Characterization of Riparian Tree Communities along a River Basin in the Pacific Slope of Guatemala

Alejandra Alfaro Pinto 1,2,*, Juan J. Castillo Mont 3, David E. Mendieta Jiménez 2, Alex Guerra Noriega 3, Jorge Jiménez Barrios 4 and Andrea Clavijo McCormick 1, *  

1 School of Agriculture & Environment, Massey University, Palmerston North 4474, New Zealand  
2 Herbarium AGUAT 'Professor José Ernesto Carrillo', Agronomy Faculty, University of San Carlos of Guatemala, Guatemala City 01012, Guatemala; jjcastillomont@hotmail.com (J.J.C.M.); david.e.mendieta@gmail.com (D.E.M.J.)  
3 Private Institute for Climate Change Research (ICC), Santa Lucía Cotzumalguapa, Escuintla 5002, Guatemala; aguerra@icc.org.gt  
4 School of Biology, University of San Carlos of Guatemala, Guatemala City 01012, Guatemala; jimenez.jorge@usac.edu.gt  
* Correspondence: malealfaro92@gmail.com (A.A.P.); A.C.McCormick@massey.ac.nz (A.C.M.)  

Abstract: Ecosystem conservation in Mesoamerica, one of the world’s biodiversity hotspots, is a top priority because of the rapid loss of native vegetation due to anthropogenic activities. Riparian forests are often the only remaining preserved areas among expansive agricultural matrices. These forest remnants are essential to maintaining water quality, providing habitats for a variety of wildlife and acting as biological corridors that enable the movement and dispersal of local species. The Acomé river is located on the Pacific slope of Guatemala. This region is heavily impacted by intensive agriculture (mostly sugarcane plantations), fires and grazing. Most of this region’s original forest is now restricted to forest remnants concentrated along the riverbank. However, the botanical composition and species diversity of the riparian communities has not been characterized. This baseline information is essential to develop restoration strategies and management plans. This study aimed to characterize the riparian tree communities along the Acomé riverbank by systematically collecting herbarium specimens and photographic material for trees over 10 cm DBH (diameter at breast height). Cluster analysis was used to identify the main riparian communities, and diversity indices were calculated for each community. A total of 115 tree species were identified, belonging to 91 genera and 43 families. The cluster analysis suggested the presence of four riparian tree communities along an altitudinal gradient. *Rhizophora mangle*, *Cecropia obtusifolia*, *Guazuma ulmifolia*, and *Brosimum costaricanum* were the dominant species of the identified communities. This research will support ongoing restoration efforts and biological connectivity plans in this region.

Keywords: arboreous species; riparian forest; plant communities; secondary forest; richness; diversity; biodiversity conservation; regional diversity

1. Introduction

Agricultural expansion (i.e., crops and livestock) is one of the main drivers of habitat change and biodiversity loss in the tropics [1,2]. Central America is considered a biodiversity hotspot and is particularly vulnerable to anthropogenic influence and climate change [3]. However, there are multiple challenges to conservation efforts in this region (e.g., socio-economic, political, and scientific) [4]. There is a paucity of scientific studies assessing the biodiversity status of vulnerable areas and such studies are urgently needed to prioritize conservation efforts and monitor biodiversity and habitat change over time.

Riparian zones are usually the only areas with natural vegetation cover within large agricultural matrices. These are maintained in order to protect water resources vital to agricultural practices [5,6]. Riparian zones are ecotones in transition areas between...
terrestrial and aquatic ecosystems [7], and may also be referred to as azonal vegetation, i.e.,
plant communities that are more severely influenced by edaphic factors than by climate [8].
These ecotones provide multiple ecosystem services that support biological diversity,
carbon storage and water quality [7,9]. The topography and soil properties of such riparian
zones are extremely diverse, contributing to the high level of structural and compositional
diversity of their vegetation [10,11].

Riparian forests provide habitat to many wildlife species and may assist with preserva-
tion of biological corridors by connecting the upper and lower parts of the basins. A
diverse range of wild fauna can use the resources provided by plants, streams and rivers
within such corridors to support the maintenance of regional biodiversity [6,12]. However,
riparian forests are also highly vulnerable to invasion and anthropogenic impact [13,14]. In
addition to the protection, restoration and rehabilitation of riparian corridors (i.e., plant
communities) current riparian zone management includes fencing out livestock and for-
bidding agricultural activities along riverbanks as widely used approaches to achieve this
aim [15–17]. To develop successful management plans, however, a baseline assessment of
the plant species within these riparian forests is essential [11].

