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*Research Article*

# Tree Species Diversity in a Naturally Regenerated Secondary Forest in the Ruhande Arboretum, Rwanda

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This work studied the vegetation in a seven-hectare self-regenerated and protected forest about nine decades-old located in a previously cultivated site in the Ruhande Arboretum to identify woody species and their diversity. Ten parallel transects were established at 34 m intervals, leaving 25 m on either side to avoid an edge effect. Along transects, circular 16 m diameter plots spaced 20 m apart were established, making a total of 56 plots. In each plot, woody species were recorded and those with heights >2 m had their diameter at breast height measured. Phytosociological data including basal area, density, and frequency and their respective relative values were computed and used to determine species and family importance value indices within each plot. Across all plots, twenty-eight genera in 17 families were identified and 844 plants were recorded, including 755 trees and 89 shrubs, with most trees found in smaller diameter classes. Across all plots, only one *Markhamia lutea* tree was in the 50–60 cm diameter class and one *Polyscias fulva* was in the >90 cm diameter class. Of all woody species, *Polyscias fulva* was the most dominant since it had individuals with the biggest diameter. The number of individuals per family across all plots ranged from one for Cupressaceae, Dracaenaceae, Moraceae, and Solanaceae to 414 for Bignoniaceae. Across all plots, the diameter at breast height ranged from 1.8–97 cm. The species importance value index ranged from 0.3–41.8 for *Nicotiana tabacum* and *P. fulva*, respectively, while the family importance value index ranged from 0.2 for Annonaceae, Cupressaceae, Dracaenaceae, and Solanaceae to 41.6 for Araliaceae. Shannon and Simpson's diversity indices were 1.772 and 0.707, respectively, while the evenness was 0.532, signifying that the forest was reasonably diverse. It is recommended that this forest can be conserved owing to its rich vegetation and to monitor its successional development.

## 1. Introduction

Forests provide many products and services that contribute to socioeconomic development and are particularly important for hundreds of millions of people, providing food and medicine, protecting soil and water, and contributing to climate change mitigation [1]. Forests cover about 31 per cent of the land on Earth, around four billion hectares, and contain more than two-thirds of the world's terrestrial species [2]. Forests and woodlands harbor immense terrestrial and aquatic biodiversity, and especially in moist tropical regions, represent the most species-rich habitat types worldwide [3].

Despite the benefits, tropical forests are undergoing widespread loss, largely because of agricultural expansion [4]. More than 150,000,000 ha of the tropical forest were converted for farming between 1980 and 2012 [4, 5]. Conversion of a tropical forest to farmland is reported as the major driver of the global extinction crisis [6], causing dramatic species loss [3] as forest specialists are replaced by widespread habitat generalists [7].

Tropical forests cover about 52% of the global forest [8] and host enormous biodiversity [9]. Unfortunately, even large areas of species-rich forests are being cleared to make way for agriculture, human habitation, and industrial development. Deforestation in tropical Africa accounts for over 23% of forest losses worldwide [10]. The threat to the tropical biota is potentially immense and beyond the current resources of conservation agencies to counter or avert by intervention management [11]. Secondary forests are known to have pivotal roles in reversing the tropical extinction crisis [12].

Rwandan forests are not an exception to the global forest state and have seen a steady decrease in area because of the pressure from the growing population. The population was estimated at 10.5 million inhabitants and was projected to reach 16.6 million inhabitants in 2032 [13]. The natural forest area in Rwanda declined by 65% during the period from 1960 to 2007 [14]. To ensure their conservation, most natural forests are protected either as national parks or forest reserves [15]. Following the failure of natural forests to meet local demand for timber and other wood requirements, a plantation forestry programme was started in Rwanda's Huye district by the colonial administration in the early 1900s [16].

In support of the then emerging afforestation programme, the Ruhande Arboretum was established in 1933 with the aim of testing suitable exotic and probable indigenous tree species that could be adapted to local conditions outside their native areas. Prior to its establishment, the area was used for human settlement and was under cultivation [17]. The Arboretum is composed of over 207 native and exotic species, with 143 hardwoods including 69 *Eucalyptus*, 57 softwoods, and three bamboo species [18].

At the establishment of Ruhande Arboretum, a seven-hectare area was set aside and allowed to self-regenerate into a mixed species forest. Together with the whole Arboretum, a variety of fauna and flora are harbored and provide several ecosystem services and values [19]. The Arboretum was dedicated to the Queen's Commonwealth Canopy (QCC) project in 2018 by the Rwandan government [20]. The QCC, conceived by the Right Honorable Frank Field MP, was launched at the Commonwealth Heads of Government Meeting in Malta, in 2015. The QCC is a unique network of forest conservation initiatives, which involves all 53 countries of the Commonwealth. This is likely to strengthen the conservation of the Arboretum and the secondary forest.

Owing to this background, this study aimed at identifying tree and shrub species and exploring their diversity in this small, naturally regenerated secondary forest 88 years after its restoration amidst a mosaic of exotic and a few indigenous tree species.

## 2. Materials and Methods

*2.1. Site Description.* The study forest is part of the Ruhande Arboretum, located near the University of Rwanda-Huye Campus in Huye district, southern Rwanda (Figure 1). This site is located at latitude 2°33′S and longitude 29°46′E and 1737 m altitude [21]. It has a mean annual rainfall of 1231 mm and mean annual temperature of 19°C, with daily temperature maxima ranging from 28.5 (April) to 32°C (September) [21]. The soils are humic and ferralitic [22].

