Floristic Composition and Structural Patterns of Riparian Vegetation in the La Vega River Micro-Watershed, Tunja–Boyacá, Colombia

Composición florística y patrones estructurales de la vegetación ribereña en la microcuenca del río La Vega, Tunja–Boyacá, Colombia

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Highlights

- Woody vegetation in the La Vega River riparian corridor reflects structural alteration and successional shifts following flood-induced channel expansion.
- The dominance of exotic Acacia species indicates an active invasion process that may threaten the ecosystem's functionality.
- Species composition and structural heterogeneity provide a scientific basis for restoring native vegetation in urban riparian systems.

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ABSTRACT

Introduction. Urban riparian corridors are critical for biodiversity conservation, hydrological regulation, and ecosystem connectivity. However, anthropogenic pressures and extreme climate events have disrupted their ecological integrity, particularly in rapidly urbanizing Andean regions. **Objectives.** This study aims to characterize the floristic composition and structural attributes of woody vegetation in a riparian section of the La Vega River micro-watershed (Tunja, Boyacá), which was disturbed by dredging activities following the 2010–2011 La Niña event. **Materials and methods.** Field sampling was conducted through 20 transects (50 × 2 m; total area 0.2 ha) along both riverbanks within the university campus. All woody individuals with a diameter at breast height (DBH) > 1 cm were recorded. Structural parameters (density, dominance, frequency, Importance Value Index), species richness estimators, and diversity indices (Shannon-Wiener, Simpson, Margalef) were calculated. **Results.** A total of 782 individuals were recorded, comprising 37 species, 28 genera, and 21 families. The family Fabaceae was dominant, with exotic species such as *Acacia decurrens* (IVI = 139%), *A. mearnsii*, and *A. melanoxylon* prevailing across the site. Native species including *Juglans neotropica*, *Sambucus peruviana*, *Quercus humboldtii*, and *Prunus serotina* showed lower abundance but play important ecological roles. **Conclusions.** The high dominance of exotic *Acacia* species indicates ongoing ecological alteration within the riparian corridor. Active management and restoration strategies are needed to curb the spread of invasive species and promote the recovery of native riparian vegetation.

RESUMEN

Introducción. Los corredores ribereños urbanos son fundamentales para la conservación de la biodiversidad, la regulación hidrológica y la conectividad ecosistémica. Sin embargo, las presiones antrópicas y los eventos climáticos extremos han afectado su integridad ecológica, especialmente en regiones andinas en proceso de urbanización acelerada. **Objetivos.** Este estudio busca caracterizar la composición florística y los atributos estructurales de la vegetación leñosa en un tramo ribereño de la microcuenca del río La Vega (Tunja, Boyacá), alterado por labores de dragado tras el fenómeno de La Niña 2010–2011. **Materiales y métodos.** El muestreo de campo se realizó mediante 20 transectos (50 × 2 m; área total 0,2 ha) distribuidos en ambas márgenes del río, dentro del campus universitario. Se registraron todos los individuos leñosos con diámetro a la altura del pecho (DAP) > 1 cm. Se calcularon parámetros estructurales (densidad, dominancia, frecuencia, IVI), estimadores de riqueza y los índices de diversidad de Shannon-Wiener, Simpson y Margalef. **Resultados.** Se censaron 782 individuos pertenecientes a 37 especies, 28 géneros y 21 familias. Fabaceae fue la familia dominante, destacándose especies exóticas como *Acacia decurrens* (IVI = 139%), *A. mearnsii* y *A. melanoxylon*. Aunque menos abundantes, especies nativas como *Juglans neotropica*, *Sambucus peruviana*, *Quercus humboldtii* y *Prunus serotina* cumplen funciones ecológicas relevantes. **Conclusiones.** La alta dominancia de especies exóticas del género *Acacia* indica una alteración ecológica en curso. Se requieren estrategias activas de manejo y restauración que limiten la expansión de especies invasoras y promuevan la recuperación de la vegetación ribereña nativa.

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INTRODUCTION

Riparian corridors in Andean forest ecosystems play a fundamental role in maintaining ecological connectivity and providing critical ecosystem services (1-2). However, these systems are increasingly threatened by urban expansion, land-use change, and climate variability (3). The longitudinal configuration of watersheds serves as natural biological corridors, enabling species dispersal, supporting genetic flow, and sustaining key ecological processes across landscapes (4). As transitional zones between terrestrial and aquatic environments, riparian vegetation contributes significantly to biodiversity by offering habitat and movement pathways for flora and fauna (5). It also influences geomorphological and biogeochemical processes, including nutrient cycling, sediment retention, and bank stabilization (6). Vegetation cover in these areas helps mitigate the impacts of floods and landslides, improves water quality, and adds aesthetic and recreational value to urban landscapes (7-8). Riparian zones are thus essential components of ecological infrastructure, contributing to air circulation and urban climate regulation (9-12).

