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Woody Plant Species Diversity in Haramaya University Main Campus, Eastern Ethiopia

Zelalem Nurlign Getahun¹  | Anteneh Belayneh Desta²  | Hussien Yimer Abate¹ 

¹Plantation Research, Ethiopia Forestry Development, Dire Dawa Center, Dire Dawa, Ethiopia | ²School of Biological Sciences and Biotechnology, Haramaya University, Dire Dawa, Ethiopia

Correspondence: Zelalem Nurlign Getahun (znurlign14@gmail.com)

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ABSTRACT

Quantifying woody species diversity is essential for managing anthropogenically modified landscapes in the Ethiopian highlands. This study evaluated the floristic composition and structural diversity of woody plant species at Haramaya University, Eastern Ethiopia. Vegetation data were collected from 16 quadrats (1600 m²) across two distinct managed zones: the College of Agricultural and Environmental Sciences (Site A) and the Haramaya University Model School (Site B). A total of 569 individuals representing 29 unique woody species were identified. Site B recorded a higher Shannon–Wiener Diversity Index ($H' = 2.78$) and an Evenness Index ($J' = 0.928$). In contrast, Site A exhibited lower diversity ($H' = 2.31$) and an Evenness Index ($J' = 0.815$) and a significantly higher Simpson's Dominance Index ($D = 0.1465$), which was double that of Site B ($D = 0.0752$). An independent sample *t*-test performed on per-plot diversity values confirmed that the higher structural diversity in Site B was statistically significant ($t(14) = 2.45$, $p = 0.028$). *Celtis africana* emerged as a major structural driver across both sites, reaching a relative density of 29.7% and a modified two-component Importance Value Index (IVI) of 35.80% in Site A. A Jaccard Similarity Index of 27.59% indicated high beta-diversity between the study sites, heavily influenced by the uneven introduction of exotic species. Notably, *Lantana camara* (IVI = 33.7%) and *Jacaranda mimosifolia* (IVI = 19.5%) have established substantial ecological presence, while indigenous target timber species such as *Podocarpus falcatus* (5.5%) and *Juniperus procera* (12%) exhibited lower IVIs. These findings indicate that the campus is transitioning toward a “novel ecosystem” structure. Strategic management, including the targeted suppression of invasive species and enrichment planting of native hardwoods such as *Hagenia abyssinica*, is recommended to maintain the historical Afromontane character of the landscape.

1 | Introduction

Biodiversity, defined as the variety of life at genetic, species, and ecosystem levels, is the cornerstone of ecosystem stability, human well-being, and the provision of essential ecosystem services [1]. At the species level, biodiversity assessment focuses on two fundamental components: species richness, representing the total count of species present within a defined area, and species evenness, which describes the equitability of individual distribution among those

species [2]. Ecosystems characterized by high richness and evenness generally exhibit greater resilience; conversely, communities dominated by a few hyperabundant species are often more susceptible to biological invasions, pests, and climatic fluctuations [3]. Ultimately, quantifying these structural metrics is critical for understanding community dynamics, monitoring ecosystem health, and guiding conservation strategies in both natural and anthropogenically modified landscapes.

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These components are quantitatively synthesized through diversity indices, such as the Shannon–Wiener (H') [4] and Simpson (D) [5] indices, which allow ecologists to evaluate community structure and functional integrity [6]. Furthermore, Pielou's Evenness Index (J') [7] and Margalef's Richness Index [8] provide standardized measures that account for the relationship between the number of species and the total number of individuals, offering a more nuanced understanding of taxonomic representation than simple species counts [9].

Ethiopia is a recognized global biodiversity hotspot, harboring a significant proportion of East African flora with approximately 6200 species, of which roughly 10% are endemic [10, 11]. However, these botanical resources are currently declining due to a high population growth rate, which remains approximately 2.5%–2.7% annually. This demographic pressure drives accelerated deforestation and habitat fragmentation as land is converted for subsistence agriculture and fuelwood extraction [12, 13]. In the Hararghe Highlands, indigenous forest cover has plummeted to less than 3% in recent decades [14]. In the Haramaya region, the proliferation of invasive species, most notably *Lantana camara*, and the dominance of exotic plantations, like *Eucalyptus camaldulensis* and *Cupressus lusitanica*, have significantly altered native floristic compositions [12, 15]. These shifts have led to a marked reduction in understory diversity and the displacement of indigenous woody species across the fragmented Afromontane landscapes of Eastern Ethiopia [16].

University campuses, such as Haramaya University, function as managed “green islands” within these transformed landscapes. The motivation for selecting the HU Main Campus lies in its status as a historical repository of Ethiopian agricultural and silvicultural practices. Established in 1952 through a partnership between the Ethiopian government and Oklahoma State University under the Point Four Program, the campus was one of the first sites in the region to undergo systematic landscape engineering [17]. The greening of the campus occurred in distinct phases: an initial foundation phase (1950s–1970s) led by the joint Ethio-US faculty who introduced exotic windbreaks and timber species for infrastructure support and research purposes [17].

These planting activities reflected a broader national urban forestry trend in Ethiopia, which historically prioritized fast-growing exotic species like *Eucalyptus* and *Cupressus lusitanica* to address critical shortages of fuelwood and construction materials [18]. *Eucalyptus* species, introduced to Ethiopia in 1895, have dominated forest development gains for over a century due to their rapid biomass production and adaptability [18]. Consequently, the campus represents a microcosm of the 20th-century Ethiopian forestry policy, where exotics were favored for economic and social utility [18, 19].