The study forest regenerated naturally after displacement of the former inhabitants of the area. No formal management intervention was applied to it except occasional disturbance through encroachment for the collection of animal fodder and deadwood for fuel wood by the surrounding communities [23].

*2.2. Field Procedure and Data Analysis.* For data collection, the forest was measured along its longest side and 10 parallel transects were established at a regular interval of 34 m. The first and the last transects were established 25 m from the forest border to avoid edge effects. Along each transect, circular plots of 16 m diameter (area 0.02 ha each) were systematically established leaving at least an interval of 20 m between plots. The number of plots per transect differed between transects because the length of transects also differed since the study forest was not regular. In total, 56 plots were established. The details of sampling points and transect layout are provided in Figure 1. The forest is heterogeneous and using many sampling plots aimed at capturing the variation that exists.

In each plot, all tree and shrub species were identified and recorded, and those with heights >2 m were measured for diameter at breast height (DBH). The DBH values were later used to group the trees and shrubs in respective diameter classes and to compute tree and shrub basal area. The phytosociological data including basal area, density and frequency and their respective relative values were computed and used to determine the species' importance value index (SIVI) for each woody species. The family importance value index (FIVI) was determined by summing the SIVI of all species recorded in a particular family. Simpson and Shannon diversity indices were also determined [24]. The parameters were determined as explained below.

Computations of the SIVI were done as follows:

(1) The Relative Frequency (RFi) was determined by using the formula:

$$\mathrm{RFi} = \left(\frac{\mathrm{Fi}}{\mathrm{TF}}\right) \times 100, \quad (1)$$

where Fi = the frequency of species i and TF = Total Frequency of all species (sum of Fi).

(2) The Relative Density (RDi) was determined by using the formula:

$$\mathrm{RDi} = \left(\frac{\mathrm{Di}}{\mathrm{TD}}\right) \times 100, \quad (2)$$

where Di = denotes the density of species i and TD = total density of all species (sum of Di).

(3) The Relative Dominance or Cover (RCi) was determined by using the formula:

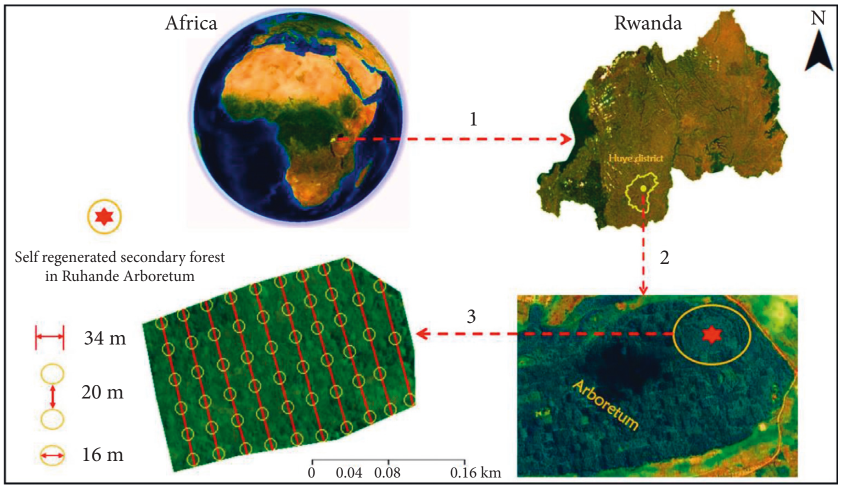


Figure 1: Map of the study area in the self-regenerated secondary forest in Ruhande Arboretum, Huye, Rwanda.

$$\mathrm{RCi} = \left(\frac{\mathrm{BAi}}{\mathrm{TBA}}\right) \times 100, \quad (3)$$

where BAi is the basal area of species i and TBA = Total basal area of all species (sum of Bai).

The importance value index at species level (SIVI) was determined as follows:

$$\mathrm{SIVI} = \frac{\mathrm{RFi} + \mathrm{RDi} + \mathrm{RCi}}{3}. \quad (4)$$

The FIVI for botanical families were then calculated as follows:

$$\mathrm{FIVI} = \left(\mathrm{SIVI}_1 + \mathrm{SIVI}_2 + \ldots + \mathrm{SIVIn}\right), \quad (5)$$

where 1, 2, . . ., $n$ represent the number of species in a given family.

Shannon–Weiner (H), species evenness ($E_H$), and Simpson's diversity (D) indices were calculated as follows:

Shannon–Weiner index (H), species evenness ($E_H$), and Simpson's diversity index (D) were calculated as: $H = -((pi)^* \ln(pi))$ where pi = number of individuals of species i/total number of samples, ln = natural logarithm; $E_H = H/H_{max}$ where $H_{max}$ is the maximum diversity possible, or = lnS; and $D = 1/\Sigma(pi^2)$.

## 3. Results

*3.1. Floristic Composition.* Across all 56 plots, twenty-eight woody species (genera) within 18 families were identified and partitioned into 17 tree species and 11 shrub species (Table 1). In total, 844 individuals of ≥2 m height were counted, consisting of 755 tree species and 89 shrub species (Figures 2 and 3). In terms of individuals' number, the most dominant tree species were *Markamia lutea,* followed by *Polyscias fulva.* The most dominant shrub species was *Erythrococca bongensis* (Figure 3).

Among the 18 woody tree and shrub species families found in the study area, Bignoniaceae had the largest number of individuals, while the Araliaceae family had the second largest number of individuals (Figure 4). However, the diversity reported here is on comparing the number of genera per family and family diversity should be taken with care. About 92% of individuals in the Bignoniaceae family belong to the genus *Markhamia* with only one species, *M. lutea*. Similarly, about 89% of the individuals in the Araliaceae family are *Polyscias fulva*. The Cupressaceae, Dracaenaceae, Moraceae, and Solanaceae families were represented by only one individual each (Figure 4). Figure 5 indicates the number of genera present in different botanical families.