In Colombia, riparian ecosystems are under increasing pressure. According to the national environmental agency (IDEAM), these areas are experiencing reduced water availability due to the combined effects of urban sprawl and unsustainable productive activities (13). Climatic disturbances, such as the 2010–2011 La Niña event, resulted in severe flooding, landscape degradation, and damage to critical infrastructure (14-15).

One affected area is the La Vega River, which flows between the city of Tunja and the municipality of Motavita in the department of Boyacá. The river system has been altered by both anthropogenic activities (16) and natural events. During La Niña 2010–2011, heavy rainfall caused the La Vega and Jordán rivers to overflow, leading to widespread flooding (17). These events highlighted the vulnerability of already disturbed ecosystems, particularly urban riparian zones that had been subjected to human interventions (18).

In response to these floods, dredging was carried out along the section of the La Vega River that crosses the campus of the Universidad Pedagógica y Tecnológica de Colombia (UPTC). While these interventions reduced flood risk, they also involved the removal of riparian vegetation, exposing the area to colonization by opportunistic species. The loss of native vegetation can intensify river discharge and disrupt hydrological cycles, thereby increasing the risk of further ecological degradation (19).

Given their role as buffer zones, riparian corridors are crucial for maintaining biodiversity, regulating sediment dynamics, and supporting trophic networks. Their floristic composition provides valuable insights into ecological functions such as water regulation and the provision of ecosystem services in urban environments. Assessing how disturbances influence vegetation structure is essential for designing conservation and restoration strategies that prioritize the recovery of native species and the control of invasive ones (20-22).

This study aims to characterize the composition and diversity of woody vegetation in the riparian corridor of the UPTC campus, focusing on the ecological impacts of the 2010–2011 La Niña event. By analyzing vegetation structure after this major disturbance, we seek to generate evidence-based recommendations for the ecological restoration of the La Vega River micro-watershed within an urban context.

MATERIALS AND METHODS

Study Area

The La Vega River micro-watershed is located in the Eastern Cordillera of the Colombian Andes. It originates at 3,250 meters above sea level (m a.s.l.) in the *El Frutillal* sector, in the municipality of Motavita, and descends to 2,770 m a.s.l. as it enters the city of Tunja. The river crosses the campus of the Universidad Pedagógica y Tecnológica de Colombia (UPTC) and eventually flows into the Jordán River, near the *Las Quintas* neighborhood [(23-24)].

Tunja's climate is characterized by a bimodal rainfall pattern, with peaks typically occurring in April and October. The city receives an annual average precipitation of 645 mm and maintains a mean temperature of 13°C, with maximum temperatures ranging from 25°C to 26°C [(23)].

The study site is located within the riparian corridor of the La Vega River, covering an approximate area of 8,000 m² and a linear distance of 2 km. This section lies within UPTC property, between 2,700 and 2,770 m a.s.l., and corresponds to the Andean forest life zone [(25)]. The sampling stretch begins at the boundary with the main road (5°33'22.22"N, 73°21'45.51"W) and extends to the area known as *Pozo de Donato*, an archaeological and cultural site, ending at coordinates 5°33'3.15"N, 73°21'12.53"W (**Figure 1**).

During the 2010–2011 La Niña event, the city of Tunja experienced heavy rainfall that caused localized landslides and flooding. Within the UPTC campus, several institutional facilities were affected. In response, emergency interventions authorized by local risk management authorities (CREPAD, CLOPAD, and the municipal risk office) included channel widening and dredging, using heavy machinery. These actions significantly altered the existing vegetation, which was then subjected to 12 years of natural regeneration—the current state evaluated in this study.

