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Research Article

Woody species diversity, structure, and regeneration status of Gole Community Managed Forest, Gamo Zone, Ethiopia

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Abstract

Forests are critical for maintaining biodiversity, carbon sequestration, and supporting local livelihoods. The Gole Community Managed Forest (GCMF) in the Kamba district of the Gamo Zone, southwest Ethiopia, plays a crucial role for ecological health and the community vague. However, there is a significant knowledge gap regarding the floristic composition, species diversity, and structural characteristics of this forest, necessitating comprehensive study. This research aimed to inventory and classifies woody species within the GCMF, assess their structural attributes, analyze species diversity, and evaluate the regeneration status of the species to inform sustainable management practices. A systematic grid sampling method was utilized within a nested plot design across 765 hectares of the forest. Diameter at breast height (DBH), tree height, frequency, and density data were collected for all woody species. A total of 47 plots were established to record and document the plant species. Relevant ecological parameters were assessed using established indices including the Shannon-Wiener diversity Index and Importance Value Index (IVI). Quantitative analyses were subsequently conducted with SPSS version 25.0 statistical software The study identified 52 woody species across 46 genera and 39 families, with Euphorbiaceae and Celasteraceae being the most dominant families. A total basal area of 168.15 m²/ ha was recorded. The regeneration analysis revealed a promising status with a high density of seedlings (17,622/ha) and saplings (4,127/ha) compared to mature trees (385/ha), indicative of robust regeneration potential. The GCMF demonstrates high floral species richness, a well-structured vegetation profile (seedlings, saplings, and mature trees), and strong natural regeneration capacity, indicating a relatively stable and resilient forest ecosystem. However, the forest is increasingly threatened by anthropogenic pressures such as agricultural expansion, fuel-wood collection, illegal logging, and grazing, which are accelerating deforestation and degrading habitat quality. The findings underscore the importance of implementing effective and community-oriented management strategies to ensure the sustainable utilization and preservation of forest resources.

Keywords: Biodiversity; Importance value index; Species regeneration dynamics

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1. Introduction

Forests are vital ecosystems that contribute significantly to biodiversity, carbon sequestration, and the livelihoods of communities that depend on them. The Gole Community Managed Forest (GCMF), located in Kamba woreda Gamo zone, south Ethiopia, is a critical habitat that supports a diverse array of woody species and provides essential resources for the local population. Community-managed forests have increasingly been recognized for their role in promoting sustainable forest management by integrating indigenous knowledge systems with formal conservation strategies and participatory governance frameworks (FAO, 2020; Chazdon et al., 2021). Understanding the existing woody species in such forests is crucial for developing effective management strategies that enhance ecological health while meeting socioeconomic needs.

Despite the importance of the GCMF, there remains a significant gap in comprehensive knowledge of its woody flora. Recent vegetation studies in Ethiopian forests have highlighted similar limitations, reporting incomplete documentation of species composition, diversity, and structural attributes (e.g., woody species diversity and structure assessments in Seqela Dry Afromontane Forest, northwestern Ethiopia; Basal area, density, and IVI analyses of woody plants in Ruruki Forest, West Shewa; and floristic and regeneration evaluations in Dabal Forest of southeastern Ethiopia) (Birhanu *et al*., 2025; Sherafu *et al*., 2024).

Research has highlighted the importance of understanding the structural characteristics of forests, including metrics such as tree height, diameter at breast height (DBH), and canopy cover, as these factors are indicative of overall forest health and biodiversity (Kattan & Alvarez, 2014; Swain et al., 2022). Furthermore, the vertical stratification of woody species is another important aspect that has received limited attention. Understanding stratification and its relationship with environmental factors can provide insights into habitat complexity and species interactions.

Regeneration status is a fundamental indicator of forest ecosystem sustainability, as it reflects the capacity of woody species to maintain population continuity under existing environmental and anthropogenic pressures. Quantitative parameters such as seedling and sapling density, diameter-class distribution, and recruitment patterns provide critical insights into population structure, regeneration potential, and long-term stand dynamics. Despite its ecological and socio-economic importance, the GCMF lacks comprehensive and up-to-date data on woody species composition, structural characteristics, and regeneration status.

Assessing floristic composition, species diversity, structural characteristics, and regeneration patterns is fundamental for understanding species richness, identifying ecologically and economically important taxa, and informing sustainable forest management practices; however, comprehensive data on woody species composition, structural attributes, regeneration dynamics, and their ecological–socioeconomic interactions remain limited for the GCMF. Therefore, this study aims to systematically evaluate the composition, diversity, structural characteristics, and regeneration status of woody species in the GCMF to generate evidence-based insights that support sustainable management and conservation planning.