Guatemala, a developing country in Central America, has very fragmentary infor-
mation about its plant species. The Flora of Guatemala was first published in 1946, and
since then, a detailed botanical study has not been carried out. Combined with scarce
information on the existing plant species, intensive agriculture, grazing, and fires have
dramatically reduced forest cover in many areas [18]. Furthermore, introduction of exotic
species and climate change may add potential threats to the survival of numerous native
species in this country [3].

Within this context, the overarching goal of this study was to characterize the riparian
arboreous vegetation of the Acomé river basin, located among sugarcane plantations in
the Pacific slope of Guatemala. To this end, we collected herbarium specimens and pho-
tographic material from trees greater than 10 cm DBH (diameter at breast height) along
the riverbank. We then identified the species and the main riparian tree communities
in this area through cluster analysis and calculated diversity indicators to describe each
community. Finally, we discussed potential drivers affecting vegetation at the local land-
scape level. This study represents a valuable contribution to our knowledge of riparian
tree communities in Central America and will support ecological restoration efforts and
riparian connectivity plans in this highly biodiverse, yet vulnerable, region.

2. Materials and Methods
2.1. Study Site

The Acomé river is 58.48 km in length. The Acomé river basin covers an area of
893.4 km$^2$ (344.9 sq mi) [19] and is located on the Pacific slope of Guatemala, which extends
from the foothills of the volcanic mountains to the Pacific Ocean [20]. It is located in
the Escuintla department, on the jurisdiction of La Democracia, La Gomera, Santa Lucía
Cotzumalguapa, Sipacate and Siquinalá. Its geographical coordinates range from 13°54′00″
to 14°22′00″ North, and 90°57′00″ to 91°13′00″ West with an altitudinal range of 0 to 570 m
above sea level (m a. s. l.) [21]. The mean annual rainfall ranges from 800 mm at its
lowest altitude to 4600 mm in the upper regions. Maximum temperatures vary between
32 and 34 °C, while the minimums oscillate between 20 and 21 °C [22]. According to the
L. Holdridge classification proposed by De la Cruz [23,24], the Acomé basin has three
life zones: very humid subtropical warm-forest (bmh-S), humid subtropical warm-forest
(bh-S) and dry subtropical forest (bs-S). According to the Forest Cover Map of Guatemala of
2010, only 3% of the Acomé basins area was reported to have forest cover [18]. The most
important activity within the region is agriculture: predominantly sugarcane (Saccharum
officinarum L.) production. The forest remnants are mainly riparian, being located along the
Acomé riverbank and its tributaries and there are also mangrove forests near the sea.
2.2. Plant Sampling

Fifty-six rectangular plots of 10 × 100 m (1000 m²) were assessed. These were systematically located at 1 km intervals along the Acomé riverbank (Figure 1). At each plot, geographical coordinates and altitude were recorded using a handheld GPS (Table S1). Within each plot, measurements of all trees >10 cm diameter at breast height (DBH) were recorded as well as tree height. We photographed and collected herbarium specimens to enable identification of each plant species. The herbarium specimens consisted of branch(es) with leaves, flowers and fruits. Additional riparian tree specimens were collected ad hoc outside the plots along the river basin for identification purposes. At least 5 specimens were collected from each of the sampled tree species. Specimens were dried using a portable dryer, consisting of an electric fan heater and a metallic base. The botanical presses were placed on the base and covered with a cotton canvas (Figure S1) [25]. Most of the specimens required approximately 24 h for drying, while those with more succulent tissues required up to 60 h.

Figure 1. Acomé river basin with its life zones and distribution of the sampling plots.

2.3. Plant Identification

Identification of plant specimens was achieved in the AGUAT Herbarium ‘Professor José Ernesto Carrillo’ of the Agronomy Faculty of the University of San Carlos of Guatemala. For identification, we used the dichotomous keys of the Flora of Guatemala [26], Flora of Nicaragua [27], Flora Mesoamericana [28] and the online databases The Plant List and World Flora Online [29,30].

