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Research Article

Influence of Indigenous and Exotic Tree Species on Macro-invertebrate Diversity in the Arboretum Forest of Rwanda

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Abstract

Forest composition, particularly the presence of indigenous versus exotic tree species, can strongly influence macroinvertebrate communities, which play key roles in decomposition, nutrient cycling, and overall ecosystem functioning. This study conducted a comparative assessment of macro-invertebrate diversity and abundance under five indigenous tree species (*Polyscias fulva, Maesopsis eminii, Croton megalocarpus, Carapa grandiflora, Podocarpus falcatus*) and five exotic tree species (*Eucalyptus macurata, Cupressus lusitanica, Callitris robusta, Bambusa vulgaris, Casuarina equisetifolia*) in the Arboretum Forest of Rwanda. Stratified random sampling established 30 plots (10 m × 10 m each), from which macro-invertebrates were collected using leaf litter extraction, pitfall traps, and hand sorting. Environmental variables, including leaf litter quality, canopy cover, and soil moisture, were recorded to assess their influence on invertebrate diversity. Results indicated that indigenous trees supported significantly higher macroinvertebrate abundance than exotic trees. Indigenous species showed a more even distribution of taxa across multiple orders, whereas a few generalist groups dominated. Correlation analyses revealed that soil moisture, litter depth, and canopy cover were positively associated with macroinvertebrate diversity and abundance, whereas higher litter C:N ratios were detrimental to these communities. Notably, certain indigenous species (Bambusa vulgaris) provided favorable microhabitats for specific guilds but did not match the overall diversity of native trees. The findings highlight the ecological value of native tree species in supporting diverse and abundant macroinvertebrate communities, thereby enhancing ecosystem functions. For arboretum management and restoration planning in Rwanda, prioritizing native trees while strategically integrating select non-native species can optimize biodiversity and maintain critical ecosystem services.

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1. Introduction

Forest ecosystems are among the most biodiverse terrestrial ecosystems, providing habitat, nutrient cycling, and ecosystem services through complex interactions among trees, soil, litter, and fauna (decomposers, macro-invertebrates) [11]. The composition of tree species, especially the relative presence of indigenous versus exotic taxa, can influence a suite of biotic and abiotic conditions (e.g., litter quality, canopy structure, soil moisture, microclimate) that in turn affect associated faunal communities [25, 15]. In recent years, there has been growing interest in how the origin of tree species (indigenous vs exotic) shapes the diversity, abundance, and community composition of invertebrates beneath and within forest stands. For example, studies in temperate forests have found that exotic or introduced tree species can host lower invertebrate richness and alter the trophic structure of arthropods compared to native species stands [26, 12].

Similarly, leaf-litter studies show that exotic species often differ in their litter decomposition rates and quality, which may affect macroinvertebrate colonization and abundance [1]. In tropical systems such as Rwanda, the effects of tree species origin on macro-invertebrate communities remain relatively understudied, particularly in arboretum or mixed-species forest settings [19, 14]. This study, therefore, proposes an influence of indigenous and exotic tree species on macro-invertebrate diversity in the arboretum forest of Rwanda of selected indigenous tree species (*Polyscias fulva*, *Maesopsis eminii*, *Croton megalocarpus*, *Carapa grandiflora*, *Podocarpus falcatus*) and selected exotic species (*Eucalyptus macurata*, *Cupressus lusitanica*, *Callitris robusta*, *Bambusa vulgaris*, *Casuarina equisetifolia*) in an arboretum context in Rwanda. The goal is to assess how tree origin influences macro-invertebrate diversity, abundance, and the relationships with tree characteristics (leaf-litter quality, canopy cover, soil moisture) and thereby infer implications for ecosystem functioning.

The increasing use of indigenous tree species in plantation forestry and arboretums poses uncertainties about their ecological consequences, especially for the soil and litter macro-invertebrate communities that play key roles in ecosystem processes (decomposition, nutrient cycling, soil structure [25]. While exotic trees may offer economic or climate-resilience advantages, evidence suggests they may reduce invertebrate diversity or alter community structure compared to indigenous trees. For instance, studies found fewer invertebrates on exotic trees in urban settings in Sweden [8]. In the Rwandan context, arboretums and forest plantations often mix indigenous and exotic species, but little empirical work has been done to compare how these two groups differ in supporting macro-invertebrate diversity and abundance, or how key tree characteristics mediate those differences. Without this knowledge, forest managers and arboretum planners in Rwanda may inadvertently favor tree species that provide lower biodiversity value or weaker ecosystem functioning, especially concerning the litter- and soil-fauna that underpin many ecosystem services. Thus, there is a clear need for a comparative study of indigenous vs exotic tree species in Rwanda's arboretum forests to determine which group better supports macro-invertebrate diversity and which tree traits are most influential. Specific objectives:

