides, Polygala paniculata, Polygala timoutou, Pterogastra minor, Rhynchospora albescens, Rhynchospora barbata, Rhynchospora cephalotes, Rhynchospora emaciata, Rhynchospora globosa, Sacciolepis myuros, Sauvagesia tenella, Schiekia orinocensis, Schultesia brachyptera, Schwenckia americana, Scleria microcarpa, Sida glomerata, Sipanea hispida, Sipanea pratensis, Solanum jamaicense, Sorghastrum setosum, Spermacoce capitata, Spermacoce verticillata, Sporobolus jacquemontii, Steinchisma laxa, Stephostachys mertensii, Stylosanthes guianensis, Syngonanthus caulescens, Thalia geniculata, Trachypogon spicatus, Trichanthecium cyanescens, Turnera scabra, Turnera ulmifolia, Urochloa decumbens, Vouarana guianensis, Xyris jupicai.

Appendix A.3. Species in Very High Threat Categories Forest

Abarema jupunba, Alchornea triplinervia, Andira inermis, Andira surinamensis, Aniba panurensis, Annona ambotay, Aspidosperma desmanthum, Aspidosperma excelsum, Aspidosperma spruceanum, Bocageopsis multiflora, Terminalia macrophylla, Terminalia viridiflora, Byrsonima japurensis, Caraipa densifolia, Cassia moschata, Clarisia biflora, Clarisia racemosa, Cupania scrobiculata, Duguetia cauliflora, Duguetia macrophylla, Duguetia odorata, Duroia eriopila, Duroia micrantha, Ficus albert-smithii, Ficus americana subsp. guianensis, Ficus dendrocida, Ficus donnell-smithii, Ficus insipida, Ficus mathewsii, Ficus maxima, Ficus obtusifolia, Ficus trigona, Guarea glabra, Guarea pubescens, Guatteria hirsuta, Guatteria inundata, Guatteria liesneri, Guatteria schomburgkiana, Henriettea cf. *goudotiana, Hieronyma alchorneoides, Hirtella elongata, Hymenopus heteromorphus, Inga alba, Inga brachyrhachis, Inga cylindrica, Inga heterophylla, Inga ingoides, Inga interrupta, Inga marginata, Inga psittacorum, Lacmellea edulis, Leptobalanus apetalus, Licania hypoleuca, Licania kunthiana, Leptobalanus longistylus, Mabea piriri, Maclura tinctoria, Matayba elegans, Mouriri guianensis, Nectandra aurea, Ocotea puberula, Parinari excelsa, Parkia discolor, Parkia nitida, Perebea xanthochyma, Protium glabrescens, Protium guianense, Samanea saman, Sapium glandulosum, Sarcaulus brasiliensis, Sorocea muriculata, Sorocea sprucei, Sorocea steinbachii, Sterculia apetala, Virola carinata, Virola elongata, Virola pavonis, Virola sebifera, Virola surinamensis, Vismia baccifera, Vitex compressa, Vochysia lehmannii, Vochysia obscura, Xylopia discreta, Xylopia emarginata* and *Xylopia sericea.*

Appendix A.4. Species in High Category Threat Categories Forest

Alchornea discolor, Alchornea fluviatilis, Aniba cylindriflora, Annona montana, Apuleia leiocarpa, Brosimum rubescens, Brownea coccinea, Bursera simaruba, Myrcia aulomyrcioides, Aiouea montana, Clathrotropis macrocarpa, Cupania latifolia, Duguetia riberensis, Duroia fusifera, Duroia hirsuta, Endlicheria multiflora, Erythrina fusca, Eugenia florida, Genipa americana, Guarea cristata, Guatteria punctata, Hieronyma oblonga, Hydrochorea corymbosa, Jacaranda caucana, Jacaranda obtusifolia, Lacmellea floribunda, Lacmellea foxii, Leptolobium nitens, Licania

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canescens, Maquira calophylla, Matayba arborescens, Micropholis venulosa, Moquilea subarachnophylla, Myrcia bracteata, Myrcia guianensis, Myrcia paivae, Myrcia splendens, Myrcia subsessilis, Myrciaria floribunda, Nectandra cuspidata, Nectandra globosa, Nectandra membranacea, Ocotea amazonica, Ocotea floribunda, Ocotea longifolia, Ocotea oblonga, Ormosia macrocalyx, Panopsis rubescens, Parahancornia oblonga, Perebea mollis, Pouteria cuspidata, Pouteria elegans, Pouteria glomerata, Pouteria gomphiifolia, Pouteria multiflora, Pouteria stipitata, Protium amazonicum, Protium crassipetalum, Protium laxiflorum, Protium sagotianum, Protium stevensonii, Protium unifoliolatum, Psidium guineense, Annona exsucca, Sapium jenmannii, Sloanea terniflora, Trattinnickia aspera, Trattinnickia lawrancei, Trichilia elegans, Trichilia hirta, Trichilia pallida, Trichilia pleeana, Trichilia quadrijuga, Trymatococcus amazonicus, Virola schultesii, Vismia cayennensis, Vismia japurensis, Vismia macrophylla, Vochysia ferruginea, Vochysia aff. tetraphylla, Warszewiczia coccinea, Xylopia calophylla, Xylopia ligustrifolia, Xylopia plowmanii, Xylopia sericophylla, Zanthoxylum fagara and *Zygia latifolia.*