2.4. Vegetation Classification

Cluster analysis on the abundance of species per plot was used to identify vegetation groups (plant communities) using Euclidean distance (as the distance measure) and Ward’s method (as a group linkage measure) [31]. The packages ‘dendextend’, ‘ggplot2’ and ‘stats’ for the R environment were used [32–34]. An analysis of similarity (ANOSIM) of the package ‘vegan’ was used to validate the groups obtained by cluster analysis [32,35]. To represent the ordination of the groups obtained from the cluster analysis, non-metric
multidimensional scaling was performed with data on the abundance of species per tree community, using Bray–Curtis dissimilarity index through ‘vegan’ package for R [32,35].

2.5. Floristic Composition and Species Diversity

The importance value index (IV) was estimated for the species in each community with data on the abundance and basal area per species per plot with the package ‘BiodiversityR’ [32,36]. Diversity indices were estimated for each plot using the package ‘vegan’ to thereafter estimate the average value per tree community [32,35].

3. Results

3.1. Tree Species Identification

One hundred and fifteen (115) tree species were identified along the Acomé riverbank, belonging to 91 genera and 43 families (Table 1).

Table 1. Updated list of the tree species found in the Acomé riverbank (nomenclature following Angiosperm Phylogeny Group system).

| Family          | Species                                                                 | Common Name                  |
|-----------------|-------------------------------------------------------------------------|------------------------------|
| Acanthaceae     | *Avicennia germinans* (L.) L.                                           | Mangle negro                 |
| Anacardiaceae   | *Spondias mombin* L.                                                    | Jocote jobo                  |
| Annonaceae      | *Annona purpurea* Moc. & Sessé ex Dunal *Rollinia mucosa* (Jacq.) Bail. | Chincuya Anona               |
| Apocynaceae     | *Aspidosperma megalocarpom* Müll. *Tabernaemontana donnell-smithii* Rose ex J.D.Sm. | Chichique Cojón             |
| Araliaceae      | *Dendropanax arbores* (L.) Decne. & Planch.                            | Mano de león                 |
| Bignoniaceae    | *Cordia alba* (Jacq.) Roem. & Schult. *Cordia alliodora* (Ruiz & Pav.) Oken | Tiguílote, Upay Laurel       |
| Burseraceae     | *Bursera simaruba* (L.) Sarg.                                           | Palo de jote                 |
| Cactaceae       | *Clysmometra retusa* Britton & Rose                                     |                             |
| Cannabaceae     | *Celtis iguanae* (Jacq.) Sarg. *Trema micrantha* (L.) Blume             | Capulín                      |
| Chrysobalanaceae| *Chrysobalanus icaco* L.                                                | Icaco                        |
| Clethraceae     | *Clethra mexicana* DC.                                                  | Zapatillo                    |
| Clusiaceae      | *Calophyllum brasiliense* var. reko (Standl.) *Clusia guatemalens* Hemsl. | Palo mario                   |
| Combretaceae    | *Conocarpus erectus* L. *Laguncularia racemosa* (L.) C.F.Gaertn. *Terminalia arbores* Koord. | Botoncillo Mangle blanco Volador |
| Dicrachetales   | *Dichapetalum donnell-smithii* Engl.                                    |                             |
| Ebenaceae       | *Diospyros nigra* (J.F.Gmel.) Perrier                                   |                             |
| Fabaceae        | *Acacia cornigera* (L.) Willd. *Acacia hindsii* Benth. *Acacia polyphylla* DC. *Albizia adenocephala* (Donn.Sm.) Record *Albizia saman* (Jacq.) Merr. *Andira inermis* (Wright) DC. *Calliandra magdalena* var. colombiana (Britton & Killip) Barneby *Dalbergia cuscattanica* (Standl.) Standl. | Ixcanal blanco Ixcanal negro Alacrán Conacaste blanco Cenicero Almendro cimarrón Chali Granadillo |
Table 1. Cont.