Despite the ecological significance of urban and institutional green spaces, a critical research gap persists: existing vegetation data is outdated and fails to account for recent shifts toward indigenous species restoration under national programs such as the Green Legacy Initiative [11]. This study evaluates woody plant species diversity, abundance, and distribution at the Haramaya University Main Campus to address this lack of contemporary data and provide an evidence-based baseline for conservation. Specifically, the research seeks to answer the following: (1) How do management intensity and human traffic influence woody species composition across different campus

zones? (2) To what extent do invasive species threaten the structural integrity of these green spaces? and (3) Does the current campus flora reflect a shift toward ornamental exotic species over native biodiversity? By employing systematic, quadrat-based inventories, the study quantifies diversity patterns using Pielou's and Margalef's indices, alongside the Jaccard Index of Similarity (J) to assess species overlap between sites. These findings offer a vital baseline for biodiversity monitoring within the broader context of land-use change in the Eastern Ethiopian highlands.

2 | Methodology

2.1 | Study Area

The study was conducted at the Haramaya University Main Campus in the Hararghe Highlands of Eastern Ethiopia. Geographically, the study area is defined by the coordinates 9°23' 12.27"–9°31'9.85" N and 41°58'28.02"–42°8'10.26" E (UTM Zone 38), at an altitudinal range of 1800–1825 m above sea level (Figure 1).

The local environment is classified as semi-arid to subhumid, with soils predominantly characterized by a clay texture. The average annual rainfall of the study area is 790 mm, while thermal conditions are characterized by mean maximum and minimum temperatures of 24.7°C and 11.5°C, respectively [20].

2.2 | Sampling Design

Vegetation sampling employed a stratified systematic quadrat inventory, a standard approach for assessing woody species diversity in tropical dryland environments. Two distinct managed zones were selected to represent the campus's core land-use types: the College of Agricultural and Environmental Sciences (Site A), representing an older, more established research-focused landscape, and the Haramaya University Model School (Site B), representing a more recently developed educational and ornamental zone.

The total area of the campus is 336 ha. Within the focused study areas, Site A covers approximately 5 ha, while Site B encompasses 3 ha. Eight quadrats were established in each site, yielding a total of 16 plots. Quadrats were arranged at a regular interval along parallel transects spaced 20 m apart to ensure adequate spatial coverage and minimize spatial autocorrelation. The total sampled area of 1600 m² represents 2.0% of the focused study zones.

Each quadrat measured 10 m × 10 m (100 m²), a plot size widely used in woody vegetation studies for capturing spatial heterogeneity while minimizing edge effects. While larger plots are often used in dense natural forests, the 100-m² quadrat size was selected due to the high stem density and fragmented nature of the managed campus landscape. This size is consistent with standard protocols for urban and institutional forestry inventories where individual tree management and high species turnover necessitate finer-scale observations [9].

To mitigate the limitations of smaller plots regarding mature tree canopies, transects were initiated 5 m from site edges, and plot locations and orientations were determined using a handheld GPS, with transects aligned approximately north–south. Furthermore, any tree with a stem base located more than 50%

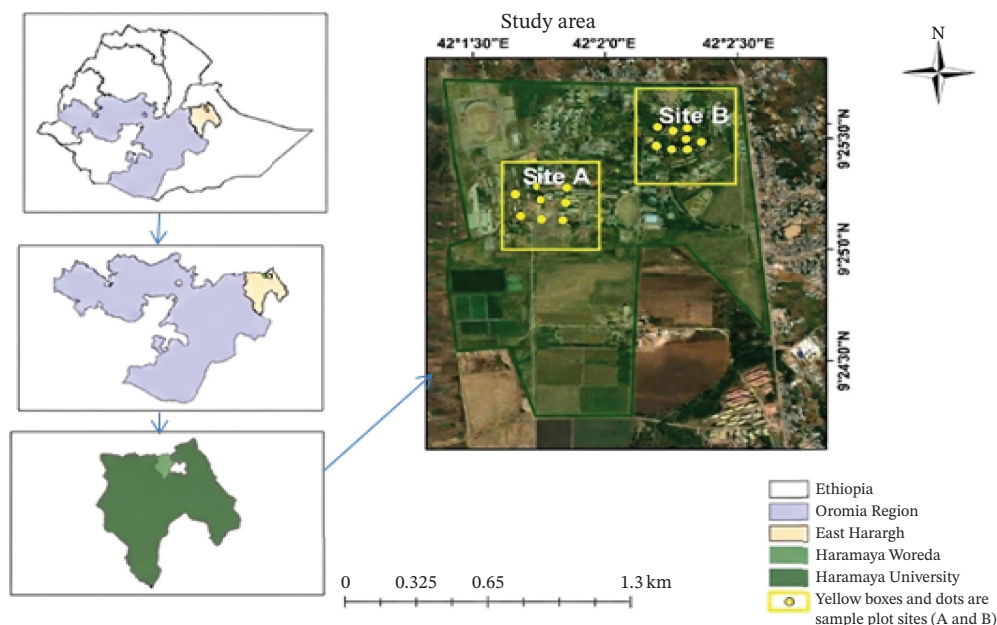


FIGURE 1 | Study area location.

within the quadrat boundary was included, ensuring structural characteristics were captured without overestimating dominance.

2.3 | Data Collection

Within each quadrat, a complete inventory of all woody plant species (trees and shrubs) was conducted. Despite the relatively small cumulative sampling area, the use of a systematic stratified approach across contrasting land-use zones ensured that the primary species pool ranging from legacy exotic timber trees to modern ornamental shrubs was effectively captured. This sampling intensity is statistically justified by the relative homogeneity of managed campus vegetation compared to primary Afromontane forests.

For each species, the number of individuals was recorded to support structural and diversity analyses. Species identification was carried out in the field using the *Flora of Ethiopia and Eritrea* [21, 22] and corroborated with local botanical keys. Representative voucher specimens were collected, labeled (HUH-2025/001–038), and deposited at the Haramaya University. All field measurements were independently verified by two observers to minimize identification and counting errors, particularly for rare species.

2.4 | Structural Attributes and Species-Level Metrics

To characterize woody vegetation structure prior to diversity analysis, several species-level ecological metrics were calculated. Species richness (S) was defined as the total number of distinct woody species recorded within each site.