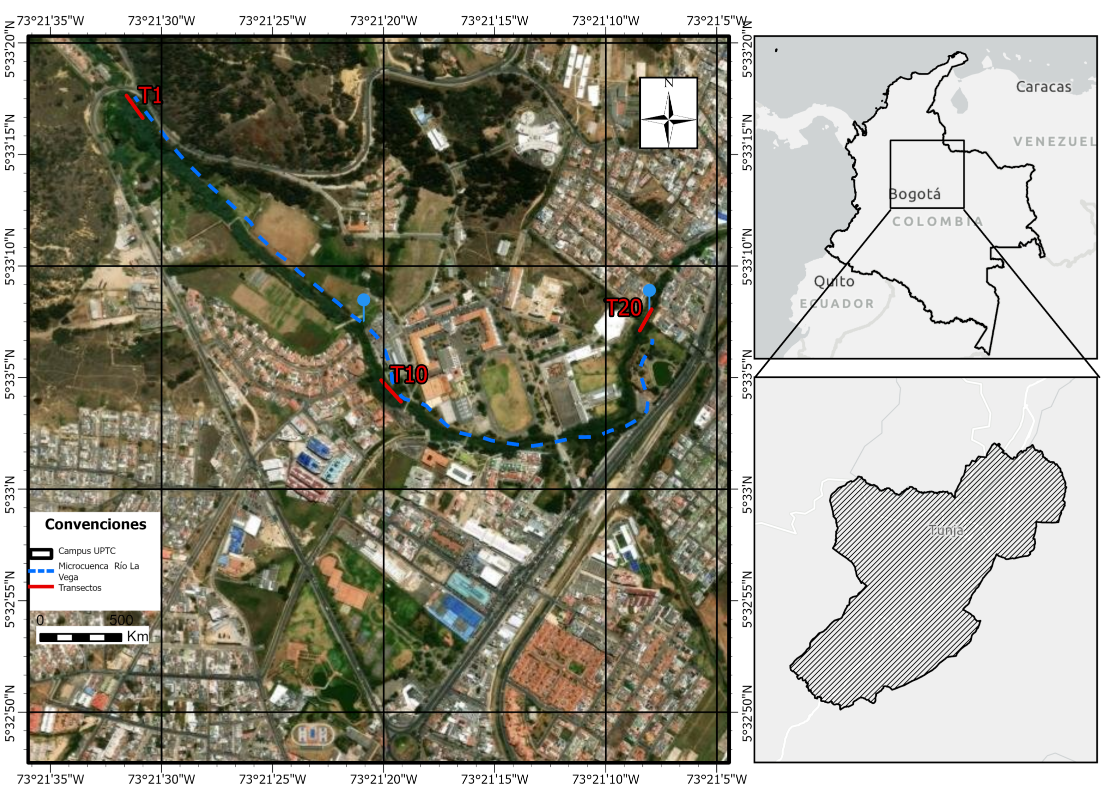

Figure 1. Location of the study area in the La Vega River micro-watershed, Tunja-Boyacá.

Vegetation Sampling

Vegetation surveys were conducted along the riparian corridor within the university campus, using Gentry's transect method [26]. A total of 20 linear transects measuring 50 × 2 meters were established, covering a total area of 0.2 hectares across both riverbanks. All woody species with a minimum height of 0.3 m were recorded. For individuals with a circumference at breast height (CBH) greater than 1 cm, total height and CBH were measured [27]. Sampling locations were selected based on noticeable changes in vegetation and terrain dynamics.

Taxonomic identification was carried out using specialized literature, dichotomous keys, and online databases such as JSTOR Global Plants and Tropicos.org.

Data Analysis

The structural parameters calculated included: relative density, frequency and relative frequency, dominance and relative dominance, and the Importance Value Index (IVI) [25].

Diameter at breast height (DBH) was derived from CBH using Equation 1:

(**Equation 1**)

Basal area (BA), representing dominance, was calculated using Equation 2:

(**Equation 2**)

Importance Value Index (IVI) was determined with Equation 3:

(**Equation 3**)

Diameter class intervals were calculated from DBH data using Equation 4:

where m= 1 + 3.3 Log N (**Equation 4**)

Here, **C** = is the class width, **N** is the number of individuals, and ***X*** is the parameter analyzed

To assess sampling effort, non-parametric richness estimators (Chao1, Jackknife1, and Bootstrap) were applied using the software EstimateS 9.1.0 [28]. Diversity indices included Simpson's dominance index, Shannon-Wiener diversity index (H'), and Margalef's richness index (DMg). To evaluate structural variation along the corridor, height and basal area were analyzed across the 20 transects. Due to non-normal data distribution, the non-parametric Kruskal–Wallis test was used to detect significant differences in these variables, given their relevance for understanding vertical structure and ecological function in riparian systems.

Disponibility Data

The dataset supporting this study is openly available in *Mendeley Data* at: Sánchez Chávez, E. C., & Galvis Rueda, M. (2025). Datos de composición y estructura florística en la microcuenca del río La Vega, Tunja – Boyacá, Colombia (Version 1). https://doi.org/10.17632/9z28ch2fwb.1

RESULTS

Species Composition and Richness

A total of 782 woody individuals were recorded across the 20 transects, representing 37 species, 31 genera, and 21 families (Dataset available at https://doi.org/10.17632/9z28ch2fwb.1). Among the richness estimators, Bootstrap showed the best performance, estimating a sampling coverage of 86.32%, followed by Chao1 (83.73%) and Jackknife1 (74.97%) (**Figure 2**).