| Family       | Species                                | Common Name                      |
|--------------|----------------------------------------|----------------------------------|
| Delonix regia (Hook.) Raf. | Diphollano                            |                                 |
| Diphysa americana (Mill.) M.Sousa | Guachipilín                          |                                 |
| Enterolobium cyclocarpum (Jacq.) Griseb. | Conacaste                           |                                 |
| Erythrina mexicana Krukoff | Palo de pito                          |                                 |
| Flacourtia sepium (Jacq.) Walp. | Madrecacáo                           |                                 |
| Inga edulis Mart. | Guanacaste                            |                                 |
| Inga laurina (Sw.) Willd. | Caspirol                              |                                 |
| Inga paterno Harms | Paternía                              |                                 |
| Inga sapindoides Willd. | Cushín                                |                                 |
| Lonchocarpus macrocarpus Benth. | Quebracho                             |                                 |
| Lonchocarpus salvadorensis Pittier | Chaperno                              |                                 |
| Lonchocarpus sericeus (Poir.) DC. | Matabuey                             |                                 |
| Pithecellobium dulce (Roxb.) Benth. | Guachimol                             |                                 |
| Platymiscium dimorphandrum Donn.Sm. | Hormigo                               |                                 |
| Poeppigia procera C.Presl | Tepemisqué                            |                                 |
| Schizolobium paralyba (Vell.) S.F.Blake | Plumillo                             |                                 |
| Senna reticulata (Willd.) H.S.Irwin & Barneby | Varajito, Aripin                     |                                 |
| Senna spectabilis (DC.) H.S.Irwin & Barneby | Vatarea lundelligi (Standl.) Record | Palo negro                       |
| **Lamiaceae** | Gmelina arborea Roxb.                  | Melina                           |
| **Lauraceae** | Nectandra membranacea (Sw.) Griseb.   | Canoj                            |
| Ocotea sinuata (Mez) Rohwer |                                       |                                 |
| **Lythraceae** | Lagerstroemia indica L.               |                                 |
| **Malpighiaceae** | Bunchosia guatemalensis Nied.         |                                 |
| Bunchosia odorata (Jacq.) Juss. |                                       |                                 |
| Byrsonima crassifolia (L.) Kunth | Nance                                |                                 |
| **Malvaceae** | Guaizuma ulmifolia Lam.               | Caulote                          |
| Hampea roviresae Standl. |                                       |                                 |
| Heliocarpus donnellsmithii Rose | Pumpujush, zapotón, pumorrojo         |                                 |
| Pachira aquatica Aubl. |                                       |                                 |
| Quararibea funebris (La Llave) Vischer | Moliynillo                            |                                 |
| Sterculia apetala (Jacq.) H.Karst. | Castaño                              |                                 |
| Trichospermum mexicanum (DC.) Baill. | Cajete                               |                                 |
| **Melastomataceae** | Conostegia xalapensis (Bonpl.) D. Don ex DC. |                                 |
| Miconia laevigata (L.) D. Don | Cacho de venado                       |                                 |
| **Meliaceae** | Guarea glabra Vahl                    | Anicillo                         |
| Guarea megantha A.Juss. | Trompillo                             |                                 |
| Swietenia macrophylla King | Caoba                                |                                 |
| Trichilia havanensis Jacq. |                                       |                                 |
| Trichilia martiana C.DC. | Chile amate                           |                                 |
| **Moraceae** | Brosimum costaricanum Liebm.          | Ujushte, Ramón                    |
| Castilla elastica Cerv. | Palo de hule                          |                                 |
| Ficus aurea Nutt. | Amate                                 |                                 |
| Ficus benjamina L. | Amate                                 |                                 |
| Ficus costaricana (Liebm.) Miq. | Amate                                 |                                 |
| Ficus crocata (Miq.) Mart. ex Miq. | Amate                                 |                                 |
| Ficus hemsleyana King | Amate                                 |                                 |
| Ficus insipida Willd. | Amate                                 |                                 |
| Ficus maxima Mill. | Amate                                 |                                 |
| Ficus obtusifolia Kunth | Poto de pito                          |                                 |
| Ficus pertusa L.f. | Amate                                 |                                 |
| Ficus sp. | Amate                                 |                                 |
| Maclura tinctoria (L.) D.Don ex Steud. | Mora                                |                                 |
| Trophis racemosa (L.) Urb. |                                       |                                 |
Table 1. Cont.