By examining 10 mostly populated woody species distribution across all plots, *P. fulva* was present in 54 of the 56 plots equivalent to (96% of all plots). *Cedrela serrata*, *C. Megalocarpus*, and *P. Africana* occurred in 14 plots (25% of all plots). *Podocarpus falcatus*, *E. excelsum*, *A. gummifera*, *M. heterphylla*, *M. lutea*, and *T. stans* were observed in 12, 10, nine, eight, five, and four plots, respectively (Figure 6).

*3.2. Size Classes.* The tree DBH ranged from 5 to 97 cm. The size classes of the different tree species found in the study area are shown in Figure 7. All trees whose DBH was >5 cm were grouped into 10 diameter classes, and the second smallest diameter class (5–10 cm) had the highest number of individuals followed by the smallest class (<5 cm) with *P. fulva* and *M. lutea* dominating, respectively. The largest diameter class (>90 cm) had only one tree of *P. fulva*.

The majority of *M. lutea* individuals were found in the two smallest (<5 and 5–10 cm) diameter classes, and the number of individuals per diameter class decreased with increasing tree size until there was only one individual in the 50–60 cm class. Young individuals of *M. lutea* outnumbered those of *P. fulva* in the classes of <5, 5–10, 10–20, and 20–30 cm in the order of 8.7, 7.6, 2.4, and 2.1-fold, respectively. In the following (larger) classes of 30–40, 40–50, and 50–60 cm, the number of individuals of *P. fulva* exceeded that of *M. lutea* by 3.4, 9.7, and 22 times, respectively. The number of individual trees in each DBH size class varied by species.

Table 1: Tree and shrub species ranked from the most to the least abundant identified in the self-regenerated secondary forest in Ruhande Arboretum, Huye, Rwanda.

| Trees | Shrubs |
|---|---|
| *Markhamia lutea* (Benth.) K. Schum. | *Maytenus heterophylla* Eckl. & Zeyh. N. Robson |
| *Polyscias fulva* Hiern. | *Erythrococca bongensis* Pax |
| *Cedrela serrata* Royle | *Ligustrum lucidium* W.T. Aiton |
| *Tecoma stans* (Linn.) H. B. & K. | *Eriobotrya japonica* (loquat) |
| *Croton megalocarpus* Hutsch. | *Acanthus pubescens* (Thomson ex Oliv.) Engl. |
| *Prunus africana* (Hook.f.) Kalkman | *Senecio manii* Hook.f. |
| *Albizia gummifera* (J.F.Gmel.) C.A.Sm. | *Annona reticulata* L. |
| *Ekebergia capensis* Sparrm. | *Dracaena steudneri* Engl. |
| *Podocarpus falcatus* (Thunb.) R.Br. ex Mirb.) | *Nicotiana tabacum* L. |
| *Erythrina abyssinica* Lam ex DC. | *Calliandra calothyrsus* Benth. |
| *Syzygium guineense* (Willd.) DC. | *Leucaena divesifolia* (Schltdl.) Benth. |
| *Grevillea robusta* A. Cunn. ex R.Br. | |
| *Spathodea companulata* P. Beauv. | |
| *Euphorbia umbellata* (Pax) Bruyns | |
| *Jacaranda mimosifolia* D. Don | |
| *Cupressus lusitanica* Mill. | |
| *Ficus benjamini* L. | |

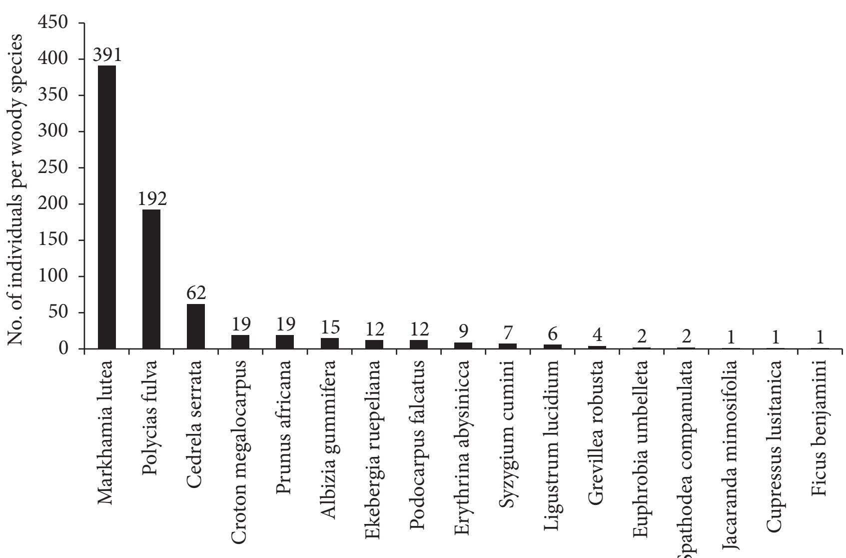


Figure 2: Number of individuals of tree species identified in the self-regenerated secondary forest in Ruhande Arboretum, Huye, Rwanda.