Appendix A.5. Species in Medium Category Threat Categories Forest

Allophylus amazonicus, Bauhinia longicuspis, Bauhinia ungulata, Bellucia grossularioides, Bellucia pentamera, Bellucia strigosa, Campsiandra angustifolia, Casearia aculeata, Casearia commersoniana, Casearia sylvestris, Casearia ulmifolia, Casearia zizyphoides, Cecropia metensis, Cecropia peltata, Cecropia sciadophylla, Chomelia tenuiflora, Clathrotropis brachypetala, Clitoria dendrina, Clitoria guianensis, Clusia amazonica, Clusia grandiflora, Clusia insignis, Cochlospermum orinocense, Combretum laxum, Cordia alliodora, Cordia bicolor, Cordia nodosa, Cordia panamensis, Cordia ucayaliensis, Couepia chrysocalyx, Coussarea paniculata, Crotalaria incana, Cynometra marginata, Dacryodes chimantensis, Deguelia scandens, Dendropanax caucanus, Desmoncus polyacanthos, Dichapetalum spruceanum, Eriotheca macrophylla, Erythroxylum amazonicum, Erythroxylum divaricatum, Erythroxylum macrophyllum, Eschweilera bracteosa, Eschweilera decolorans, Eschweilera parviflora, Eschweilera parvifolia, Eschweilera tenuifolia, Pterocarpus dubius, Eugenia cribrata, Garcinia macrophylla, Garcinia madruno, Gnetum leyboldii, Gnetum nodiflorum, Godmania aesculifolia, Guatteria ucayalina, Gustavia augusta, Gustavia hexapetala, Herrania nitida, Hevea benthamiana, Hirtella americana, Hirtella bullata, Hirtella paniculata, Hirtella racemosa, Ilex inundata, Laetia suaveolens, Machaerium biovulatum, Machaerium floribundum, Machaerium quinata, Macrolobium bifolium, Macrolobium multijugum, Macrosamanea consanguinea, Macrosamanea discolor, Macrosamanea pubiramea, Marsdenia macrophylla, Melicoccus bijugatus, Miconia dolichorrhyncha, Miconia holosericea, Miconia minutiflora, Miconia tomentosa, Miconia trinervia, Mouriri myrtilloides, Mouriri nigra, Ormosia macrophylla, Osteophloeum platyspermum, Petrea volubilis, Phyllanthus attenuatus, Phyllanthus elsiae, Picramnia magnifolia, Plinia involucrata, Posoqueria latifolia, Pourouma minor, Quassia simaruba, Rinorea flavescens, Rudgea crassiloba, Ruprechtia tenuiflora, Ryania speciosa, Senna silvestris, Simaba orinocensis, Simira rubescens, Siparuna guianensis, Sloanea guianensis,

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Stachyarrhena penduliflora, Stylogyne turbacensis, Swartzia leptopetala, Swartzia myrtifolia, Tabernaemontana amygdalifolia, Tapura guianensis, Theobroma subincanum, Tovomita spruceana, Ruprechtia ramiflora and *Tacarcuna amanoifolia*.

Appendix A.6. Species in Low Category Threat Categories Forest

Abuta grandifolia, Albizia subdimidiata, Alchorneopsis floribunda, Alibertia bertierifolia, Allophylus racemosus, Amaioua guianensis, Aparisthmium cordatum, Bignonia aequinoctialis, Campsiandra nutans, Capirona decorticans, Casearia hirsuta, Casearia javitensis, Casearia mollis, Cathedra acuminata, Chomelia spinosa, Miconia tococoidea, Coccoloba lucidula, Coccoloba mollis, Coccoloba portuguesana, Combretum coriifolium, Conceveiba guianensis, Connarus lambertii, Connarus ruber, Cordia tetrandra, Cordiera concolor, Cornutia microcalycina, Crateva tapia, Croton cuneatus, Croton orinocensis, Cuspidaria sceptrum, Cybianthus llanorum, Cynometra bauhiniifolia, Dalbergia foliosa, Dalbergia hygrophila, Diospyros poeppigiana, Discocarpus gentryi, Doliocarpus dentatus, Doliocarpus major, Doliocarpus multiflorus, Olax candida, Faramea capillipes, Faramea sessilifolia, Faramea torquata, Forsteronia affinis, Guapira pacurero, Guapira sipapoana, Heisteria acuminata, Heisteria duckei, Henriettea fissanthera, Hirtella subscandens, Homalium guianense, Isertia haenkeana, Lacistema aggregatum, Leonia glycycarpa, Lindackeria paludosa, Macrolobium angustifolium, Malouetia grandiflora, Malouetia virescens, Maprounea guianensis, Miconia dispar, Miconia elata, Miconia stephananthera, Mouriri acutiflora, Mouriri pauciflora, Ouratea brevipedicellata, Ouratea castaneifolia, Pachira brevipes, Pachira paraensis, Palicourea crocea, Palicourea croceoides, Phyllanthus niruri, Picramnia antidesma, Piper arboreum, Potalia resinifera, Pourouma tomentosa, Palicourea justiciifolia, Psychotria lupulina, Quararibea ochrocalyx, Quiina florida, Quiina macrophylla, Quiina rhytidopus, Randia dioica, Richeria grandis, Rinorea falcata, Rinorea pubiflora, Rourea glabra, Sacoglottis guianensis, Schizocalyx bracteosa, Securidaca diversifolia, Homolepis cedron, Sloanea eichleri, Stachyarrhena duckei , Sterculia guapayensis, Strychnos brasiliensis, Strychnos bredemeyeri, Strychnos mitscherlichii, Stylogyne longifolia, Styrax guyanensis, Swartzia pittieri, Tabernaemontana amplifolia, Tabernaemontana grandiflora, Tabernaemontana macrocalyx, Tabernaemontana sananho, Tabernaemontana siphilitica, Tachigali hypoleuca, Tachigali plúmbea, Tapura acreana, Miconia tococoronata, Urera baccifera, Vasivaea alchorneoides and *Vismia guianensis*.

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