| Family             | Species                                      | Common Name            |
|--------------------|----------------------------------------------|------------------------|
| Muntingiaceae      | *Muntingia calabura* L.                      | Capulín blanco         |
| Nyctaginaceae      | *Neea psychotrioides* Donn.Sm.               | Siete camisas          |
| Olacaceae          | *Ximenia americana* L.                       |                        |
| Phyllanthaceae     | *Astrocasia austina* (Standl.) G.L.Webster   | Pimientillo            |
| Polygonaceae       | *Cocoloba barbadensis* Jacq.                 | Papaturro              |
|                    | *Cocoloba escuintliensis* Lundell            | Papaturro              |
|                    | *Triplaris melaenodendron* (Bertol.) Standl. & Steyerm. | Mulato           |
| Primulaceae        | *Bonellia macrocarpa* (Cav.) B.Ståhl & Källersjö | Naranjillo            |
| Rhamnaceae         | *Colubraria arborescens* (Mill.) Sarg.       | Coshte                 |
| Rhizophoraceae     | *Rhizophora mangle* L.                       | Mangle Rojo            |
| Rubiaceae          | *Hamelia patens* Jacq.                       | Chichipín              |
|                    | *Psychotria limonensis* K.Krause             |                        |
|                    | *Simira salvadorensis* (Standl.) Steyerm.   |                        |
| Rutaceae           | *Zanthoxylum riedelianum* subsp. kellerianii (P.Wilson) Reynel ex C.Nelson | Lagarto                |
| Salicaceae         | *Casearia arguta* Kunth                      | Raspa lengua           |
|                    | *Salix humboldtiana* Willd.                   | Sauce                  |
| Sapindaceae        | *Sapindus saponaria* L.                      | Jaboncillo             |
| Sapotaceae         | *Pouteria sapota* (Jacq.) H.E.Moore & Stearn | Zapote                 |
|                    | *Sideroxylon capiri* subsp. tempisque (Pittier) T.D.Penn. | Tempisque           |
|                    | *Sideroxylon celastrinum* (Kunth) T.D.Penn. |                        |
|                    | *Sideroxylon capiri* (A.DC.) Pittier         |                        |
| Simaroubaceae      | *Simarouba amara* Aubl.                      | Aceitunó               |
| Solanaceae         | *Cestrum racemosum* Ruiz & Pav.              | Huele de noche         |
|                    | *Solanum diphyllum* L.                       |                        |
| Staphyleaceae      | *Turpinia occidentalis* (Sw.) G.Don          |                        |
| Urticaceae         | *Cecropia obtusifolia* Bertol.               | Guaramo                |
| Verbenaceae        | *Citharexylum affine* D.Don                  | Cola de iguana         |

3.2. Vegetation Classification

Classification of the vegetation was made through cluster analysis on the abundance of species per plot. Five of the 56 plots (3, 6, 7, 14 and 27) were not included in the analysis, as they were located on heavily disturbed areas. The cluster analysis identified four groups of vegetation along an altitudinal gradient (Figure 2). The analysis of similarity (ANOSIM) showed that the formed clusters were well separated (R = 0.55), and that the separation was significant (p = 0.001). To verify and validate the groups obtained through cluster analysis, a non-metric multidimensional scaling was performed. The results support the grouping in the ordination graph (Figure S2).

3.3. Floristic Composition in the Riparian Tree Communities

Of the 115 species collected along the river basin, only 69 were within the sampling plots, which represents 60% of the species. Riparian tree community 1 is located at sea level on the Pacific coast, where 118 trees were sampled belonging to 12 species. Riparian community 2 is located above 100 m a.s.l, where 167 trees were sampled belonging to 28 species. Community 3 is located at around 50 m a.s.l, where 172 trees were sampled belonging to 31 species, and community 4 is located between 50 and 546 m a.s.l, where 463 trees were sampled belonging to 54 species (Figure 3).
Figure 2. Cluster analysis based on species abundance data, in 51 0.1-hectare plots on the banks of the Acomé River, using Euclidean distance and Ward’s method. Plots are grouped on the horizontal axis, while the vertical axis indicates the degree of proportional similarity between the species within the plots. Clusters are numbered 1 to 4.

Figure 3. Distribution of tree communities on the banks of the Acomé River.