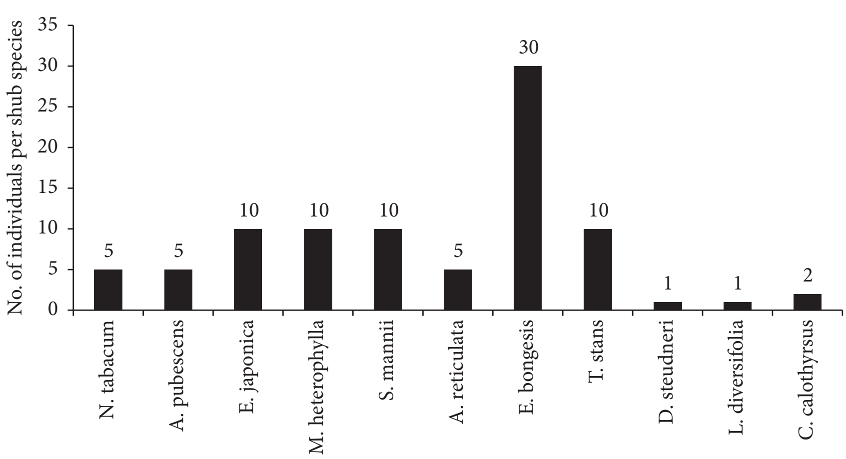


Figure 3: Number of individual shrub species identified in the self-regenerated secondary forest in Ruhande Arboretum, Huye, Rwanda.

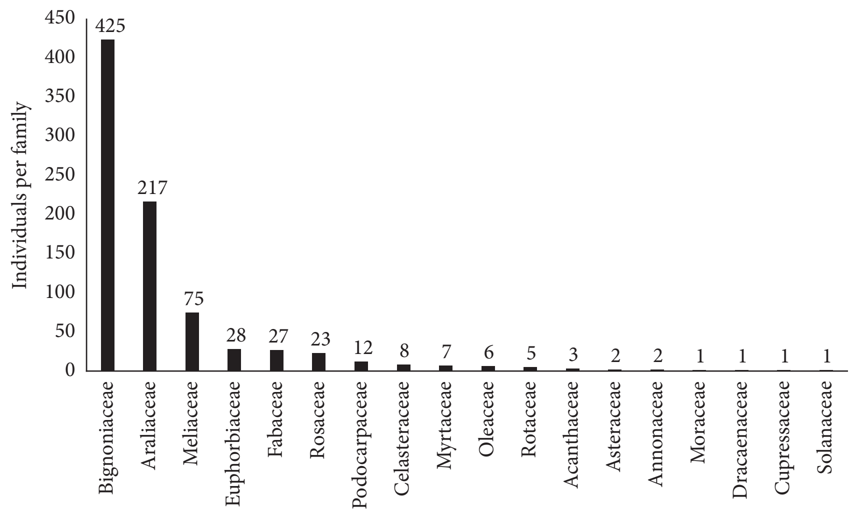


Figure 4: Number of individual trees and shrubs occurring in respective families in the self-regenerated secondary forest in Ruhande Arboretum, Huye, Rwanda.

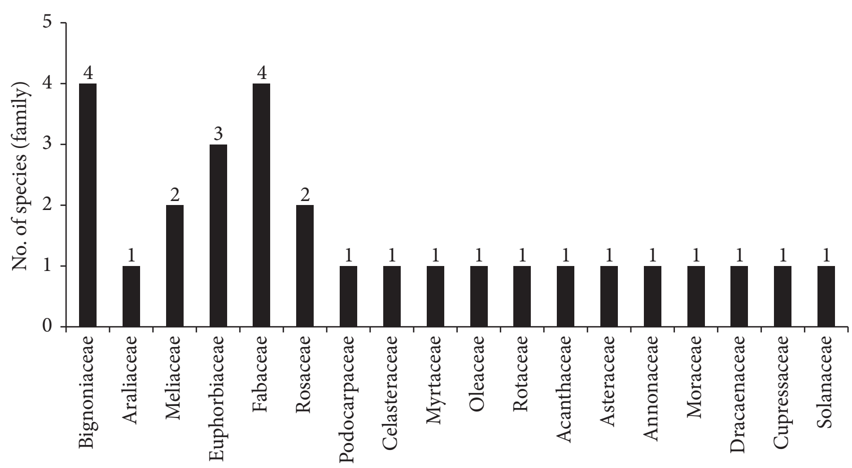


Figure 5: Number of genera per family in the self-regenerated secondary forest in Ruhande Arboretum, Huye, Rwanda.

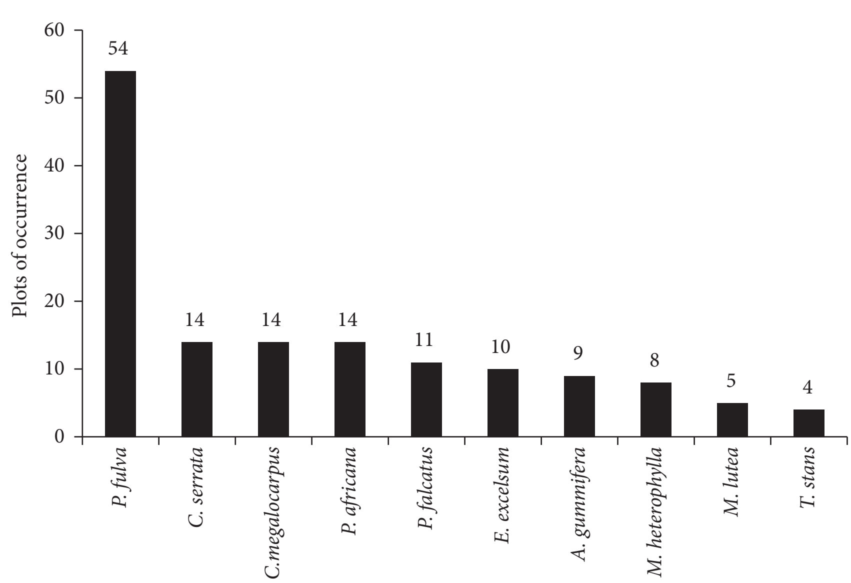


Figure 6: Distribution of 10 most populated woody species across plots in the self-regenerated secondary forest in Ruhande Arboretum, Huye, Rwanda.