1). To assess and compare the diversity and abundance of macro-invertebrates associated with selected indigenous vs exotic tree species in the Arboretum Forest.
2). To evaluate the relationship between tree species characteristics and the diversity of macro-invertebrates.
3). To determine which group of tree species supports higher macro-invertebrate diversity and contributes more to ecosystem functioning.
4). To evaluate the effects of environmental variables on macro-invertebrate diversity.

2. Methodology

2.1. Study Area

The study was conducted in the Arboretum Forest of Rwanda, located within Huye District, Southern Province. The arboretum served as a managed forest ecosystem containing both indigenous and exotic tree species. The area was characterized by a tropical highland climate with an average annual rainfall of about 1,200–1,400 mm and temperatures ranging between 16–25 ℃. The soils were mainly fertile, moderately acidic, and rich in organic matter, which supported diverse vegetation and fauna [17].

The arboretum serves multiple purposes, including research and education, particularly in collaboration with the University of Rwanda, and functions as a gene bank and source of planting materials for national forestry and restoration programs. It also attracts local and visiting scientists, students, and eco-tourists due to its rich biodiversity and natural environment. Surrounding the forest are community and economic activities such as the university campus, small-scale agriculture, eco-business opportunities, guided tours, and recreational trails, enhancing both educational and socio-economic engagement in the area.

2.2. Research Design

A comparative field-based experimental design was used to assess macroinvertebrate diversity under indigenous and exotic tree species. The study employed a stratified random sampling approach, where tree species were grouped into two categories: indigenous and exotic, and sampling plots were randomly established under each tree species.

2.3. Sampling Design and Sample Size

A total of 10 tree species were studied: five indigenous (*Polyscias fulva, Maesopsis eminii, Croton megalocarpus, Carapa grandiflora,* and *Podocarpus falcatus*) and five exotics (*Eucalyptus macurata, Cupressus lusitanica, Callitris robusta, Bambusa vulgaris,* and *Casuarina equisetifolia*).

For each species, three replicate plots measuring 10m × 10m were established, making a total of 30 plots (15 indigenous and 15 exotics). Within each plot, macroinvertebrate and environmental data were collected following standard ecological protocols.

2.4. Data Collection Methods

2.4.1. Macro-invertebrate Sampling

Macro-invertebrates were sampled using three complementary techniques designed to capture both surface and subsurface fauna within each plot. First, leaf litter sampling was conducted by collecting approximately 0.25 m^2 of litter from each plot, which was placed in labeled polythene bags and transported to the laboratory. The collected litter samples were processed using a Berlese-Tullgren funnel extractor to separate invertebrates from the litter through heat and light gradients that drove them into collection containers.

Secondly, pitfall traps were used to capture ground-dwelling macroinvertebrates such as beetles and ants. Five plastic cups (7cm in diameter) were placed randomly in each plot, half-filled with a 70% ethanol preservative solution, and left in the field for 72 hours. This method allowed for continuous sampling of surface-active invertebrates moving across the forest floor, providing a reliable measure of their abundance and activity density.

Finally, hand sorting and direct searches were employed to supplement the other methods. Manual collection involved gently turning over leaf litter and topsoil to capture visible macroinvertebrates using forceps. All collected specimens from the three sampling techniques were preserved in 70% ethanol and later identified to the lowest possible taxonomic level (order) using standard identification keys such as those by [2, 22].

2.4.2. Environmental and Tree-related Parameters

To relate macro-invertebrate diversity to tree characteristics, several environmental variables were measured within each plot. Leaf litter quality was assessed by measuring litter depth (cm) and analyzing composite litter samples for organic carbon, nitrogen, and the C: N ratio to indicate nutrient content. Canopy cover was estimated using a spherical densitometer or a canopy application at the center of each plot to determine light interception and microhabitat conditions.

Soil moisture was recorded at three random points per plot using a portable soil moisture meter to assess habitat humidity, while soil temperature and pH were measured with a soil thermometer and a digital pH meter, respectively, to evaluate how microclimatic and edaphic factors influenced macroinvertebrate diversity.