Species distribution across plots was quantified using frequency (f_i), expressed as the proportion of quadrats in which a given species occurred. Relative frequency (RF %) was calculated as the frequency of a species divided by the sum of frequencies for all species, multiplied by 100.

Abundance was further quantified using density (d_i), calculated as the number of individuals of a species (n_i) per unit area. In this study, density was standardized to the 100-m² quadrat size and calculated as n_i divided by 100. Relative density (RD %) was then derived as the proportion of a species' density relative to the total density of all species.

Additionally, relative abundance (RA%) was calculated to express the commonness or rarity of each species, defined as the number of individuals of a given species divided by the total number of individuals recorded across all species, multiplied by 100. These metrics collectively enabled the identification of dominant, codominant, and rare species and formed the basis for subsequent diversity index calculations.

2.5 | Biodiversity Indices and Data Analysis

Woody plant diversity at each site was quantified using standard community-level diversity indices that integrate species richness and relative abundance. Species diversity was specifically calculated using the Shannon–Wiener Index (H'), Simpson's Dominance Index (D), Pielou's Evenness Index (J'), and Margalef's Richness Index (D_{mg}). The Shannon–Wiener index was employed to assess the overall diversity by accounting for both richness and evenness. To determine if the observed differences in diversity indices between Site A and Site B were statistically significant, inferential statistical analyses specifically independent sample t -tests were performed. All diversity calculations and statistical comparisons were conducted using SPSS Version 25 and Microsoft Excel 2021. Additionally, spatial data and site coordinates were managed and visualized using ArcGIS 10.8

$$H' = -\sum_{i=1}^S p_i \ln p_i, \quad (1)$$

where p_i is the proportion of individuals belonging to species i .

Species dominance was further evaluated using Simpson's Dominance Index (D), calculated as

$$D = \sum_{i=1}^S p_i^2. \quad (2)$$

Lower values of D indicate lower dominance and greater diversity.

Species richness adjusted for sample size was estimated using Margalef's Richness Index (D_{mg}):

$$D_{mg} = \frac{(S-1)}{\ln N}, \quad (3)$$

where S is the total number of species and N is the total number of individuals recorded.

Species evenness was assessed using Pielou's Evenness Index (J'), calculated as

$$J' = \frac{H'}{\ln S} \quad (4)$$

Floristic similarity between the two study sites was evaluated using the Jaccard Similarity Index (percentage similarity), based on the proportion of shared species relative to total species richness

$$\text{Jaccard Index}(J)\% = \frac{c}{a+b-c} * 100, \quad (5)$$

where a species unique to A , b species unique to B , c shared species from a and b .

2.6 | Importance Value Index (IVI)

The IVI for the woody species was computed to determine the structural importance of each species within the study area. Because diameter at breast height (DBH) or basal area data were not collected, relative dominance could not be calculated. To avoid mathematical redundancy between RD and relative abundance (as both are determined by n_i/N), the IVI in this study was strictly computed as a two-component index summing RD and RF, scaled to a maximum value of 200% or (2) as follows:

$$\text{IVI} = \text{RDi} + \text{RFi}, \quad (6)$$

where RDi = Relative Density (%) of species i , RFi = Relative Frequency (%) of species i .

All metrics and indices were computed using standard spreadsheet and statistical software. Results were interpreted following established ecological thresholds and through comparison with findings from similar dryland and campus-based vegetation studies.

3 | Results

3.1 | Species Composition and Floristic Diversity

A total of 569 individuals belonging to 29 unique woody species were identified across the 16 sampled quadrats, covering a total area of 1600 m². The two study sites exhibited distinct differences in both abundance and species richness. Haramaya University Model School (Site B) contained 20 species with 367 individuals (Table A2), while College of Agricultural and Environmental Sciences (Site A) contained 17 species with 202 individuals (Table A1). The Jaccard Index of Similarity between the two locations was calculated at 0.2759, indicating that only 27.59% of the species (8 species) were shared between them (Table 1).

3.2 | Diversity, Evenness, and Dominance Indices

To test for significant differences in structural diversity between the two study sites, an independent sample t -test was performed on the mean per-plot Shannon–Wiener Indices (H'). Site B exhibited a significantly higher mean per-plot diversity ($H' = 2.78 \pm 0.65$ SD) compared to Site A ($H' = 2.31 \pm 0.50$ SD; $t(14) = 2.45$, exact $p = 0.028$). Site B also recorded a high Evenness Index (J') of 0.928, indicating a nearly uniform distribution of individuals among the species present. In contrast, Site A recorded a lower evenness ($J' = 0.815$). This disparity is further reflected in the Simpson's Dominance Index, which was more than double at Site A ($D = 0.1465$) compared to Site B ($D = 0.0752$). Additionally, Margalef's Richness Index measured a more complex community structure at Site B ($D_{mg} = 3.217$) than at Site A ($D_{mg} = 3.014$) (Table 2).

3.3 | Community Structure and Species Dominance

The community structure of the Haramaya University Arboretum is composed of a mix of native, exotic, and invasive taxa. At Site A, species distribution is concentrated among a small number of taxa. A few species heavily dominate the environment, with the top five species alone accounting for over 71% of the total individual count. This concentration is reflected in the high Simpson's Dominance Index ($D = 0.1465$) (Table 2).

In contrast, Site B recorded an evenness index of $J' = 0.928$, with a more distributed population among species appearing more ecologically robust, demonstrating exceptional evenness ($J' = 0.928$) and a more distributed population. Here, the top five most abundant species represent approximately 49% of the community structure, suggesting a more balanced ecosystem than Site A. However, in Site B, invasive species represent a high proportion of the top-ranked taxa. Exotics and invasives currently hold three of the top five positions in the population hierarchy. Most notably, the invasive shrub *Lantana camara* has achieved parity with the native *Celtis africana*, with each now accounting for 13.08% of the total individuals (Table 3).