The most diverse families were Fabaceae (5 species), Asteraceae, Euphorbiaceae, and Solanaceae (each with 3 species). Of the 37 species recorded, 12 were exotic, with the most abundant being *Acacia decurrens* Willd. (456 individuals), *A. melanoxylon* R. Br. (74), and *A. mearnsii* De Wild. (66). The remaining 25 native species included *Sambucus peruviana* Kunth (14), *Tecoma stans* (L.) Juss. ex Kunth (13), *Prunus serotina* Ehrh. (12), and *Smallanthus pyramidalis* (Triana) H. Rob. (12). This composition reflects the influence of urbanization, vegetation cover change, and extreme climatic events such as the 2010–2011 La Niña [17, 29-30]

Diversity and Dominance

The Margalef index was 5.40, indicating moderate species richness. The Simpson index (0.6418) revealed high dominance, primarily by exotic species of the *Acacia* genus (*A. decurrens*, *A. mearnsii*, and *A. melanoxylon*), which together accounted for 76.2% of all individuals. The Shannon–Wiener diversity index (H' = 1.845) also suggested moderate diversity [31].

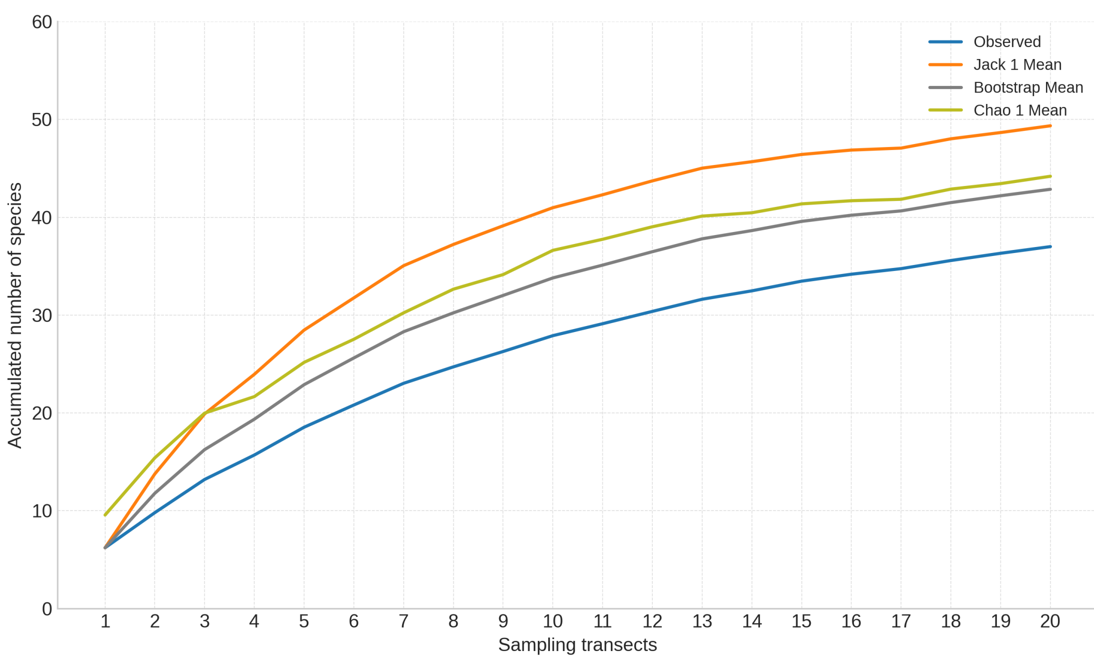

Figure 2. Species accumulation curves based on non-parametric richness estimators (Chao1, Jackknife1, and Bootstrap) for woody flora along the La Vega River riparian corridor.

Among exotic species, *Acacia decurrens* exhibited the highest Importance Value Index (IVI) (139%), followed by *A. mearnsii* and *A. melanoxylon*. In terms of basal area, other dominant species included *Juglans neotropica*, *Pittosporum undulatum*, *Sambucus peruviana*, and *Quercus humboldtii* (**Figure 3**). Higher diameter classes were often dominated by these species [32,33].

Size Structure

The diameter distribution of individuals followed an inverted-J pattern, typical of early successional or regenerating communities. Most individuals fell within the 1.00–6.99 cm (48.33%) and 7.00–12.99 cm (24.42%) diameter classes (**Figure 4**). In contrast, upper diameter classes (≥ 26 cm) were sparsely represented, with only one individual per class in categories 8, 9, and 10.