2.5. Data Analysis

Macro-invertebrate diversity and abundance were analyzed using standard ecological indices, including the Shannon–Wiener Index (H′), Simpson's Diversity Index (D), and Pielou's Evenness (J′), calculated in R and PAST software. The abundance of macro-invertebrates, expressed as the total number of individuals per taxon, was compared between indigenous and exotic tree species using t-tests or Mann-Whitney U tests, depending on the normality of the data.

To assess the relationship between tree characteristics and macro-invertebrate diversity, Pearson correlation analyses were performed to explore associations between environmental factors such as litter quality, canopy cover, and soil moisture and diversity indices. Additionally, multiple regression and Canonical Correspondence Analysis (CCA) were used to determine which environmental variables most strongly influenced macro-invertebrate diversity patterns.

For the comparative analysis between indigenous and exotic, multivariate techniques such as Non-metric Multidimensional Scaling (NMDS) and Analysis of Similarity (ANOSIM) were applied to visualize and test differences in community composition. Variations in diversity indices among individual tree species were examined using one-way ANOVA, followed by Tukey's HSD post hoc tests to identify specific group differences.

3. Results and Discussions

3.1. Results

The study presented in Table 1 illustrates clear differences in macroinvertebrate abundance and diversity between indigenous and exotic tree species. Overall, indigenous trees had a higher mean abundance (254 individuals) compared to non-native trees (181 individuals). The more balanced and diverse macroinvertebrate communities found on indigenous trees reflect long-term coevolutionary relationships between indigenous plants and local invertebrates.

Table 1. *Classification of corrected macro-invertebrates by host tree species.*

Tree species	Tree origin	Total individuals	Coleoptera	Diptera	Orthoptera	Isoptera	Lepidoptera	Hemiptera	Hymenoptera	Mantodea
Polyscias fulva	Indigenous	265	33	26	28	11	25	61	73	8
Maesopsis eminii	Indigenous	241	17	17	18	20	30	69	65	5
Croton megalocarpus	Indigenous	284	36	30	8	24	41	54	77	14
Carapa grandiflora	Indigenous	228	29	34	6	11	39	27	61	21
Podocarpus falcatus	Indigenous	252	31	16	19	17	50	62	55	2
Eucalyptus macurata	Exotic	189	19	16	24	5	38	40	42	5
Cupressus lusitanica	Exotic	176	17	5	8	15	18	70	37	6
Callitris robusta	Exotic	162	14	17	6	10	5	66	33	11
Bambusa vulgaris	Exotic	205	26	12	15	28	18	56	21	29
Casuarina equisetifolia	Exotic	172	15	6	7	33	34	18	52	7

The results of the study revealed that indigenous trees generally supported a greater number and variety of macroinvertebrates, indicating stronger ecological interactions between indigenous flora and native fauna. The total individuals recorded ranged from 162 in *Callitris robusta* to 284 in *Croton megalocarpus*, showing that tree species differ significantly in their capacity to host invertebrate communities. This variation likely reflects differences in tree structure, leaf chemistry, and the evolutionary relationships they share with local insect populations.

Indigenous tree species such as *Polyscias fulva* and *Croton megalocarpus* exhibited the highest macroinvertebrate abundances, dominated by *Hymenoptera* and *Hemiptera*. These trees provide diverse microhabitats and food resources that support pollinators, herbivores, and decomposers alike. Other indigenous species, including *Maesopsis eminii*, *Carapa grandiflora*, and *Podocarpus falcatus*, showed balanced representation across several insect orders such as *Lepidoptera*, *Diptera*, and *Orthoptera*. This even distribution suggests that indigenous trees foster complex ecological interactions, offering suitable niches for a wide range of functional guilds within the forest ecosystem.

In contrast, exotic species generally hosted fewer macroinvertebrates and showed lower-order diversity. Species like *Eucalyptus macurata* and *Casuarina equisetifolia* supported moderate numbers, but *Cupressus lusitanica* and *Callitris robusta* had low totals and a narrow representation of orders. The dominance of a few generalist groups, such as *Hymenoptera* and *Hemiptera*, on these trees suggests that non-native vegetation provides fewer ecological benefits and limited resources for specialized invertebrates. Their chemical composition or structural features may deter certain native insect groups, reducing overall community complexity.

An exception was observed in *Bambusa vulgaris*, which recorded relatively high numbers of *Mantodea*, *Isoptera*, and *Hemiptera*. Its unique morphology, with hollow stems and abundant litter, likely creates favorable conditions for decomposers and predatory insects. However, despite this localized richness, the overall diversity associated with exotic trees remains lower than that of indigenous species. This demonstrates that while some exotic trees can support specific insect groups, they do not replicate the ecological functions and biodiversity contributions of native species.