3.4 | Abundance and Stand Density

Stand density differed significantly between the two study sites. Site B exhibited a mean stand density of 4588 stems/ha, which is nearly double that of Site A, which recorded 2525 stems/ha. In Site A, *Celtis africana* was the single most abundant species, contributing 29.70% to the total abundance ($n_i = 60$), followed by *Olea africana* at 14.85% ($n_i = 30$).

In contrast, Site B showed a more evenly distributed yet heavily altered species composition. The highest relative abundances were shared equally between the native *Celtis africana* and the invasive shrub *Lantana camara*, each accounting for 13.08% of the total recorded individuals ($n_i = 48$). Exotic species were also notably prominent in Site B, with *Jacaranda mimosifolia* and *Cupressus arizonica* contributing 10.35% and 8.99% to the total pool, respectively (Table 4). These patterns indicate that while Site A's community structure is anchored by a few key native structural species, Site B maintains a higher overall woody density driven with a higher relative abundance of invasive and exotic species.

TABLE 1 | Frequency, density, and abundance of species.

Parameter	Site A	Site B	Total/combined
Total individuals (N)	202	367	569
Species richness (S)	17	20	29
Shared species	8	8	—
Jaccard Similarity Index	—	—	0.2759

TABLE 2 | Diversity, evenness, and dominance index.

Diversity index	Site A	Site B
Shannon–Wiener Index (H')	2.31	2.78
Simpson’s Dominance Index (D)	0.1465	0.0752
Pielou’s Evenness Index (J')	0.815	0.928
Margalef’s Richness Index (D_{mg})	3.014	3.217

3.5 | IVI

The IVI scores provided an integrated measure of each species’ ecological significance, combining RF and RD. *Celtis africana* emerged as the leading structural component across both locations, anchoring the top rank in Site A with an IVI of 0.3580 and in Site B with an IVI of 0.2308. In Site A, the native *Olea africana* (IVI = 0.2695) and the exotic *Cupressus arizonica* (IVI = 0.1903) followed as the second and third major structural contributors, respectively. Meanwhile, in Site B, ecological “weight” was heavily shared between *Celtis africana* and the invasive shrub *Lantana camara* (IVI = 0.2059), which secured the second rank. High-value indigenous timber species like *Juniperus procera* maintained a relatively low structural presence, ranking fifth in Site A with an IVI of 0.1204 and dropping out of the top five entirely in Site B. In contrast, exotic, ornamental, and invasive species including *Jacaranda mimosifolia* (IVI = 0.1947 in Site A; 0.2035 in Site B) and *Tithonia diversifolia* (IVI = 0.1486 in Site B) maintained prominent high ranks across the study area (Table 5). These results highlight a highly modified community structure in which select native species coexist with aggressive invasive and exotic elements that have established a commanding ecological presence.

4 | Discussion

The comparative ecological analysis of the two institutional forest fragments within the Haramaya University campus reveals fundamentally divergent community structures, driven by gradients of anthropogenic disturbance and localized micromanagement. Site B emerges as the more ecologically robust and

taxonomically balanced environment, characterized by a higher Shannon–Wiener Diversity Index (H') of 2.78 (Table A4) and an Evenness Index (J') of 0.928 (Table 2), alongside a low Simpson’s Dominance Index ($D = 0.0752$) (Table A2). Regionally, these indices align closely with intact dry Afromontane forest fragments remaining in the Ethiopian highlands. In these highland ecosystems, an H' value approaching or exceeding 2.5 typically serves as a key indicator of environmental “refugia” status capable of preserving indigenous germplasm amidst expanding agricultural and urban matrices [23]. This pattern confirms observations across Eastern Ethiopian dry Afromontane remnants, where small, isolated church forests and institutional enclosures preserve disproportionately high woody species richness compared to the surrounding degraded landscapes, acting as vital regional biodiversity arks [24].

The balanced distribution of relative densities across multiple taxa in Site B implies that resource allocation is distributed across diverse functional groups rather than being severely monopolized by a single dominant taxon. This high level of structural diversity directly validates the theoretical tenets of the diversity–stability hypothesis. By maintaining an array of species across different functional types, Site B exhibits a strong ecological buffering capacity. This structural richness provides insurance against environmental stochasticity, climate fluctuations, or localized pest outbreaks.

Globally, the floristic diversity observed in Site B surpasses values commonly reported for highly managed urban green spaces. For example, urban parks in compact Asian cities such as Taipei ($H' \approx 2.1$ – 2.4) display lower diversity profiles due to an over-reliance on a restricted palette of cultivated ornamental species [25]. From a management perspective, Taipei’s lower diversity stems from deliberate, highly artificial landscape planning that prioritizes esthetic uniformity. In contrast, Site B benefits from a “semi-protected” management framework combining restricted human access with low-intensity maintenance, which allows for the simultaneous preservation of mature canopy species and the uninhibited recruitment of multilayered natural regeneration alongside planted specimens.

In contrast, Site A exhibits diminished structural and taxonomic diversity ($H' = 2.31$) (Table A3) and Evenness Index ($J' = 0.815$), coupled with an elevated Simpson’s Dominance Index ($D = 0.1465$) that is double that of Site B ($D = 0.0752$), as shown in the raw data summaries (Tables A1 and A2). This shift mirrors degradation patterns documented in highly stressed global urban landscapes, such as Gaziantep, Türkiye, where intense urban stress creates a severe taxonomic imbalance dominated by a narrow cohort of stress-tolerant, aggressive taxa [26].

TABLE 3 | Community structure and species dominance.

Rank	Site A scientific name	Count (n_i)	RA (%)	Status	Site B scientific name	Count (n_i)	RA (%)	Status
1	<i>Celtis africana</i>	60	29.70	Native	<i>Celtis africana</i>	48	13.08	Native
2	<i>Olea africana</i>	30	14.85	Native	<i>Lantana camara</i>	48	13.08	Invasive
3	<i>Jacaranda mimosifolia</i>	27	13.37	Exotic	<i>Jacaranda mimosifolia</i>	38	10.35	Exotic
4	<i>Cupressus arizonica</i>	14	6.93	Exotic	<i>Cupressus arizonica</i>	33	8.99	Exotic
5	<i>Juniperus procera</i>	12	5.94	Native	<i>Tithonia diversifolia</i>	27	7.36	Invasive

Abbreviation: RA, relative abundance.