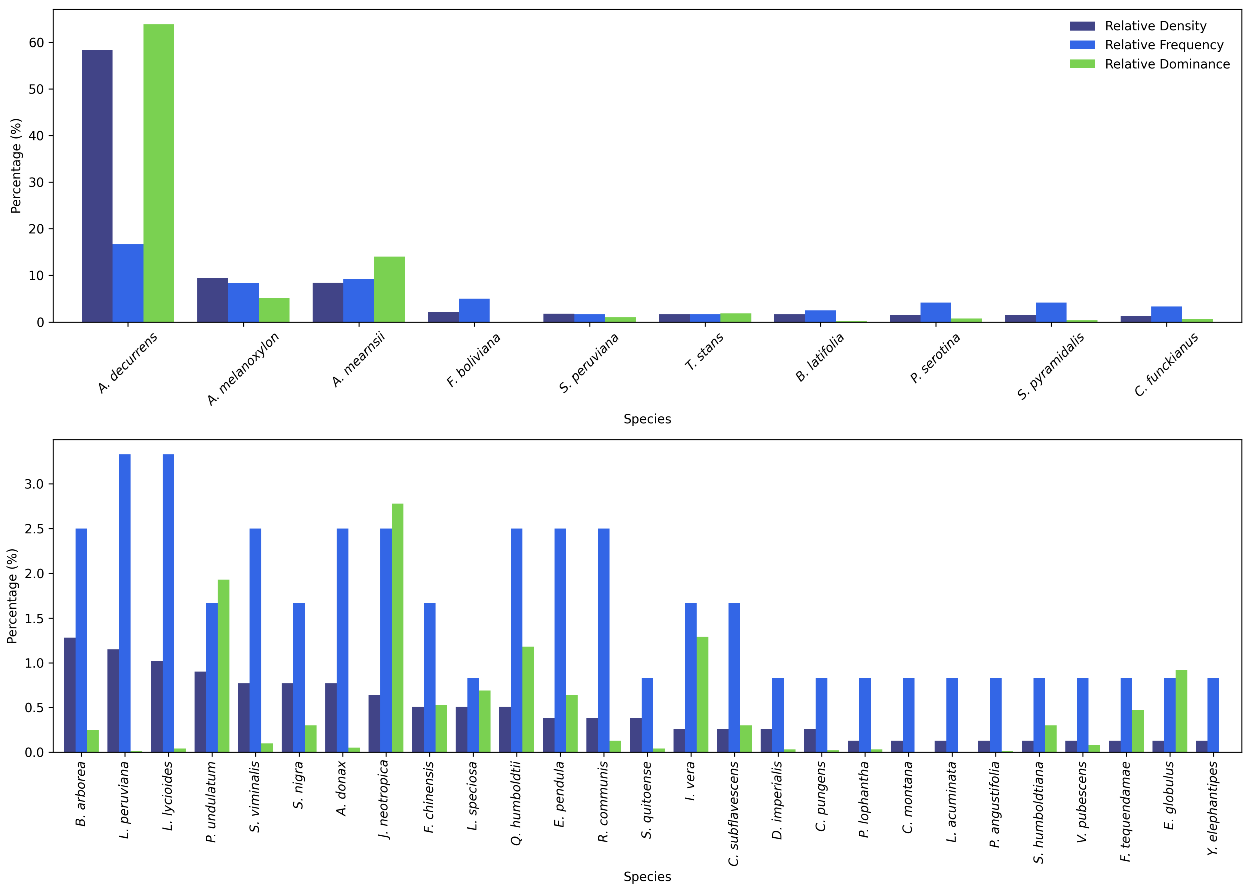

Figure 3. Relative density, frequency, and dominance of woody and shrub species recorded in the La Vega River micro-watershed. (**A**) 10 most abundant species. (**B**) Remaining species).

The height distribution showed a heterogeneous pattern. Classes 2 and 4 recorded the highest frequencies (102 and 95 individuals, respectively), while classes 3, 5, 10, and 11 each exceeded 60 individuals. Upper height classes were poorly represented, suggesting the predominance of young trees or shrub-sized individuals, indicative of active regeneration along the riparian corridor (**Figure 4**).