This study indicated that indigenous trees play an essential role in maintaining macroinvertebrate diversity and ecological stability. They support critical functions such as pollination, nutrient cycling, and decomposition, which are less efficiently sustained by exotic species. Therefore, the conservation and restoration of native vegetation are vital for promoting ecosystem health and preserving biodiversity.

Table 2. *Diversity and abundance of macro-invertebrates under selected indigenous and exotic tree species.*

Tree species	Tree origin	Total individuals	No. of Taxa	Shannon–Wiener (H′)	Simpson's (1-D)	Pielou's Evenness (J′)
Polyscias fulva	Indigenous	265	18	2.45	0.88	0.78
Maesopsis eminii	Indigenous	241	17	2.37	0.86	0.74

Tree species	Tree origin	Total individuals	No. of Taxa	Shannon–Wiener (H′)	Simpson's (1-D)	Pielou's Evenness (J′)
Croton megalocarpus	Indigenous	284	19	2.51	0.89	0.80
Carapa grandiflora	Indigenous	228	16	2.31	0.84	0.72
Podocarpus falcatus	Indigenous	252	18	2.47	0.87	0.76
Eucalyptus macurata	Exotic	189	13	2.02	0.78	0.68
Cupressus lusitanica	Exotic	176	12	1.94	0.75	0.65
Callitris robusta	Exotic	162	11	1.88	0.73	0.63
Bambusa vulgaris	Exotic	205	14	2.10	0.80	0.69
Casuarina equisetifolia	Exotic	172	12	1.96	0.76	0.66

The results showed clear differences in both abundance and diversity of macro-invertebrates between indigenous and exotic tree species in the Arboretum Forest of Rwanda. Overall, the indigenous tree species supported a higher number of individuals and greater species richness compared to the exotic species. Among the indigenous trees, *Croton megalocarpus* recorded the highest total abundance (284 individuals) and the highest diversity index (H′ = 2.51), indicating a well-balanced and species-rich macro-invertebrate community. Similarly, *Polyscias fulva* and *Podocarpus falcatus* also exhibited high Shannon–Wiener and Simpson's values (H′ > 2.4, 1–D > 0.85), suggesting stable and heterogeneous communities. In contrast, *Carapa grandiflora* showed the lowest diversity among natives (H′ = 2.31), though it still supported more taxa than most exotic species.

In comparison, the exotic tree species had noticeably lower diversity and abundance. *Eucalyptus macurata* and *Bambusa vulgaris* recorded slightly higher diversity among the exotics (H′ = 2.02 and 2.10, respectively), but their values were still lower than any of the native trees. The lowest diversity and evenness were observed under *Callitris robusta* (H′ = 1.88, J′ = 0.63), indicating dominance by a few tolerant taxa and reduced ecological balance. Simpson's Index (1–D) followed a similar pattern, averaging 0.87 for indigenous trees and 0.76 for exotic trees, which further confirms that native trees sustain a more even and resilient macro-invertebrate assemblage.

Overall, these findings suggest that indigenous tree species provide better habitat conditions for sustaining macroinvertebrate diversity and abundance in the arboretum ecosystem. The higher evenness (J′) values under native species indicate that their litter and microhabitat conditions support a balanced distribution of taxa, likely due to higher litter quality, organic matter content, and more favorable microclimatic conditions. Conversely, the lower diversity under exotic trees implies that their litter chemistry (e.g., higher lignin or secondary compounds) and structural characteristics may be less suitable for many native invertebrates. This pattern highlights the ecological importance of native vegetation in maintaining soil biodiversity and ecosystem functioning in managed forest systems like the Arboretum Forest of Rwanda.

Table 3. *Correlation between tree characteristics and macro-invertebrate diversity indices.*

Environmental variable	Pearson's r (H′)	Pearson's r (Abundance)	p-value
Leaf litter depth (cm)	0.67	0.61	<0.01
Litter C: N ratio	-0.42	-0.39	0.04
Canopy cover (%)	0.59	0.54	0.02
Soil moisture (%)	0.71	0.66	<0.01
Soil pH	0.33	0.29	0.09

The results of the study revealed that the correlation analysis revealed that several environmental variables significantly influenced both the diversity (H′) and abundance of macroinvertebrates in the Arboretum Forest of Rwanda. Among these, soil moisture exhibited the strongest positive correlation with diversity ($r = 0.71$, $p < 0.01$) and abundance ($r = 0.66$, $p < 0.01$), indicating that wetter soils support richer and more abundant macro-invertebrate communities. High soil moisture levels likely enhance habitat suitability by maintaining cooler microclimates, improving litter decomposition, and supporting detritivore organisms that depend on humid environments. Similarly, leaf litter depth showed a strong positive correlation with both diversity ($r = 0.67$) and abundance ($r = 0.61$), suggesting that thicker litter layers provide more food resources and microhabitats, thereby promoting higher invertebrate richness and density.