TABLE 4 | Comparison of abundance parameters.

Parameter	Site A	Site B
Total individuals (<i>N</i>)	202	367
Total area sampled	800 m ² (8 plots)	800 m ² (8 plots)
Stand density (stems/ha)	2525	4588
Most abundant species	<i>Celtis africana</i> (29.7%)	<i>Celtis africana</i> (13.08%)
Second dominant species	<i>Olea africana</i> (14.85%)	<i>Lantana camara</i> (13.08%)
Third dominant species	<i>Jacaranda mimosifolia</i> (13.37%)	<i>Jacaranda mimosifolia</i> (10.35%)

TABLE 5 | Important value index for the species.

Rank	Site A species	IVI (Site A)	Site B species	IVI (Site B)
1	<i>Celtis africana</i>	0.3580	<i>Celtis africana</i>	0.2308
2	<i>Olea africana</i>	0.2695	<i>Lantana camara</i>	0.2059
3	<i>Cupressus arizonica</i>	0.1903	<i>Jacaranda mimosifolia</i>	0.2035
4	<i>Jacaranda mimosifolia</i>	0.1947	<i>Cupressus arizonica</i>	0.1650
5	<i>Juniperus procera</i>	0.1204	<i>Tithonia diversifolia</i>	0.1486

While the ecological filter in Gaziantep is driven by extreme climatic conditions and widespread soil sealing, the primary driver in Site A is intense, unregulated human traffic and its close proximity to active campus infrastructure. This pressure directly manifests in highly skewed structural dynamics, such as uneven relative densities and limited species richness (*S* = 17) detailed across the inventory plots in Table A1. The elevated dominance index in Site A signifies a community under acute ecological stress, where a limited number of opportunist or highly tolerant taxa suppress broader biodiversity by monopolizing open space and available nutrients.

The ecological imbalance identified in Site A is heavily linked to deterministic niche filtering induced by human activity. Continuous foot traffic within this institutional zone causes severe soil compaction. This compaction alters the physical properties of the soil by breaking down soil aggregates, increasing bulk density, and drastically reducing macroporosity. The resulting loss of soil aeration and reduction in water infiltration rates creates a hostile edaphic filter that prevents the root respiration and moisture uptake required by sensitive, deep-rooted native species.

Furthermore, as established by Teketay [27] in regional seed and regeneration ecology studies, the structural stability of dry Afromontane systems relies heavily on seed bank viability and steady seedling-to-sapling cohort transitions. Severe soil compaction from high human foot traffic selectively suppresses this seed bank; the heightened mechanical resistance of compacted institutional soils directly limits radicle emergence and early root elongation of larger-seeded native trees while favoring lighter, wind-dispersed exotics [27]. Additionally, Site A is vulnerable to intense edge effects generated by the surrounding campus infrastructure. These artificial boundaries alter microclimatic conditions by increasing understory light levels, elevating air temperatures, and lowering relative humidity. Consequently, late-successional, shade-tolerant indigenous species are filtered out of the community assembly process, leaving an open niche space easily filled

by hardy, disturbance-adapted taxa capable of exploiting degraded soils.

The structural backbone of the campus canopy across both zones is heavily anchored by *Celtis africana*, but it exhibits different community roles in each site. It reaches its highest abundance in Site A, where it constitutes 29.70% of the population (Tables A1 and A5) and maintains a leading modified IVI of 35.80% (Table A5). This high architectural prominence is directly linked to institutional landscaping history; the university has extensively protected and cultivated *Celtis africana* for ornamental purposes, shade production, and esthetic campus greening over several decades.

Regionally, these high-importance metrics match findings from wider studies across Central and Northern Ethiopian dry Afromontane remnants, where *Celtis africana* functions as an indigenous keystone species that modulates understory microclimates and provides critical ecosystem services [28]. However, the extreme structural dominance of *Celtis africana* in the disturbed zones of Site A also underscores the ecological vacuum left by the decline of other co-occurring, nonornamental native canopy trees that lacked targeted administrative protection or selection.

Despite their close geographic proximity within a single university campus, the compositional divergence between Site A and Site B is remarkably stark. A Jaccard Similarity Index of 27.59% reveals that only about a quarter of the woody species are shared between the datasets in Tables A1 and A2. This low similarity highlights a high degree of beta-diversity, indicating that the two sites are experiencing completely separate community assembly pathways. Rather than forming a homogeneous institutional forest, these spaces function as distinct microhabitats representing different stages of “novel ecosystem” development. This divergence is driven by the university’s fragmented historical land-use patterns. Localized differences in historical fencing, past clearing events, and varying levels of daily foot traffic have directed these adjacent plant communities down entirely separate successional trajectories.

As noted by Lemenih and Teketay [24], the footprint of historical land use creates lasting legacies in understory recruitment dynamics, where prior clearing and selective management fundamentally dictate, which native species can successfully colonize and establish under existing canopies. In this context, Site A is heavily influenced by continuous human disturbance and edge effects that select for opportunistic, disturbance-adapted species. Site B, meanwhile, reflects a mix of past botanical protection and natural successional development, allowing late-successional Afromontane species to persist.

A significant ecological concern and a troubling marker of habitat degradation across these campus matrices is the aggressive expansion of exotic and invasive species. *Lantana camara* has established a major codominant position in Site B, securing the second-highest importance value ($IVI = 20.59\%$) (Table A6) driven by a high RD ($RD = 13.11\%$). Its codominance alongside native canopy trees represents a critical shift in the site's natural composition. This invasion mirrors degradation patterns observed in other fragmented East African urban and peri-urban forest patches, such as those surrounding Nairobi, Kenya. In those systems, forest fragmentation and canopy opening create ideal high-light conditions along newly created edges, allowing *Lantana camara* to rapidly invade [29]. *Lantana camara* utilizes aggressive vegetative sprawling, high seed production spread by birds, and allelopathy (the chemical suppression of surrounding plants) to arrest the recruitment of native climax species. In Nairobi's urban forest fragments, unmanaged edges quickly get converted into mono-specific *Lantana* thickets, completely halting natural forest succession.