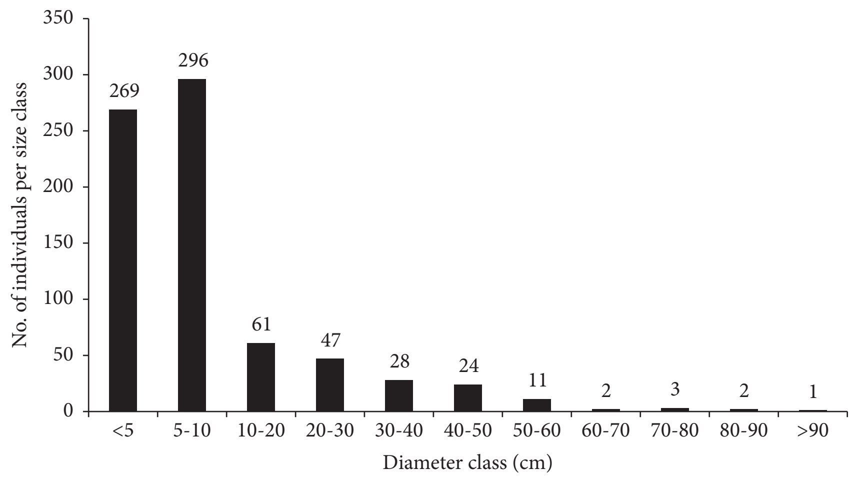


Figure 7: Size class distribution of individual woody species of DBH ≥5 cm identified in the self-regenerated secondary forest in Ruhande Arboretum, Huye, Rwanda.

For *P. fulva*, individuals were relatively similarly abundant from 5 to 50 cm DBH. By contrast, ~90% of the *M. lutea* individual trees were in the 0–10 cm DBH classes. The number of individuals in different size classes for the most abundant four tree species is indicated in Figure 8. Only *P. fulva* was distributed in all size classes, although it was only represented by one individual in the largest (>90 cm) class. Other woody species were not represented in size classes larger than 50–60 cm DBH. *Polyscias fulva* showed the largest basal area owing to its individual tree sizes which were large compared to other species (Figure 9).

*3.3. Species and Family Importance Values.* Although *M. lutea* was more abundant than *P. fulva* in terms of the number of individuals, the latter species showed a significantly higher importance value index owing to the greater variation in the sizes of its individuals. For all species, the species importance value indices ranged from 0.3 to about 42 for *Nicotiana tabacum* and *Polyscias fulva,* respectively. Species and family importance values (SIVI and FIVI) are shown in Figures 10 and 11, respectively, and ranged from 0.3 for *Nicotiana tabacum* to 41.8 for *Polyscias fulva*. *Markhamia lutea* had a SIVI value of 35.1. The families Araliaceae and Bignoniaceae had FIVI values of 41.6 and 28.6, respectively, while Annonaceae, Cupressaceae, Dracaenaceae, and Solanaceae had a FIVI of 0.2.

*3.4. Species Diversity and Evenness.* Shannon–wiener (H) and Simpson's diversity (D) indices and the evenness (E) for the species in the study area were 1.772, 0.707, and 0.532 respectively (Table 2).

## 4. Discussion

Despite the fact that the Ruhunde Arboretum was established on a previously highly disturbed, cultivated, and inhabited site [17], the forest studied showed a considerable number of species. A similar restored forest in the region (southwestern Uganda) was observed to be less diverse compared to a degraded forest [25]. The study forest is regarded as secondary since it fits with the definition of secondary forests, namely, those regenerating largely through natural processes after significant human and/or natural disturbance [26]. Based on its age, the study forest can be classified in the third phase of secondary forest because it falls within the age range of 75–100 years [27].

*4.1. Species Composition.* The number of individual trees varied within species in a given class and the tree species with the highest number of individuals was found in the two smallest DBH classes of <0.5 and 5–10 cm diameter. This concurs with the findings by others [28] who reported that some species stood out by the higher number of individuals within the smallest DBH classes. The highest number of shrubs was obtained in the two classes of 5–10 cm diameter.

It is difficult to track the origin of the germplasm for the regeneration of this forest since it is surrounded by a mosaic of many $50 \times 50\ m^2$ plots planted with exotics. The numerical dominance of *M. lutea* may be ascribed to the fact that the tree species is traditionally found on farmlands in the area surrounding Ruhande Arboretum. Since the area was under cultivation before this forest was allowed to regenerate [17], some individuals of *M. lutea* trees, especially the mature ones, may have been left on the site or at least some seed may have been stored in the soil seed bank by the time the Arboretum was created. Rwandan agroforestry systems traditionally have *M. lutea* as a favorable tree species used for timber production, crafts, and for medicinal purposes in most communities [29]. However, this needs to be taken with care because [30] reported that previous land use types do not influence the biodiversity of secondary forests.