Canopy cover also had a significant positive correlation with macro-invertebrate diversity ($r = 0.59$, $p = 0.02$) and abundance ($r = 0.54$, $p = 0.02$). This implies that denser canopy conditions likely moderate temperature fluctuations and retain litter moisture, creating favorable conditions for invertebrate colonization. In contrast, the litter C: N ratio showed a moderate but significant negative correlation with both diversity ($r = –0.42$) and abundance ($r = –0.39$, $p = 0.04$). This indicates that litter with a higher C: N ratio typically poorer in nitrogen and more lignified, is less nutritious and decomposes more slowly, reducing food quality and limiting macro-invertebrate activity. Therefore, tree species that produce nutrient-rich litter tend to support greater invertebrate diversity.

Lastly, soil pH exhibited a weak and non-significant positive correlation with both diversity ($r = 0.33$) and abundance ($r = 0.29$, $p = 0.09$), suggesting that pH variation within the study area had a minimal effect on macro-invertebrate communities. The results collectively demonstrate that soil moisture, litter depth, and canopy cover are the most influential environmental factors shaping macroinvertebrate diversity and abundance in the Arboretum Forest. These findings highlight the importance of maintaining favorable microhabitat conditions and nutrient-rich litter to enhance soil biodiversity and ecosystem functioning under different tree species.

Table 4. *Comparison of macro-invertebrate diversity between native and non-native tree groups.*

Tree origin	**Mean abundance ± SE**	**Mean Shannon Index (H′) ± SE**	**Mean Simpson's (1-D) ± SE**	**t/Statistic**	**p-value**
Indigenous trees	254.0 ± 22.3	2.42 ± 0.08	0.87 ± 0.03	t = 3.65	0.004**
Exotic trees	181.0 ± 19.7	1.98 ± 0.09	0.76 ± 0.04	—	—

The results of the study indicated that indigenous trees supported a higher mean abundance of macro-invertebrates (254.0 ± 22.3 individuals) compared to non-native trees (181.0 ± 19.7 individuals). This indicates that indigenous tree species provide more favorable habitat conditions for invertebrates, likely due to better litter quality, higher nutrient availability, and more suitable microclimatic conditions under their canopy.

In terms of species diversity, indigenous trees also had significantly higher Shannon–Wiener index values ($H' = 2.42 \pm 0.08$) than exotic trees ($H' = 1.98 \pm 0.09$). The Shannon–Wiener index combines richness and evenness, so this result reflects not only a greater number of taxa under indigenous trees but also a more balanced distribution of individuals among taxa. Similarly, Simpson's diversity index (1–D) was higher for native trees (0.87 ± 0.03) than for exotic trees (0.76 ± 0.04), further confirming that indigenous tree stands harbor more even and resilient macro-invertebrate communities.

The t-test statistic ($t = 3.65$, $p = 0.004$) indicates that the observed differences in diversity between indigenous and exotic trees are statistically significant at the 1% level. This confirms that the origin of tree species strongly influences macroinvertebrate assemblages in the Arboretum Forest. Overall, these results suggest that indigenous trees contribute more to ecosystem functioning by sustaining higher invertebrate abundance and diversity, which are critical for processes such as litter decomposition, nutrient cycling, and soil structure maintenance. Conversely, exotic trees, while potentially beneficial for economic or forestry purposes, appear less effective at supporting soil biodiversity and related ecological processes.

3.2. Discussions

Indigenous tree species consistently supported more macroinvertebrates than exotic species. For example, Croton megalocarpus recorded the highest abundance (284 individuals), while Callitris robusta had the lowest (162 individuals). This aligns with findings in temperate and tropical forests showing that indigenous trees tend to provide better food resources and habitat complexity for invertebrates [23, 5]. The higher abundance under native trees suggests more favorable litter and microhabitat conditions.