This process of competitive displacement is clearly visible on campus through the suppressed importance values of high-value indigenous conifers listed in Table A6, such as *Podocarpus falcatus* ($IVI = 5.5\%$) and *Juniperus procera* ($IVI = 5.8\%$). Historically, these slow-growing, long-lived conifers should form the dominant climax overstory of the dry Afromontane landscape. Currently, they are trapped in an unfavorable community assembly process where competitive exclusion is highly active. This structural arrest matches broader global patterns of forest fragmentation; as demonstrated by Laurance et al. [30] in long-term studies of ecosystem decay, habitat fragmentation triggers severe ecological alterations that systematically eliminate specialized, slow-growing canopy species while driving a hyperproliferation of resource-opportunistic invasive elements and disturbance-adapted woody shrubs.

The combination of increased canopy openness from fragmentation and intense resource monopolization by understory *Lantana camara* and exotic overstory trees such as *Jacaranda mimosifolia* (which maintains an IVI of 19.47% in Site A (Table A5) and *Cupressus arizonica* ($IVI = 16.50\%$) (Table A6) means these key native conifers are being actively outcompeted for light, space, and soil nutrients. Furthermore, as structurally verified by Wassor et al. [31], when invasive understories and dense exotic overstories close off the resource pool in Afromontane remnants, the microhabitats required for indigenous regeneration are severely diminished. This lack of microhabitat diversity halts the recruitment of shade-tolerant forest understory seedlings, trapping the native conifer community in

a state of population senescence [31]. Without targeted management interventions to disrupt this competitive exclusion, the long-term diversity–stability relationship of these campus green spaces will degrade, ultimately leading to the biotic homogenization of these valuable highland biodiversity remnants.

Collectively, these findings demonstrate that while the campus fragments maintain higher structural complexity than many global urbanized landscapes, they remain at an ecological crossroads. The high dominance values seen in highly frequented institutional zones highlight a critical need for active management to prevent the permanent degradation of these highland remnants. While this study provides a robust structural snapshot, it is limited by its focus on two specific managed zones within a single season. The 16-plot sample size, while appropriate for the fragmented, human-dominated nature of the campus, may not capture rare species in less-managed periphery areas.

Furthermore, the calculation of the IVI in this study was bound by specific structural data parameters. Because DBH or basal area data were not collected, relative dominance could not be calculated to quantify the total biomass dominance. To avoid mathematical redundancy between RD and relative abundance (as both are fundamentally determined by the ratio of individual species counts over the total sample size, or ni/N), the IVI in this study was strictly computed as a two-component index summing RD and RF, scaled to a maximum value of 200%. Consequently, these IVI values strictly reflect numerical density and spatial distribution rather than volumetric tree size or biomass dominance, which limits absolute structural comparisons to old-growth native forests. Future research should incorporate multiseasonal sampling, standard overstory basal metrics, and detailed soil analyses to better understand the chemical and edaphic drivers of these observed diversity patterns.

Author Contributions

Zelalem Nurlign Getahun performed data collection, analysis, and formal writing, Anteneh Belayneh Desta performed supervising and manuscript editing, while Hussen Yimer Abate performed data collection and manuscript editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data supporting the findings of this study are derived from primary field inventories. All relevant data, including raw frequency and density

metrics as well as calculated Importance Value Indices (IVIs), are fully documented and available within the article's Appendix (Tables A1–A6).

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Appendix A

TABLE A1 | Frequency, density, and abundance—Site A.

No.	Scientific name	n_i	f_i	RF	Density ($n_i/100 \text{ m}^2$)	RD	p_i	$\ln(p_i)$	$p_i \ln(p_i)$	p_i^2
1	<i>Cupressus arizonica</i>	14	1.00	0.121	0.1400	0.0693	0.0693	-2.6693	-0.1850	0.0048
2	<i>Cordia africana</i>	6	0.50	0.061	0.0600	0.0297	0.0297	-3.5166	-0.1044	0.0009
3	<i>Vernonia amygdalina</i>	3	0.25	0.030	0.0300	0.0149	0.0149	-4.2064	-0.0627	0.0002
4	<i>Juniperus procera</i>	12	0.50	0.061	0.1200	0.0594	0.0594	-2.8235	-0.1677	0.0035
5	<i>Olea africana</i>	30	1.00	0.121	0.3000	0.1485	0.1485	-1.9072	-0.2832	0.0221
6	<i>Melia azedarach</i>	3	0.50	0.061	0.0300	0.0149	0.0149	-4.2064	-0.0627	0.0002
7	<i>Yucca gigantea</i>	10	0.50	0.061	0.1000	0.0495	0.0495	-3.0058	-0.1488	0.0025
8	<i>Ficus benjamina</i>	3	0.50	0.061	0.0300	0.0149	0.0149	-4.2064	-0.0627	0.0002
9	<i>Jacaranda mimosifolia</i>	27	0.50	0.061	0.2700	0.1337	0.1337	-2.0122	-0.2690	0.0179
10	<i>Hagenia abyssinica</i>	9	0.75	0.091	0.0900	0.0446	0.0446	-3.1100	-0.1387	0.0020
11	<i>Grevillea robusta</i>	4	0.25	0.030	0.0400	0.0198	0.0198	-3.9221	-0.0777	0.0004
12	<i>Ficus elastica</i>	2	0.25	0.030	0.0200	0.0099	0.0099	-4.6152	-0.0457	0.0001
13	<i>Euphorbia cotinifolia</i>	4	0.25	0.030	0.0400	0.0198	0.0198	-3.9221	-0.0777	0.0004
14	<i>Bauhinia variegata</i>	9	0.25	0.030	0.0900	0.0446	0.0446	-3.1100	-0.1387	0.0020
15	<i>Bersama abyssinica</i>	2	0.50	0.061	0.0200	0.0099	0.0099	-4.6152	-0.0457	0.0001
16	<i>Casuarina equisetifolia</i>	4	0.25	0.030	0.0400	0.0198	0.0198	-3.9221	-0.0777	0.0004
17	<i>Celtis africana</i>	60	0.50	0.061	0.6000	0.2970	0.2970	-1.2140	-0.3606	0.0882
Sum		202	8.25	1.000	2.0200	1.0000	1.0000		-2.3087	0.1465

TABLE A2 | Frequency, density, and abundance—Site B.