2. Materials and Methods

2.1 Study area

The research was conducted in the GCMF, situated in the Kamba district of the Gamo Zone in southwest Ethiopia. Geographically, the forest spans from 6°05'43" N latitude to 37°12'42" E longitude, with an altitudinal range extending from 1,837 to 2,723 meters above sea level and encompasses a total area of 765 hectares (Figure 1). The study site is located approximately 597 kilometers southwest of Addis Ababa, the capital city of Ethiopia.

The region experiences a bimodal rainfall pattern, characterized by a prolonged rainy season from April to October, peaking at the beginning of this period, and a shorter rainy season from November to February. The average annual rainfall measures 1,729 mm, while the mean annual temperature ranges between 13.7°C and 23.0°C. The GCMF is classified within the moist evergreen montane forest vegetation zone of southwest Ethiopia, a forest type characterized by a multi-stratified, high-diversity Afromontane evergreen ecosystem occurring between approximately 1500 and 3000 m above sea level (typical of southwestern Ethiopian montane forests) (Mengesha et al., 2020). Soils commonly associated with moist evergreen Afromontane forests in the Ethiopian highlands include Dystric Nitosols and Acrisols, often occurring alongside Regosols and Cambisols under humid, well-drained conditions, reflecting the deeply weathered, and clay-textured soils typical of these ecosystems.

22.2 Methods

2.2.1 Delineation of study area

To identify plot locations in the field, a systematic grid sampling method was employed at regular intervals. The Quantum Geographic Information System (QGIS version 3) was utilized to create a grid over the mapped forest area, with equally spaced grid lines set along the latitude and longitude to establish intersection points (Figure 2). The geographic coordinates of the study area were mapped, and contours were placed at intervals of 400 meters. This process resulted in the identification of a total of 47 intersection points throughout the mapped area. Each plot was designated a unique location using GPS coordinates, and temporary identification numbers were assigned during the field assessment.