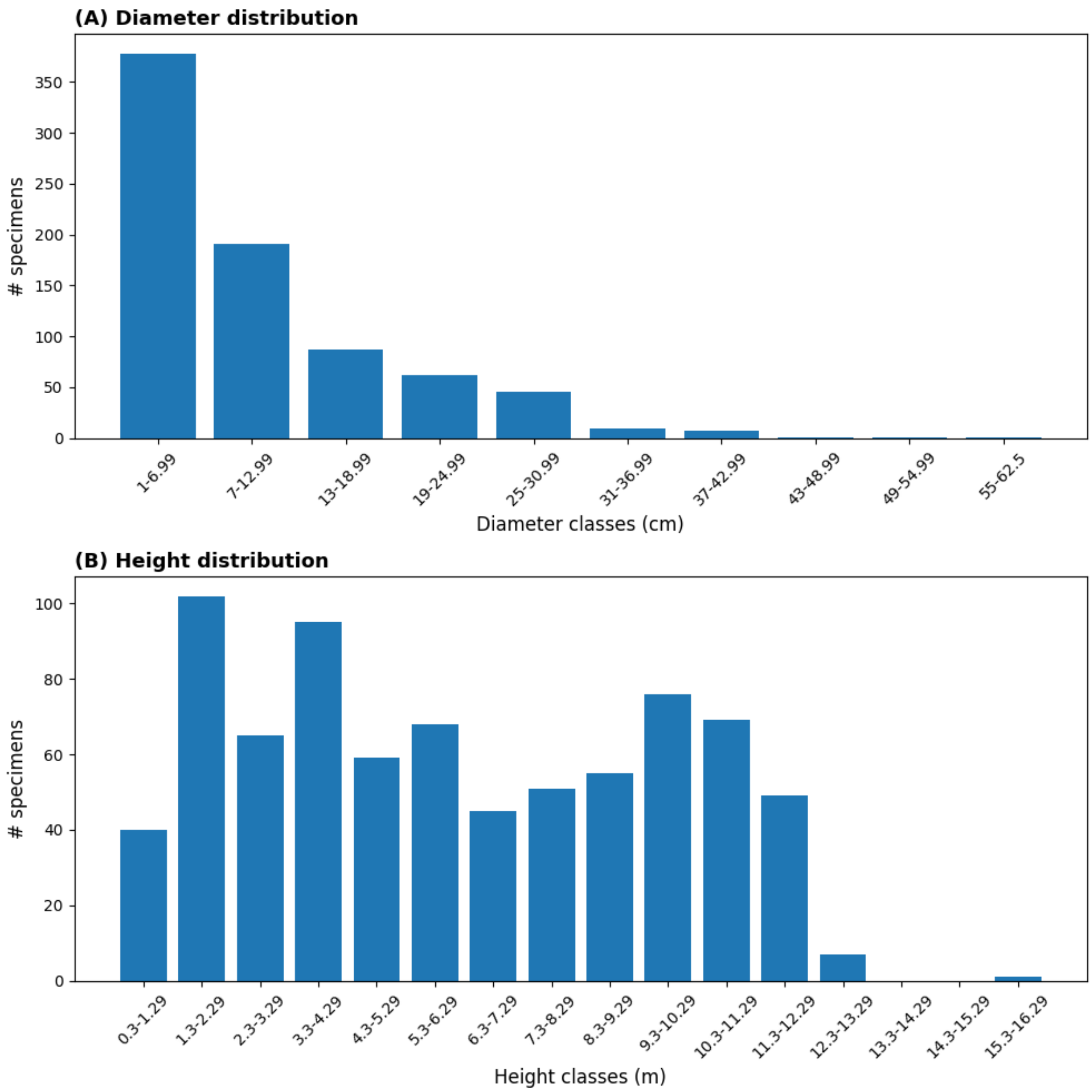

Figure 4. Frequency distribution of individuals across (**A**) diameter at breast height (DBH ≥ 1 cm) classes and (**B**) height classes within the riparian corridor of the La Vega micro-watershed, Tunja.

Structural Variability Across Transects

The Kruskal–Wallis test detected significant differences in both height ($H = 24.942$; $df = 3$; $p < 0.001$) and **basal area** ($p < 0.001$) among transects. In terms of height, transects T8, T18, and T20 exhibited taller individuals, whereas T13, T14, and T16 showed a lower canopy profile. Basal area was highest in T4, T5, and T20 (**Figure 5**), and lowest in T12, T13, and T14 (**Figure 6**).

Several transects (e.g., T16) displayed outliers exceeding 2000 cm^2, associated with remnant individuals of *Acacia decurrens* and *Eucalyptus globulus*, species known for their large size and persistence after disturbance. Conversely, areas subjected to dredging showed more homogeneous and juvenile vegetation, corresponding to early successional stages.

These patterns underscore a structurally heterogeneous corridor, shaped by past interventions and local environmental conditions. While some sections host mature canopy trees, others are dominated by early-successional or shrubby vegetation, reflecting differential responses to light availability, soil conditions, and disturbance intensity.

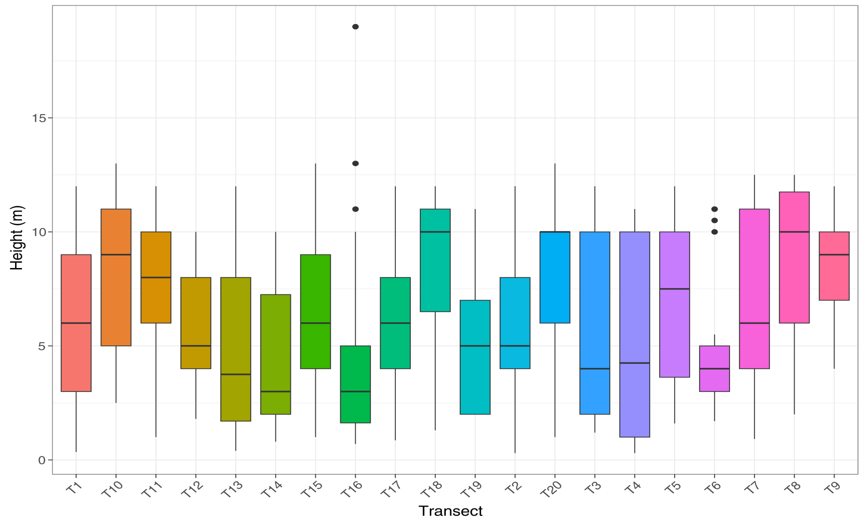

Figure 5. Boxplot of individual height distribution by transect along the La Vega River riparian corridor.