No.	Scientific name	n_i	f_i	RF	Density ($n_i/100 \text{ m}^2$)	RD	p_i	$\ln(p_i)$	$p_i \ln(p_i)$	p_i^2
1	<i>Podocarpus falcatus</i>	11	0.25	0.025	0.1100	0.030	0.0300	-3.507	-0.1052	0.0009
2	<i>Cupressus arizonica</i>	33	0.75	0.075	0.3300	0.090	0.0899	-2.409	-0.2166	0.0081
3	<i>Lantana camara</i>	48	0.75	0.075	0.4800	0.131	0.1308	-2.034	-0.2661	0.0171
4	<i>Cordia africana</i>	11	0.50	0.050	0.1100	0.030	0.0300	-3.507	-0.1052	0.0009
5	<i>Juniperus procera</i>	12	0.25	0.025	0.1200	0.033	0.0327	-3.420	-0.1118	0.0011
6	<i>Albizia schimperiana</i>	11	0.25	0.025	0.1100	0.030	0.0300	-3.507	-0.1052	0.0009
7	<i>Carissa edulis</i>	22	0.50	0.050	0.2200	0.060	0.0599	-2.815	-0.1686	0.0036
8	<i>Olea africana</i>	9	0.50	0.050	0.0900	0.025	0.0245	-3.709	-0.0909	0.0006
9	<i>Jacaranda mimosifolia</i>	38	1.00	0.100	0.3800	0.104	0.1035	-2.268	-0.2347	0.0107
10	<i>Grevillea robusta</i>	7	0.25	0.025	0.0700	0.019	0.0191	-3.958	-0.0756	0.0004
11	<i>Casuarina equisetifolia</i>	8	0.25	0.025	0.0800	0.022	0.0218	-3.826	-0.0834	0.0005
12	<i>Pinus radiata</i>	11	0.25	0.025	0.1100	0.030	0.0300	-3.507	-0.1052	0.0009
13	<i>Tithonia diversifolia</i>	27	0.75	0.075	0.2700	0.074	0.0736	-2.609	-0.1920	0.0054
14	<i>Acacia saligna</i>	18	0.75	0.075	0.1800	0.049	0.0490	-3.016	-0.1478	0.0024
15	<i>Eucalyptus camaldulensis</i>	16	0.75	0.075	0.1600	0.044	0.0436	-3.133	-0.1366	0.0019
16	<i>Dovyalis caffra</i>	13	0.25	0.025	0.1300	0.035	0.0354	-3.341	-0.1183	0.0013
17	<i>Cascabela thevetia</i>	11	0.50	0.050	0.1100	0.030	0.0300	-3.507	-0.1052	0.0009
18	<i>Terminalia mantaly</i>	8	0.50	0.050	0.0800	0.022	0.0218	-3.826	-0.0834	0.0005
19	<i>Borassus aethiopum</i>	5	0.25	0.025	0.0500	0.014	0.0136	-4.298	-0.0585	0.0002
20	<i>Celtis africana</i>	48	1.00	0.100	0.4800	0.131	0.1308	-2.034	-0.2661	0.0171
Sum		367	10.03	1.00	3.6700	1.00	1.00		-2.78	0.0752

TABLE A3 | Shannon–Wiener Index: Site A ($N = 202$, $S = 17$).

No.	Scientific name	Family	n_i	$p_i (n_i/202)$	$\ln(p_i)$	$p_i \ln(p_i)$
1	<i>Cupressus arizonica</i>	Cupressaceae	14	0.0693	−2.6692	−0.1850
2	<i>Cordia africana</i>	Boraginaceae	6	0.0297	−3.5165	−0.1045
3	<i>Vernonia amygdalina</i>	Asteraceae	3	0.0149	−4.2097	−0.0625
4	<i>Juniperus procera</i>	Cupressaceae	12	0.0594	−2.8234	−0.1677
5	<i>Olea africana</i>	Oleaceae	30	0.1485	−1.9071	−0.2832
6	<i>Melia azedarach</i>	Meliaceae	3	0.0149	−4.2097	−0.0625
7	<i>Yucca gigantea</i>	Asparagaceae	10	0.0495	−3.0057	−0.1488
8	<i>Ficus benjamina</i>	Moraceae	3	0.0149	−4.2097	−0.0625
9	<i>Jacaranda mimosifolia</i>	Bignoniaceae	27	0.1337	−2.0124	−0.2690
10	<i>Hagenia abyssinica</i>	Rosaceae	9	0.0446	−3.1110	−0.1386
11	<i>Grevillea robusta</i>	Proteaceae	4	0.0198	−3.9220	−0.0777
12	<i>Ficus elastica</i>	Moraceae	2	0.0099	−4.6151	−0.0457
13	<i>Euphorbia cotinifolia</i>	Euphorbiaceae	4	0.0198	−3.9220	−0.0777
14	<i>Bauhinia variegata</i>	Fabaceae	9	0.0446	−3.1110	−0.1386
15	<i>Bersama abyssinica</i>	Melanthaceae	2	0.0099	−4.6151	−0.0457
16	<i>Casuarina equisetifolia</i>	Casuarinaceae	4	0.0198	−3.9220	−0.0777
17	<i>Celtis africana</i>	Cannabaceae	60	0.2970	−1.2139	−0.3606
Sum			202	1.0000		−2.3087

TABLE A4 | Shannon–Wiener Index: Site B ($N = 367$, $S = 20$).