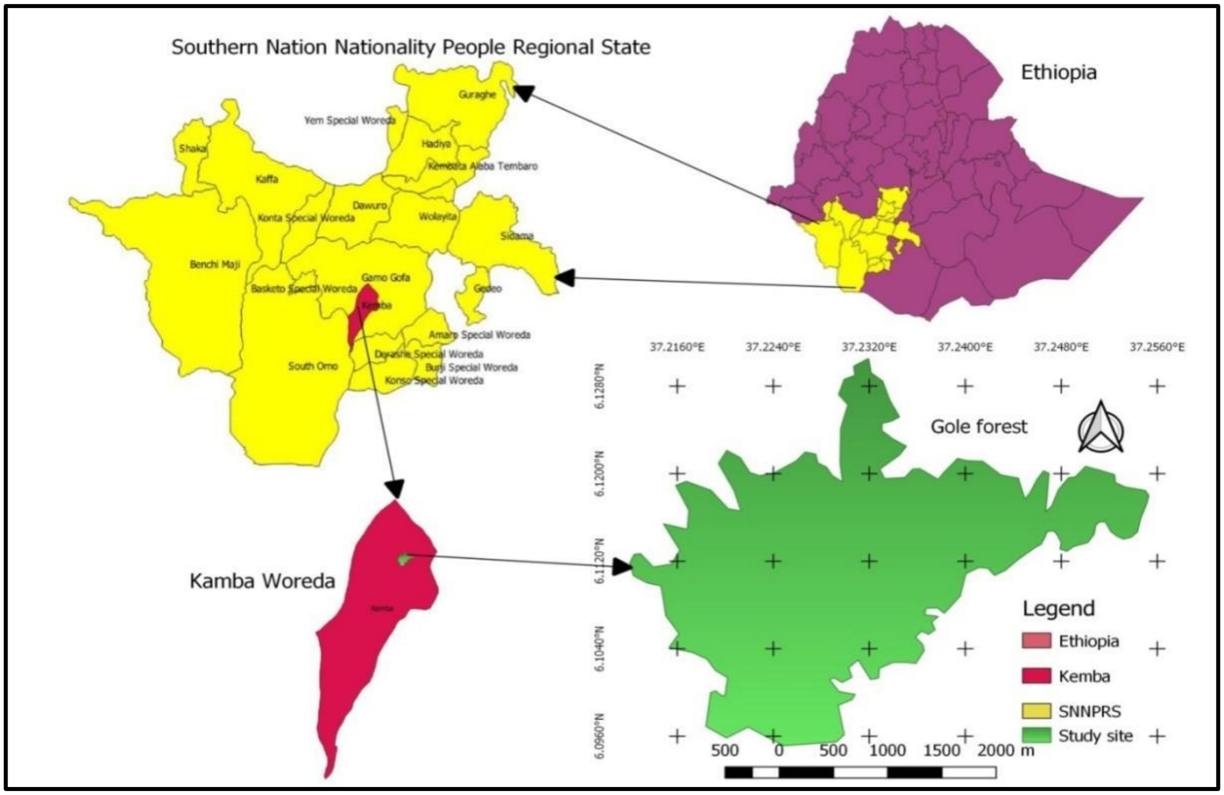

Figure 1. Map of the Gole Community Managed Forest

Plot locations that were inaccessible due to barriers such as rivers, roads, or boundaries were either excluded or shifted to nearby accessible locations. To reduce the influence of edge effects, all plots were positioned at least 50 meters away from the nearest roads or borders. Ultimately, 47 plots were established for floristic data collection across the study area.

2.2.2 Sampling design

The research was employed a combination of quantitative and qualitative methods to provide a comprehensive analysis of the forest's woody species, structural characteristics, and regeneration status.