The four major or dominant species in each riparian tree community and their importance values are shown in Table 2.
Table 2. Importance values (IVs) of dominant species of the riparian tree communities along the Acomé riverbank.

| Community | Species                        | IV (%) |
|-----------|--------------------------------|--------|
| 1         | *Rhizophora mangle* L.         | 41.6   |
|           | *Avicennia germinans* (L.) L.  | 22.7   |
|           | *Pithecellobium dulce* (Roxb.) Benth. | 6.8   |
|           | *Laguncularia racemosa* (L.) C.F.Gaertn. | 5.6   |
| 2         | *Cecropia obtusifolia* Bertol. | 19.1   |
|           | *Guazuma ulmifolia* Lam.       | 10.9   |
|           | *Andira inermis* (Wright) DC.  | 8.8    |
|           | *Ficus aurea* Nutt.            | 7.7    |
| 3         | *Guazuma ulmifolia* Lam.       | 18.4   |
|           | *Ceiba pentandra* (L.) Gaertn. | 17.3   |
|           | *Enterolobium cyclocarpum* (Jacq.) Griseb. | 11.3   |
|           | *Salix humboldtiana* Willd.    | 7.2    |
| 4         | *Brosimum costaricanum* Liebm. | 9.2    |
|           | *Acacia polyphylla* DC.        | 7.7    |
|           | *Cecropia obtusifolia* Bertol. | 7.0    |
|           | *Ceiba pentandra* (L.) Gaertn. | 5.9    |

3.4. Species Diversity of the Riparian Tree Communities

Table 3 shows the diversity indices for each riparian tree community of the Acomé river. According to the indices, community 1 had the lowest diversity and evenness values, with *R. mangle* as a dominant species. Community 2 had intermediate diversity and evenness values, with *C. obtusifolia* being the dominant species. Communities 3 and 4 had the highest evenness values (above 0.9), but diversity was ranked second lowest for community 3 and highest for community 4. *G. ulmifolia* and *B. costaricanum* were the dominant species in communities 3 and 4, respectively.

Table 3. Species diversity indices for the riparian tree communities of the Acomé riverbank.

| Diversity Index                  | Riparian Tree Community |
|----------------------------------|-------------------------|
|                                  | 1  | 2  | 3  | 4  |
| Number of plots                  | 2  | 5  | 23 | 21 |
| Total number of species          | 12 | 28 | 31 | 54 |
| Richness per plot (s) *          | 8  | 10.8 | 4.2 | 11.3 |
| Evenness (J') *                  | 0.64 | 0.78 | 0.92 | 0.91 |
| Simpson diversity (D_s) *        | 0.63 | 0.77 | 0.7 | 0.89 |

Note: Fields marked with asterisk (*) represent mean values for each group.

4. Discussion

This study provides a detailed tree characterization of the Acomé riverbank, reporting 115 tree species belonging to 91 genera and 43 families. A study investigating tree diversity in tropical riparian forest fragments in the Mountain Pine Ridge savannah in Belize (400 to 1000 m a.s.l.) found similar numbers, with 106 morphospecies, 78 genera and 42 families in micro-forests and 117 morphospecies, 71 genera and 41 families in tree thickets [37]. However, the floristic composition of both studies is remarkably different, possibly due to differences in the altitudinal and latitudinal range.

Most of the tree species reported in this study such as *A. hindsii*, *A. purpurea*, *C. guatemalensis* and *S. salvadorensis* are native to Mesoamerica, with one, *S. salvadorensis*, being listed in the *Red List of Trees of Guatemala* [38]. However, there are non-native species in the list, such as *G. arborea* (originally from Asia) *D. regia* (originally from Madagascar), *L. sericeus* (originally from Mexico) and *S. campanulate* (originally from Africa) indicating that at least some of the species found in this region are introduced or exotic. Introduced
species are usually the result of anthropogenic activities, and the vicinity of riparian habitats may facilitate their establishment and spread [39]. Therefore, efforts to predict their occurrence, manage areas of high abundance and prevent further spread must be included in future management programs [39].

We identified four riparian tree communities in the Acomé river basin along an altitudinal gradient, where the species *R. mangle, C. obtusifolia, G. ulmifolia*, and *B. costaricanum* were dominant. The communities are very consistent with the bioclimatic classification of life zones at the recognition level inferred by L. Holdridge as suggested by De la Cruz [23,24]. Community 1 overlaps with the dry subtropical forest life zone (bs-S). Community 3 coincides with the humid subtropical warm-forest zone (bh-S) and has secondary forest trees as its dominant species. Riparian tree communities 2 and 4 are included in the very wet subtropical warm-forest zone (bmh-S) and have different dominant species, but these are all distinctive of secondary forests [26,27], suggesting intermediate successional stages.