The high density of *M. lutea* observed in the present forest is different from that observed in other forests in the region. For example, the distribution of this species in Kibale National Park, Uganda, is much lower, due to the consumption of its fruits by red colobus monkeys [31]. Since the present study area is surrounded by human habitations, it does not harbor colobus monkeys but rather vervet monkeys

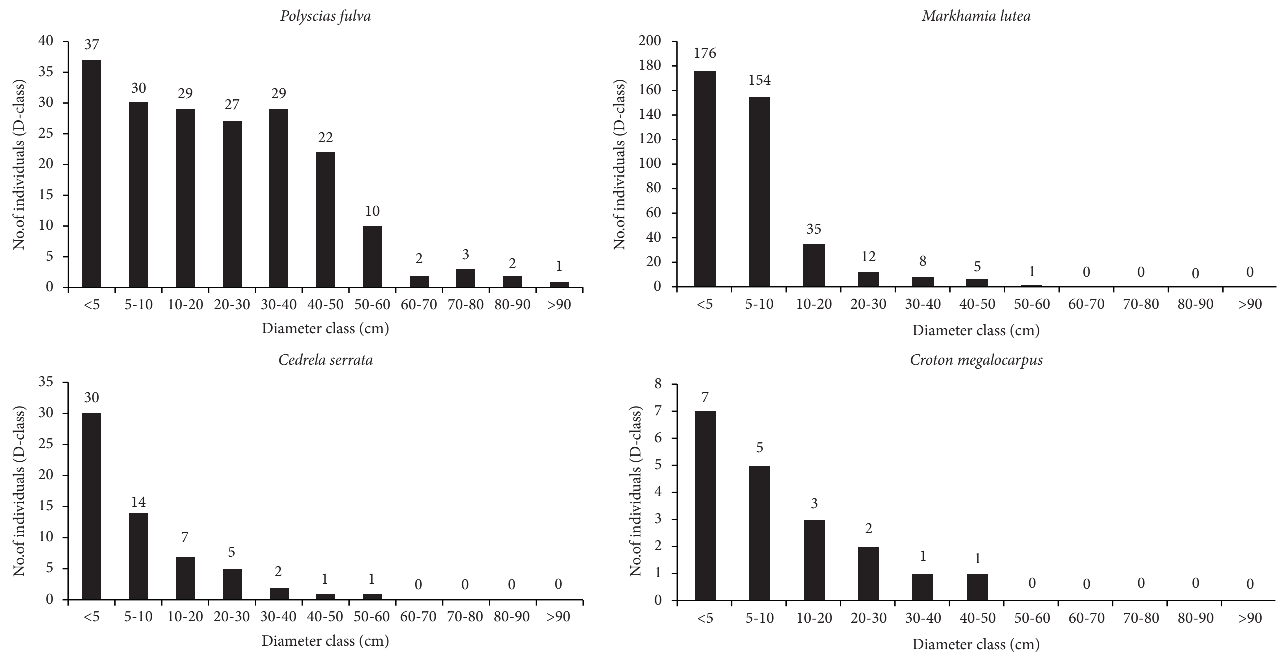


Figure 8: Size class distribution of individual trees in four of the tree species observed in the self-regenerated secondary forest in Ruhande Arboretum, Huye, Rwanda.

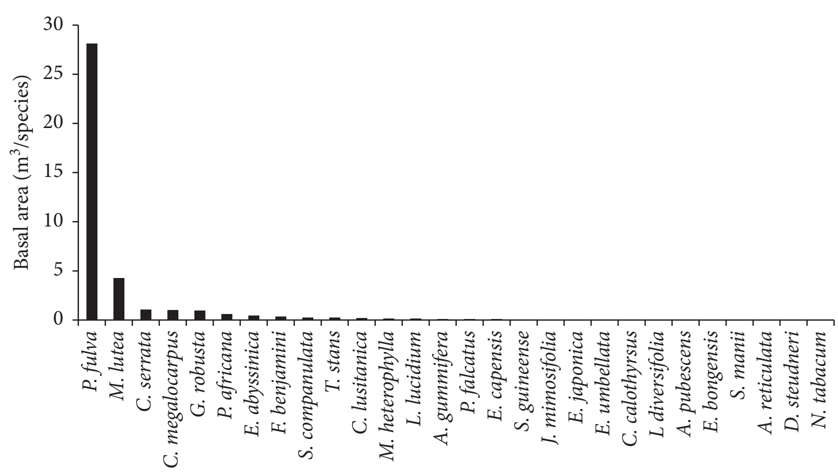


Figure 9: Basal area across all plots per woody species measured in the self-regenerated secondary forest in Ruhande Arboretum, Huye, Rwanda.

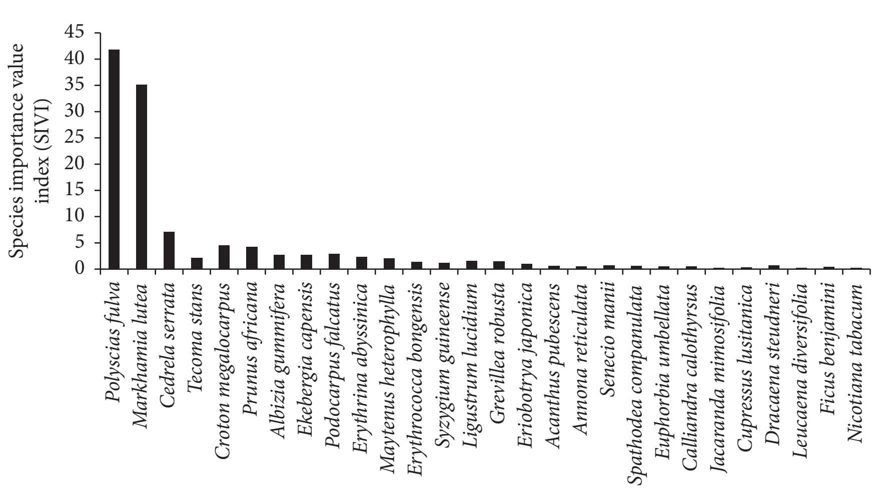


Figure 10: Importance value indices of woody species identified in the self-regenerated secondary forest in Ruhande Arboretum, Huye, Rwanda.