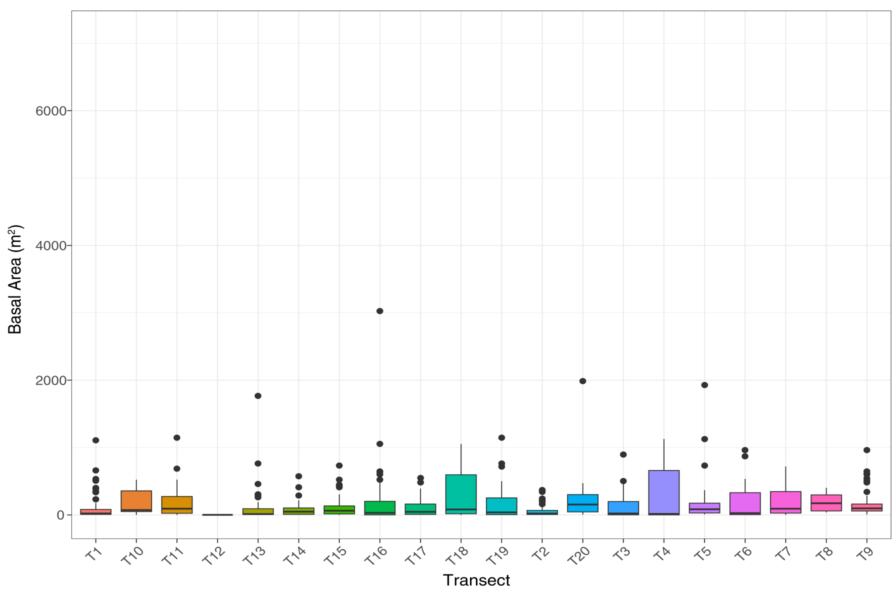

Figure 6. Boxplot of basal area (cm²) distribution by transect in the La Vega River riparian corridor.

DISCUSSION

The floristic composition documented along the La Vega River riparian corridor—located within the campus of the Universidad Pedagógica y Tecnológica de Colombia (UPTC)—revealed 37 woody species over a 1.3 km stretch. The assemblage included both native species (25), such as *Juglans neotropica*, *Quercus humboldtii*, and *Lafoensia acuminata*, as well as exotic species (12), notably *Ricinus communis*, *Acacia decurrens*, *A. mearnsii*, *A. melanoxylon*, and *Paraserianthes lophantha* [27].

This species richness appears to be shaped by a combination of factors including urban reforestation programs, land-use change, and anthropogenic pressures, compounded by climatic disturbances such as the 2010–2011 La Niña event. The flooding associated with this phenomenon triggered extensive channel dredging across parts of the corridor, which in turn led to significant removal of riparian vegetation [17, 29-30].

Among all transects, exotic *Acacia* species dominated ecologically, as reflected in their high Importance Value Index (IVI) scores. These species have adapted remarkably well to the Cundiboyacense highland environment and have been used for purposes ranging from silviculture and soil stabilization to nitrogen fixation. For instance, *A. decurrens* was initially introduced as an ornamental species and for silvopastoral systems [34-35].

In the urban context of Tunja, a study by Buitrago Campos based on reports from the Universidad Nacional de Colombia—identified *Tecoma stans*, *Acacia decurrens*, and *Pittosporum undulatum* as dominant elements of the urban tree canopy [29]. Similarly, surveys reported both native and exotic woody species, including *Cedrela montana*, *Juglans neotropica*, *Escallonia pendula*, *Sambucus nigra*, *Quercus humboldtii*, *Smallanthus pyramidalis*, and *Baccharis latifolia*, which were also recorded in this study [36]. These native taxa play key roles in urban forest regeneration, riparian protection, and biodiversity conservation.

In Bogotá's urban hillsides, *Acacia decurrens* and *Eucalyptus globulus* dominate early successional communities, while native species such as *Quercus humboldtii* and *Juglans neotropica* have shown strong potential for ecological restoration [37]. Moreover, *A. decurrens* has been recognized as an invasive species in wetland environments, along with *Ricinus communis* and *Brugmansia arborea*, though the latter two have a lower invasive potential [38].