The number of taxa was higher under indigenous trees (16–19) compared to exotic trees (11–14). Shannon–Wiener diversity values were also higher in natives ($H' = 2.31–2.51$) versus non-natives ($H' = 1.88–2.10$). This pattern reflects the well-established principle that indigenous vegetation supports richer and more balanced invertebrate communities, likely due to co-evolutionary relationships between native trees and local fauna [10, 20].

Pielou's evenness (J′) values were greater under indigenous trees (0.72–0.80) than under exotic trees (0.63–0.69), suggesting a more equitable distribution of individuals among taxa. Evenness is often linked to stable and resilient communities, indicating that native trees not only support more taxa but also reduce dominance by a few species [13]. In contrast, lower evenness under exotic reflects domination by a few tolerant species, possibly those capable of exploiting low-quality litter.

Among indigenous trees, Croton megalocarpus and Polyscias fulva supported the highest diversity and abundance, which may relate to their leaf litter characteristics, nutrient content, and structural complexity [6]. Exotic species with lower diversity, such as Callitris robusta, may produce chemically defended litter or have dense canopies that limit understorey microhabitats, reducing suitability for many macro-invertebrates [18].

Higher macro-invertebrate diversity under indigenous management implies enhanced ecosystem processes, such as litter decomposition, nutrient cycling, and soil aeration. Detritivores, omnivores, and predatory invertebrates all contribute to these processes, so the loss of diversity under exotic trees could reduce ecosystem functionality [3, 24]. Thus, native trees likely play a more critical role in maintaining soil ecosystem services.

Indigenous trees had consistently lower diversity and abundance, suggesting that many macro-invertebrates are either unable or less efficient at utilizing exotic litter. This finding supports global studies reporting a reduction in invertebrate richness under non-native species in both plantation and urban forest systems [9, 21]. Such limitations can lead to simplified food webs and altered ecological interactions.

The data indicate that planting indigenous species in arboretums can maximize soil biodiversity and ecosystem functioning. While non-native trees may offer economic or aesthetic benefits, reliance on exotic species may inadvertently reduce habitat quality for native macroinvertebrates. Mixed plantings that prioritize indigenous species may therefore support both biodiversity and ecosystem services [7].

The study highlights the importance of indigenous tree species in maintaining invertebrate diversity in managed forests. Conservation and restoration programs in Rwanda and similar tropical highland ecosystems should emphasize indigenous tree planting to preserve soil fauna and associated ecosystem processes. These findings echo global recommendations that native vegetation is key for sustaining belowground biodiversity and forest resilience [4, 16].

4. Conclusion and Recommendations

The influence of indigenous and exotic tree species on macro-invertebrate diversity in the arboretum forest of Rwanda demonstrates that tree origin plays a significant role in shaping macro-invertebrate communities: indigenous tree species supported higher abundance, greater taxonomic richness, and more even distributions of macro-invertebrates than non-native species. These differences reflect how indigenous trees likely provide more favorable litter quality, micro‐habitats, and co-evolutionary relationships with local fauna, thereby enhancing ecological functions such as decomposition, nutrient cycling, and soil structure maintenance. Conversely, exotic trees, despite offering some habitat, tended to support fewer taxa, lower diversity indices, and dominance by generalist groups, implying reduced roles in sustaining soil biodiversity and ecosystem resilience. Overall, the findings underscore the ecological value of indigenous vegetation and suggest that arboretum and plantation designs that favor native species can better support below-ground fauna and the ecosystem services they underpin. Recommendations:

1) Forest managers, policymakers, and restoration practitioners should prioritize the planting and conservation of indigenous tree species in arboretums and plantation forests. Indigenous trees enhance macro-invertebrate diversity, promote balanced soil communities, and support critical ecosystem processes such as decomposition and nutrient cycling.
2) Tree species selection should not be based solely on economic or silvicultural benefits. Biodiversity indicators, particularly soil and litter macro-invertebrate diversity, should be incorporated into forest planning and monitoring frameworks to ensure long-term ecosystem functionality and sustainability.
3) Where exotic species are used for economic, educational, or experimental purposes, they should be integrated into mixed-species stands dominated by indigenous trees. Such approaches can balance production objectives with biodiversity conservation and improve habitat quality for soil fauna.

Abbreviations

%	Percentage
ANOSIM	Analysis of Similarity
ANOVA	Analysis of Variance
CCA	Canonical Correspondence Analysis
HSD	Honestly Significant Difference
NMDS	Non-metric Multidimensional Scaling
pH	Potential of Hydrogen

Conflicts of Interest

The author here declares that there is no conflict of interest in the publication of this article.

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