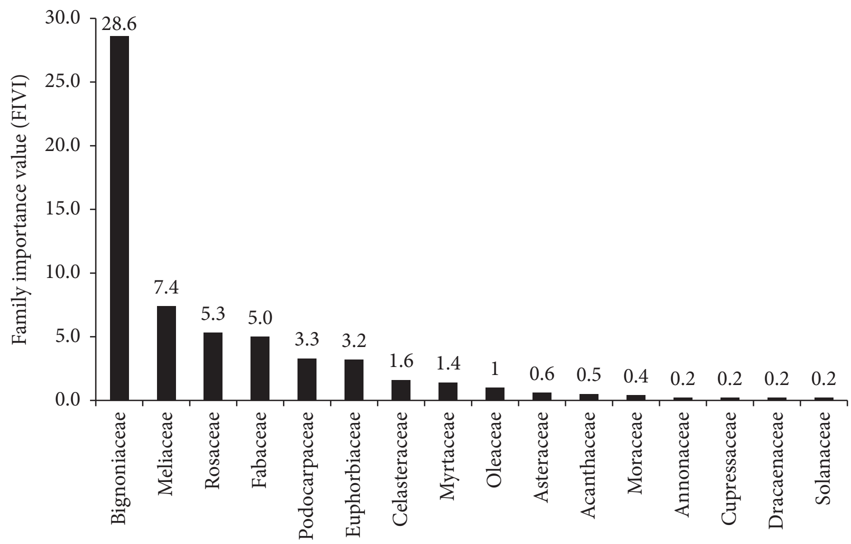


Figure 11: Family importance values observed in the self-regenerated secondary forest in Ruhande Arboretum, Huye, Rwanda.

Table 2: Shannon–Weiner (H), species evenness (E), and Simpson's diversity (D) indices of woody species identified in the study area. Pi stands for the proportion of individuals of a species/plot (n) to the total population of that species (N); ln is the natural log and S denotes the species richness in the study area.

| S/N | Species name | n/N (=pi) | $pi^2$ | lnpi | pi* (lnpi) | H/lnS |
|---|---|---|---|---|---|---|
| 1 | *Markhamia lutea* | 0.466 | 0.217185 | −0.764 | 0.356 | 0.107 |
| 2 | *Polyscias fulva* | 0.259 | 0.066895 | −1.352 | 0.350 | 0.105 |
| 3 | *Cedrela serrata* | 0.081 | 0.006569 | −2.513 | 0.204 | 0.061 |
| 4 | *Tecoma stans* | 0.024 | 0.000568 | −3.736 | 0.089 | 0.027 |
| 5 | *Croton megalocarpus* | 0.023 | 0.000513 | −3.788 | 0.086 | 0.026 |
| 6 | *Prunus africana* | 0.023 | 0.000513 | −3.788 | 0.086 | 0.026 |
| 7 | *Albizia gummifera* | 0.018 | 0.000320 | −4.024 | 0.072 | 0.022 |
| 8 | *Ekebergia capensis* | 0.014 | 0.000205 | −4.247 | 0.061 | 0.018 |
| 9 | *Podocarpus falcatus* | 0.014 | 0.000205 | −4.247 | 0.061 | 0.018 |
| 10 | *Erythrina abyssinica* | 0.011 | 0.000115 | −4.535 | 0.049 | 0.015 |
| 11 | *Maytenus heterophylla* | 0.011 | 0.000115 | −4.535 | 0.049 | 0.015 |
| 12 | *Syzygiummguineense* | 0.008 | 0.000070 | −4.786 | 0.040 | 0.012 |
| 13 | *Erythrococcabongensis* | 0.008 | 0.000070 | −4.786 | 0.040 | 0.012 |
| 14 | *Ligustrum lucidium* | 0.007 | 0.000051 | −4.940 | 0.035 | 0.011 |
| 15 | *Grevillea robusta* | 0.006 | 0.000036 | −5.123 | 0.031 | 0.009 |
| 16 | *Eriobotrya japonica* | 0.005 | 0.000023 | −5.346 | 0.025 | 0.008 |
| 17 | *Acanthus pubescens* | 0.004 | 0.000013 | −5.634 | 0.020 | 0.006 |
| 18 | *Spathodea companulata* | 0.002 | 0.000006 | −6.039 | 0.014 | 0.004 |
| 19 | *Calliandracalothyrsus* | 0.002 | 0.000006 | −6.039 | 0.014 | 0.004 |
| 20 | *Senecio manii* | 0.002 | 0.000006 | −6.039 | 0.014 | 0.004 |
| 21 | *Euphorbia umbellata* | 0.002 | 0.000006 | −6.039 | 0.014 | 0.004 |
| 22 | *Annona reticulata* | 0.002 | 0.000006 | −6.039 | 0.014 | 0.004 |
| 23 | *Nicotiana tabacum* | 0.001 | 0.000001 | −6.732 | 0.008 | 0.002 |
| 24 | *Jacaranda mimosifolia* | 0.001 | 0.000001 | −6.732 | 0.008 | 0.002 |
| 25 | *Cupressus lusitanica* | 0.001 | 0.000001 | −6.732 | 0.008 | 0.002 |
| 26 | *Ficus benjamini* | 0.001 | 0.000001 | −6.732 | 0.008 | 0.002 |
| 27 | *Leucaena diversifolia* | 0.001 | 0.000001 | −6.732 | 0.008 | 0.002 |
| 28 | *Dracaena steudneri* | 0.001 | 0.000001 | −6.732 | 0.008 | 0.002 |
| | . | | 0.293500 | H′ | 1.772 | 0.532 |
| | . | | | D | 3.407 | |
| | . | | | E | 0.532 | |

H, D, and E stand for Shannon–Weiner index, Simpson's diversity, and species evenness, respectively.