No.	Scientific name	Family	n_i	$p_i (n_i/367)$	$\ln(p_i)$	$p_i \ln(p_i)$
1	<i>Podocarpus falcatus</i>	Podocarpaceae	11	0.0300	−3.507	−0.1052
2	<i>Cupressus arizonica</i>	Cupressaceae	33	0.0899	−2.409	−0.2167
3	<i>Lantana camara</i>	Verbenaceae	48	0.1308	−2.034	−0.2655
4	<i>Cordia africana</i>	Boraginaceae	11	0.0300	−3.507	−0.1052
5	<i>Juniperus procera</i>	Cupressaceae	12	0.0327	−3.420	−0.1118
6	<i>Albizia schimperiana</i>	Fabaceae	11	0.0300	−3.507	−0.1052
7	<i>Carissa edulis</i>	Apocynaceae	22	0.0600	−2.813	−0.1685
8	<i>Olea africana</i>	Oleaceae	9	0.0245	−3.709	−0.0910
9	<i>Jacaranda mimosifolia</i>	Bignoniaceae	38	0.1035	−2.268	−0.2350
10	<i>Grevillea robusta</i>	Proteaceae	7	0.0191	−3.958	−0.0755
11	<i>Casuarina equisetifolia</i>	Casuarinaceae	8	0.0218	−3.826	−0.0835
12	<i>Pinus radiata</i>	Pinaceae	11	0.0300	−3.507	−0.1052
13	<i>Tithonia diversifolia</i>	Asteraceae	27	0.0736	−2.609	−0.1920
14	<i>Acacia saligna</i>	Fabaceae	18	0.0490	−3.016	−0.1476
15	<i>Eucalyptus camaldulensis</i>	Myrtaceae	16	0.0436	−3.133	−0.1365
16	<i>Dovyalis caffra</i>	Salicaceae	13	0.0354	−3.341	−0.1183
17	<i>Cascabela thevetia</i>	Apocynaceae	11	0.0300	−3.507	−0.1052
18	<i>Terminalia mantaly</i>	Combretaceae	8	0.0218	−3.826	−0.0835
19	<i>Borassus aethiopum</i>	Arecaceae	5	0.0136	−4.298	−0.0586
20	<i>Celtis africana</i>	Cannabaceae	48	0.1308	−2.034	−0.2655
Sum			367	1.0000		−2.7808

TABLE A5 | IVI for Site A.

No.	Scientific name	Relative frequency (RF)	Relative density (RD)	Importance Value Index (IVI)
1	<i>Cupressus arizonica</i>	0.1210	0.0693	0.1903
2	<i>Cordia africana</i>	0.0610	0.0297	0.0907
3	<i>Vernonia amygdalina</i>	0.0300	0.0149	0.0449
4	<i>Juniperus procera</i>	0.0610	0.0594	0.1204
5	<i>Olea africana</i>	0.1210	0.1485	0.2695
6	<i>Melia azedarach</i>	0.0610	0.0149	0.0759
7	<i>Yucca gigantea</i>	0.0610	0.0495	0.1105
8	<i>Ficus benjamina</i>	0.0610	0.0149	0.0759
9	<i>Jacaranda mimosifolia</i>	0.0610	0.1337	0.1947
10	<i>Hagenia abyssinica</i>	0.0910	0.0446	0.1356
11	<i>Grevillea robusta</i>	0.0300	0.0198	0.0498
12	<i>Ficus elastica</i>	0.0300	0.0099	0.0399
13	<i>Euphorbia cotinifolia</i>	0.0300	0.0198	0.0498
14	<i>Bauhinia variegata</i>	0.0300	0.0446	0.0746
15	<i>Bersama abyssinica</i>	0.0610	0.0099	0.0709
16	<i>Casuarina equisetifolia</i>	0.0300	0.0198	0.0498
17	<i>Celtis africana</i>	0.0610	0.2970	0.3580
Sum	Total Across Site A	1.0000	1.0000	2.0000

TABLE A6 | IVI for Site B.

No.	Scientific name	Relative frequency (RF)	Relative density (RD)	Importance Value Index (IVI)
1	<i>Podocarpus falcatus</i>	0.0249	0.0301	0.0550
2	<i>Cupressus arizonica</i>	0.0748	0.0902	0.1650
3	<i>Lantana camara</i>	0.0748	0.1311	0.2059
4	<i>Cordia africana</i>	0.0499	0.0301	0.0800
5	<i>Juniperus procera</i>	0.0249	0.0328	0.0577
6	<i>Albizia schimperiana</i>	0.0249	0.0301	0.0550
7	<i>Carissa edulis</i>	0.0499	0.0601	0.1100
8	<i>Olea africana</i>	0.0499	0.0246	0.0745
9	<i>Jacaranda mimosifolia</i>	0.0997	0.1038	0.2035
10	<i>Grevillea robusta</i>	0.0249	0.0191	0.0440
11	<i>Casuarina equisetifolia</i>	0.0249	0.0219	0.0468
12	<i>Pinus radiata</i>	0.0249	0.0301	0.0550
13	<i>Tithonia diversifolia</i>	0.0748	0.0738	0.1486
14	<i>Acacia saligna</i>	0.0748	0.0492	0.1240
15	<i>Eucalyptus camaldulensis</i>	0.0748	0.0437	0.1185
16	<i>Dovyalis caffra</i>	0.0249	0.0328	0.0577
17	<i>Cascabela thevetia</i>	0.0499	0.0301	0.0800
18	<i>Terminalia mantaly</i>	0.0499	0.0219	0.0718
19	<i>Borassus aethiopum</i>	0.0249	0.0137	0.0386
20	<i>Celtis africana</i>	0.0997	0.1311	0.2308
Sum	Total Across Site B	1.0000	1.0000	2.0000