Dominant species may naturally differ between communities due to the azonal condition of the vegetation inherent to the riparian habitat [8]. Factors affecting the distribution and composition of the species in these communities include altitude, edaphic factors and anthropogenic intervention (especially fires) [40]. Therefore, we strongly suggest that future studies incorporate ecological predictors including soil properties, distance from river course, depth of the groundwater table, landscape cover surrounding the plot and disturbance effects (e.g., fire history) in order to explain the observed differences.

We estimated the average species richness or number of species (s), the average evenness that indicates the relative abundance of species (J’) and the average Simpson diversity (Ds) for each tree community. Community 1, located in the mangrove ecosystem, had a lower richness (8 species), evenness (0.64) and diversity (0.63) when compared with the other communities. This is expected, as only a few halophytic species, such as mangroves, can survive under the high-salinity conditions of river estuaries [41]. However, despite having a low diversity and evenness, mangroves serve important ecological roles, providing mating and nesting habitats for a variety of birds and aquatic fauna [41]. Furthermore, from the four identified communities, the mangrove community is the least disturbed by anthropogenic activities, as it is located within a protected area (the Sipacate-Naranjo Natural Park).

The remaining communities include tree species characteristic of secondary forests which are surrounded by sugarcane plantations, urban zones and grazing areas. Despite being located near heavily disturbed areas, communities 2, 3 and 4 have a relatively high evenness (0.78, 0.92 and 0.91, respectively) and diversity (0.77, 0.7 and 0.89, respectively).

Currently, secondary forests cover extensive areas across Central America. These mostly originate from the natural regeneration of previously deforested land from the native seedbank rather than from intentional reforestation efforts [42]. Secondary forests are positioned among the most significant sources of biodiversity and carbon reservoirs on earth, serving as both habitats for wildlife and regulators of the carbon cycle [2]. However, the capability of these secondary forests in regaining the biological features and diversity of an undisturbed primary forest is still poorly understood [2,9], as is the contribution of secondary forest remnants in fragmented landscapes in maintaining diversity across agricultural matrices [43].

This study can be used as a reference for the riparian tree vegetation of the Pacific lowlands of Guatemala. Further studies are needed to characterize secondary forests of the region in detail to monitor change over time, create predictive models, and establish conservation priorities. We acknowledge that this work is limited by the lack of ecological data (e.g., soil properties, distance from a river course and disturbance effects) needed to explain the observed patterns and suggest that future research incorporates ecological predictors in order to address this. We also suggest the inclusion of other vegetation strata, such as shrubs, herbs, lianas, epiphytic plants and aquatic plants, in future studies. A more accurate representation of the riparian vegetation composition is essential to support future
ecological restoration projects, the reintroduction of native species, the management of exotic species and other in situ conservation efforts.

5. Conclusions and Future Outlook

Presently, the loss and fragmentation of forests due to changes in land use is considered one of the greatest threats to global biodiversity, particularly in the tropics. In tropical regions that have lost most of their forest cover, it is essential to consider the remaining forest patches as a priority for conservation [37,44,45]. In the Pacific lowlands of Guatemala, most of the remnant forests are located along riverbanks. However, their riparian tree community composition and biodiversity status are poorly known. This study provided a list of plant species and identified tree communities along the Acomé river, in the Pacific slope of Guatemala. We found many native tree species, but exotic tree species were also recorded along the river basin, supporting the need for urgent conservation and restoration efforts. This study can be used as a reference by local landscape managers and government or conservation organizations. We consider that restoring riparian forests should be a priority in the region, with a focus on native species, as they are more likely to support native fauna. More studies at a local and regional scale, including detailed ecological information and disturbance impacts, are needed to accurately assess and monitor biodiversity and identify conservation priorities [46].

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/f12070898/s1, Table S1: Location of the sampling plots along the Acomé riverbanks; Figure S1: System used to dry botanical specimens; and Figure S2: Non-metric multidimensional scaling with data on the abundance of species per tree community.