(*Chlorocebus pygerythrus*) which may not be feeding on *M. lutea* fruits.

*Polyscias fulva* was the most evenly distributed species across the study site but its largest individuals were observed in the periphery of the study forest while those found in the inner plots were small, suppressed individuals. The dominance of *P. fulva* would be expected because it is well adapted to open forests, a characteristic of secondary forests where it enjoys full-solar radiation to maximize its growth. It was reported to be abundant among midsuccessional species that occupied secondary forests on abandoned cultivation sites of 11–30 years [32]. *Polyscias fulva* can be found both in intact and in fragmented forests and is said to be a long-lived pioneer, signifying that it can grow across different successional stages of secondary forests [33]. Larger DBH values at the edge compared to the middle of the forest is not unexpected. A previous study showed that tree DBH, tree height, and stand volume increased from the central areas of forests to the edge areas and this was attributed to the increased availability of light density, temperature, and moisture [34].

The germplasm of some of the woody plants observed in the area may have originated from mature trees growing in the Ruhande Arboretum. *Calliandra calothyrsus* and *Tecoma stans* grown in some plots in the Arboretum, for example, were reported to be invasive [35, 36]. In less than five years, *C. calothyrsus* trees had self-established up to 55 m from the edges of plots in which they were originally planted [37].

*4.2. Size Classes.* The appearance of many individual tree and shrub species in smaller diameter classes is expected for young secondary forests and this is reported elsewhere [28]. This may be an indication of study forest stability and is promising for its continued development. Forests which show an inverted J-shape of sapling distribution represent healthy regeneration of the species [38]. The presence, abundance, and species composition of tree saplings are good indicators of recovery trends in degraded natural forests, as they indicate how species composition and diversity may develop in the future [39].

The number of tree and shrub species found in the study forest is generally low, probably because the forest is still young (86 years). In addition, it is not surrounded by the original mature forest which would otherwise act as a source of germplasm for the species to regenerate. In a restoration study following cultivation, tree seedling and sapling richness were the highest close to the mature forest edge and lower further away 19 years after cessation of cultivation [40]. It was observed that the abundance of woody seedlings and saplings can recover within 15–20 years in post-agricultural sites that are close to mature forest areas [41].

Young forests in secondary succession were reported to have fewer trees per unit area [42, 43] where the young regeneration declined as the forests grew thicker. Tree species and individuals per species outnumbering shrub species is not unexpected in secondary forests. The number of shrubs was also observed elsewhere to be less compared to that of trees [43].

*4.3. Plant Diversity, Species and Family Importance Values.* The Shannon–Weiner and Simpson diversity indices obtained in this study indicate that the forest was reasonably diverse. According to [44], Simpson's index values less than one imply that the forest is dominated by many species. Species or family IVI values greater than one indicate that a particular species or family dominates [42] and that its impact in the community structure is high [44]. The parameter also indicates stability and sustainability of the site [45]. The study forest may have recovered quickly owing to the observed diversity of the woody species present. According to [30], the time needed for full recovery of old-growth forest was estimated to be 54 years for species richness and 780 years for species composition. Many secondary forests have tree species richness that surpasses that of old-growth forests, which is commensurate with the intermediate disturbance hypothesis [46], which states that biodiversity peaks in midsuccessional forests because of the co-occurrence of persisting pioneer species that was established just after disturbance and late successional, shade-tolerant species that established in the shade of pioneers [47].

## 5. Conclusion

This study identified 28 woody species consisting of 17 tree and 11 shrub species belonging to 17 families in a seven-hectare self-regenerated, 88-year-old forest in the Ruhande Arboretum. Within the study area, 844 trees and shrubs with DBH >5 cm were counted, consisting of 755 trees and 89 shrubs. The number of individuals per family ranged from one for each of Cupressaceae, Dracaenaceae, Moraceae, and Solanaceae families to 414 for Bignoniaceae. Tree DBH ranged from 5 to 97 cm. Species IVI ranged from 0.3 to 41.8 for *Nicotiana tabacum* and *P. fulva,* respectively, while FIVI was 28.6 for Bignoniacae and 41.6 for Araliaceae. Diversity indices were 1.772 and 0.707 for Shannon–Weiner and Simpson, respectively, and the evenness across all plots was 0.532, signifying the forest to be reasonably diverse. The findings suggest that small forests developing after complete disturbance like several others present in Rwanda and elsewhere can reconstitute to significantly contribute to biodiversity conservation and to the restoration efforts being carried out to revive seriously degraded forestlands. It is recommended that this forest be conserved because it is species-rich and for further studies to monitor its successional development as it progresses toward maturity.

## Data Availability

The vegetation data used to support the findings of this study are included within the article.

## Conflicts of Interest

The authors declare that there are no known conflicts of interest to the best of their knowledge.

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