The observed floristic shifts reflect broader patterns of urban riparian degradation, in which channel modifications, hard engineering, and urban expansion facilitate the proliferation of non-native species, often at the expense of native diversity and ecological connectivity [39-40]. In particular, *A. decurrens* contributes to this degradation through leaf litter accumulation, which can suppress native seedling establishment [41]. More broadly, exotic *Acacia* species have been associated with altered hydrological dynamics, soil modification, seedbank persistence, and high resilience to flooding, making them particularly competitive in disturbed areas [42-47].

In Colombia, *Acacia decurrens*, *Ricinus communis*, and *Arundo donax* have all been officially classified as invasive plants [34]. In contrast, native species such as *Juglans neotropica,* listed as endangered (EN A2cd), offer critical ecological and climatic resilience and are ideal candidates for urban reforestation [48-49]. Other native species found in this corridor—*Prunus serotina*, *Baccharis latifolia*, *Smallanthus pyramidalis*, *Ficus tequendamae*, *Salix humboldtiana*, and *Sambucus peruviana*—are well documented for their roles in riparian restoration and watershed protection [50-51].

The structural analysis of the woody community (based on DBH, basal area, and height) revealed a heterogeneous vegetation profile, typical of riparian ecosystems [52]. In urban areas, this heterogeneity is often the result of disturbance regimes such as vegetation clearing, channelization, effluent discharge, and hydrological disruption, which collectively produce a mosaic of successional stages [53-54]. Within La Vega, this pattern manifested as a mixture of mature canopy individuals—such as *A. decurrens*, *E. globulus*, and *J. neotropica*—coexisting with younger or shrub-like elements, particularly in areas recovering from recent disturbances. Notably, higher diameter classes were often dominated by exotic species, suggesting rapid post-disturbance colonization. Similar successional trends have been reported in other Colombian highland systems, including the Tominé Reservoir and the Eastern Hills of Bogotá, where *A. decurrens* and *E. globulus* also dominate early recovery stages [32-33].

Similar dynamics have been described in urban tropical rivers, such as those in Monterrey and Nuevo León, Mexico, where exotic species tend to dominate over natives under conditions of altered hydrology and urban encroachment [53, 55 -56]. These findings are directly applicable to the La Vega micro-watershed.

As essential components of green infrastructure, riparian corridors play a pivotal role in biodiversity maintenance, hydrological regulation, and ecosystem resilience in urban settings. The proliferation of exotic species such as *Acacia decurrens* poses a threat to this ecological functionality, emphasizing the urgent need for restoration strategies that favor native species recovery and effective management of biological invasions.

CONCLUSIONS

The floristic and structural characterization of the riparian corridor along the La Vega River, within the campus of the Universidad Pedagógica y Tecnológica de Colombia (UPTC), reveals a system undergoing ecological regeneration. Despite this positive dynamic, the high abundance and dominance of exotic species, particularly those of the *Acacia* genus, suggest that successional trajectories are being shaped predominantly by non-native flora. This shift represents a significant threat to native biodiversity and favors the establishment of biological invasion processes, compromising the ecological integrity of the corridor.

To address this situation, we recommend the implementation of seed bank control trials aimed at limiting the regeneration potential of *Acacia* species. These efforts should be accompanied by species replacement programs, focused on removing exotic individuals and introducing native species of ecological importance. Additionally, planned forestry harvesting that includes complete removal of plant debris (stems, branches, bark) is essential to prevent vegetative regrowth and facilitate natural regeneration.

Given the strong regenerative capacity of *Acacia*—through both seed banks and vegetative sprouting—restoration strategies must be integrated, long-term, and adaptive to the ecological dynamics of these invasive species. Moreover, we propose the active promotion and planting of native Andean riparian species, including *Juglans neotropica*, *Prunus serotina*, *Salix humboldtiana*, *Sambucus peruviana*, *Ficus tequendamae*, *Baccharis latifolia*, *Smallanthus pyramidalis*, *Cedrela montana*, *Myrsine guianensis*, *Viburnum triphyllum*, *Vallea stipularis*, *Escallonia paniculata*, and *Oreopanax floribundum*, among others. These species not only offer ecological benefits, but also contribute to the urban resilience needed in the face of extreme environmental events. Restoring the La Vega River corridor through native vegetation will enhance its role as a biodiversity refuge, strengthen hydrological regulation, and improve ecological connectivity. Ultimately, this riparian system can become a model of urban green infrastructure, essential for the environmental and spatial planning of Tunja and similar Andean cities.

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ETHICAL CONSIDERATIONS

The study was conducted exclusively through in situ observations and estimates of plant cover in a riparian corridor located within a university area that is freely accessible to the academic community. No plant specimens were collected, extracted, or manipulated, and no laboratory or experimental procedures were carried out. Consequently, neither collecting permits nor approval from an ethics committee were required, in accordance with current institutional and national guidelines.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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