Author Contributions: Conceptualization and methodology A.A.P., J.J.C.M. and D.E.M.J.; data collection A.A.P., J.J.C.M., and D.E.M.J.; data analysis A.A.P. and J.J.B.; revision and discussion A.A.P., A.C.M., A.G.N., D.E.M.J. and J.J.B.; manuscript written by A.A.P. and A.C.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by The Private Institute for Climate Change Research (ICC).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data that support the findings of this study are available from the corresponding authors upon reasonable request.

Acknowledgments: We are grateful to the technical team of the Integrated Watershed Management Program of the Private Institute for Climate Change Research for the support provided in the field and for providing the financial assistance to carry out this research. We also especially want to thank Nereyda Trabanino, Conrado Gámez and Carlos Tivo for their support and assistance during the field phase, to Amy Molina for her support with map editing. We are grateful to Paul Barrett for proofreading the final version of the manuscript, and to Massey University for supporting open access publication.

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

References

1. Laurance, W.F.; Sayer, J.; Cassman, K.G. Agricultural expansion and its impacts on tropical nature. Trends Ecol. Evol. 2014, 29, 107–116. [CrossRef]
2. Phalan, B.; Bertzky, M.; Butchart, S.H.; Donald, P.F.; Scharlemann, J.P.; Stattersfield, A.J.; Balmford, A. Crop expansion and conservation priorities in tropical countries. PLoS ONE 2013, 8, e51759. [CrossRef]
3. Sempris, E.; Carrillo, R.; Portillo, R.H.O.; Carranza, A.C.; Fuller, C.; Peters, R.E.; Stokes, C.; Castaño, C.C.; Irwin, D.; Barraza, E. Potential Impacts of Climate Change on Biodiversity in Central America, Mexico and the Dominican Republic; Water Center for the Humid Tropics of Latin America and the Caribbean: Panama City, Panama, 2008.
4. DeClerck, F.A.; Chazdon, R.; Holl, K.D.; Milder, J.C.; Finegan, B.; Martinez-Salinas, A.; Imbach, P.; Canet, L.; Ramos, Z. Biodiversity conservation in human-modified landscapes of Mesoamerica: Past, present and future. Biol. Conserv. 2010, 143, 2301–2313. [CrossRef]
37. Pither, R.; Kellman, M. Tree species diversity in small, tropical riparian forest fragments in Belize, Central America. *Biodivers. Conserv.* **2002**, *11*, 1623–1636. [CrossRef]
38. Vivero, J.L.; Szejner, M.; Gordon, J.; Magin, G. *The Red List of Trees of Guatemala*; UNEP: Ginebra, Switzerland; IUCN: Gland, Switzerland; FFI: Cambridge, UK; BGCI: Surrey, UK, 2006.
39. Hoffman, J.D.; Narumalani, S.; Mishra, D.R.; Merani, P.; Wilson, R.G. Predicting potential occurrence and spread of invasive plant species along the North Platte River, Nebraska. *Invasive Plant Sci. Manag.* **2008**, *1*, 359–367. [CrossRef]
40. Rios, B.; Raga, G.B. Spatio-temporal distribution of burned areas by ecoregions in Mexico and Central America. *Int. J. Remote Sens.* **2018**, *39*, 949–970. [CrossRef]
41. Lugo, A.E.; Snedaker, S.C. The ecology of mangroves. *Annu. Rev. Ecol. Syst.* **1974**, *5*, 39–64. [CrossRef]
42. Henao Bravo, E.I.; Ordóñez, Y.; Camino Velozo, R.D.; Soto, R.V.; Gambeta, F.C. *El Bosque Secundario en Centroamérica: Un Recurso Potencial de uso Limitado por Procedimientos y Normativas Inadecuadas*; CATIE: Cartago, Costa Rica, 2015.
43. Fahrig, L. Habitat fragmentation: A long and tangled tale. *Glob. Ecol. Biogeogr.* **2019**, *28*, 33–41. [CrossRef]
44. Wilson, E.O. Threats to biodiversity. *Sci. Am.* **1989**, *261*, 108–117. [CrossRef]
45. Chazdon, R.L. J.S. Tropical forests—Log’em or leave’em? *Science* **1998**, *281*, 1295–1296. [CrossRef]
46. Noss, R.F. Assessing and monitoring forest biodiversity: A suggested framework and indicators. *For. Ecol. Manag.* **1999**, *115*, 135–146. [CrossRef]