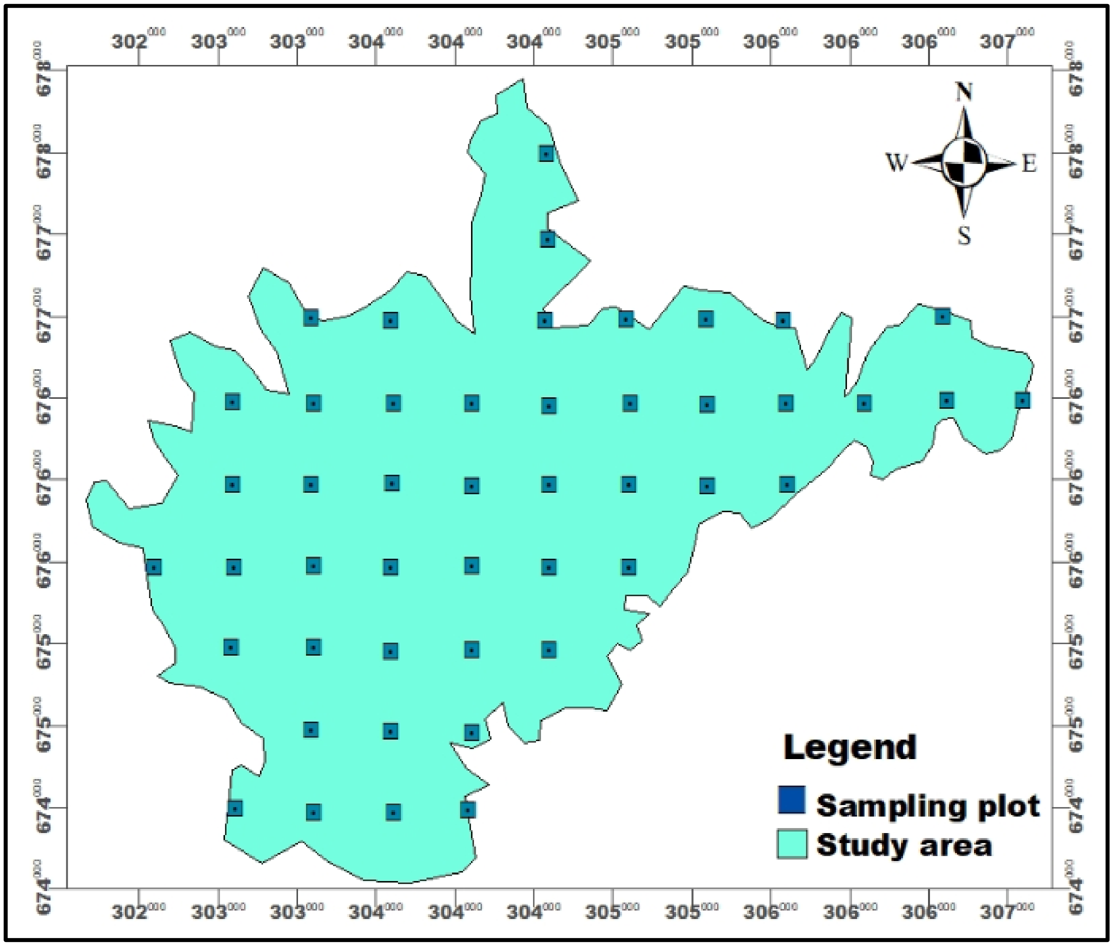

Figure 2. Systematic grid sampling using QGIS software using version 3

A nested plot design was implemented, featuring a main plot measuring 20 m x 20 m (400 m²), along with subplots of 5 m x 5 m (25 m²) and 1 m x 1 m (1 m²). This design was utilized for the assessment of trees with a DBH of 5 cm or greater, as well as for the sampling of shrubs, saplings, and seedlings (Figure 3).

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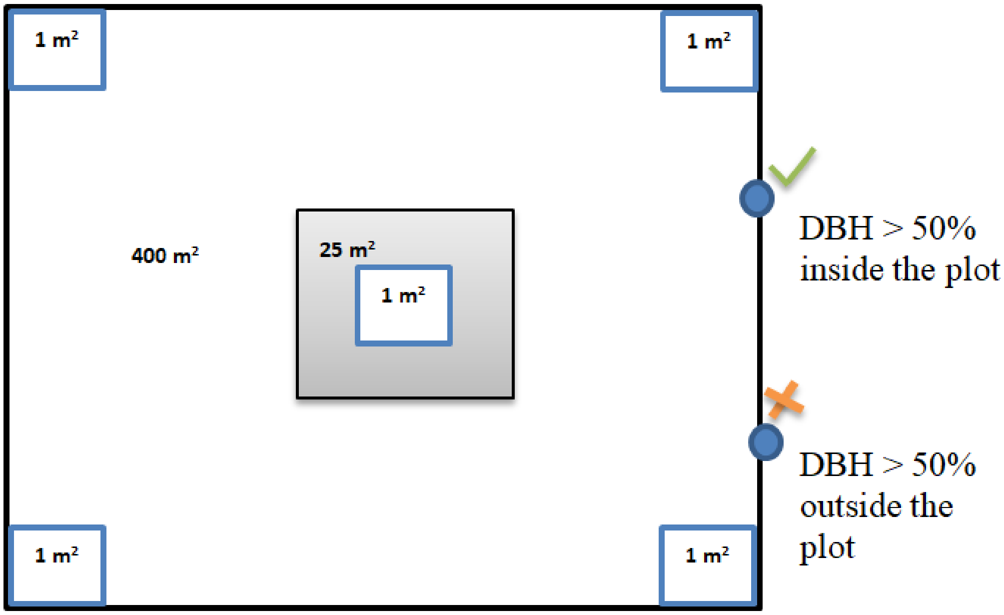

Figure 3. Design of plots for vegetation sampling

2.2.3 Data collection methods

All woody plant species encountered within each quadrat were documented and assigned codes, including their vernacular and local names. For this study, all live trees and shrubs with a diameter of ≥1 cm were recorded in each quadrat using calipers and measuring tape. The total tree height (to the top of the crown) and the DBH of all live trees with a height of ≥5 m were measured on-site using a Suunto Hypsometer for height and measuring tape for DBH. For trees or shrubs with multiple stems at a height of 1.3 m, they were considered as a single individual; the diameter for each branch was measured separately, and the measurements were averaged to establish one DBH value. For boles of trees or shrubs, the DBH measurement was taken from the point just above 1.3 m. Similarly, trees with multiple stems or forks below 1.3 m were also treated as a single individual (Kent & Coker, 1992).

In each quadrat, the species present, along with the number of seedlings and saplings, were recorded to evaluate regeneration status. For this study, seedlings were defined as woody individuals with a DBH of <1 cm and a height of <1 m, saplings as individuals with a DBH and height between 1–5 cm, and mature trees as those with a DBH ≥5 cm and a height ≥5 m, following standard definitions in tropical forest regeneration studies (Zobel et al., 2021).

The frequency distribution of diameter classes for selected tree species in the area was divided into nine categories: (1) 1≤ 5 cm, (2) ≥ 5–20 cm, (3) > 20–40 cm, (4) > 40–60 cm, (5) > 60–80 cm, (6) >80–100 cm, (7) >100–120 cm, (8) >120–140 cm, and (9) >140 cm. Additionally, tree heights were categorized into six classes based on their respective heights: (1) 1≤5 m, (2) ≥5–15 m, (3) >15–25 m, (4) >25–35 m, (5) >35–45 m, and (6) >45 m.

2.2.4 Vegetation identification

Plant identification was conducted in the field using resources such as "Useful Trees and Shrubs for Ethiopia" (Azene, 1993), the published volumes of the "Flora of Ethiopia and Eritrea" (Edwards & Hedberg, 1995), and the Natural Database for Africa (NDA) developed by Ermias Dagne (Version 2.0) (Ermias, 2011). For species that proved difficult to identify on-site, fresh voucher specimens were collected, properly pressed, and dried before being transported to the National Herbarium of Ethiopia (ETH) at Addis Ababa University for further identification.

2.3 Data analysis

A recent Ethiopia-focused study that used the Shannon–Wiener diversity index (H′) to quantify woody species diversity provides a suitable citation for your methods description: Shannon–Wiener diversity values were calculated to assess species richness and evenness in a forest in southwest Ethiopia (Modi-Geyi Forest, Andracha District) (H′ ≈ 2.92–3.73) (Awoke et al., 2025). The formula used for calculation is as follows (Eq. 1):

$$H' - \sum_{i=1}^{k} pilnpi \quad (1)$$

Where, H'= Shannon diversity index, Pi= the proportion of individuals or the abundance of the i^{th} species expressed as a proportion of a total cover K= the number of species, ln= log base n

Species evenness was calculated using widely accepted and commonly applied methods that quantify the uniformity of individual distribution among species, following standard ecological approaches (Eq. 2) such as Pielou's evenness index (Pielou, 1966) and its application in recent Ethiopian forest studies (Birhanu et al., 2025).

$$J = H'/H'\,max \quad (2)$$

Where, J= Evenness, H'= Shannon-Wiener diversity index and H 'max= lns where s is the number of species

Relative density (Eq. 3) referred to as the relative abundance**,** is calculated by dividing the number of individuals of a given species (with a DBH ≥2.5 cm) by the total number of individuals of all species in the study area, then multiplying by 100 to express it as a percentage. Relative dominance (Eq. 4), expressed in terms of basal area, is computed by dividing the basal area of a particular species by the total basal area of all species (considering only individuals with DBH ≥2.5 cm), and multiplying by 100. Relative frequency (Eq. 5) reflects the distribution of a species across the forest and is determined by dividing the frequency of occurrence of a species across all sampled plots by the sum of frequencies of all species, then multiplying by 100 (e.g., used in woody species assessments in Ethiopian Afromontane forests) (Birhanu et al., 2025; Sherafu et al., 2024).

The Important Value Index (IVI) was calculated to evaluate and compare the ecological significance of woody species by summing (Eq. 6) relative density, relative frequency, and relative dominance, with species exhibiting higher IVI values. Structural parameters were computed for selected species using the guidelines of Mueller-Dombois and Ellenberg (1974). Diameter was determined from the circumference of each tree, while basal area was defined as the cross-sectional area of all stems within a stand measured at breast height (1.3 meters above ground level).

$$\text{Relative density} = \frac{\text{Number of individuals of species}}{\text{Total number of individuals of all species}} \times 100 \quad (3)$$

$$\text{Relative dominance or basal area} = \frac{\text{basal area of each species}}{\text{Total basal area}} \times 100 \quad (4)$$

$$\text{Relative frequency} = \frac{\text{Frequency of each species}}{\text{Total frequency of species}} \times 100 \quad (5)$$

$$\text{IVI} = \text{Relative density} + \text{Relative frequency} + \text{Relative dominance} \quad (6)$$

The regeneration status of the Gole Community Forest was assessed by analyzing the ratio of saplings and seedlings to mature trees, in accordance with the established methodologies (Dhaulkhandi et al., 2008; Tiwari et al., 2010).

In this study, quantitative data were also analyzed using SPSS version 25.0**.** Descriptive statistics, including means, standard deviations, and frequency distributions, were used to summarize the data. Inferential statistical analyses were employed to explore relationships and patterns among vegetation variables. The software was also used to analyze the diameter height relationships**,** construct histograms of diameter and height class distributions**,** and characterize the overall structural attributes of the woody species stand**.**

2.4 Ethical Considerations

All research activities will adhere to ethical guidelines regarding environmental stewardship and respect for local communities. Engagement with local stakeholders will be prioritized to ensure alignment with community values and consent for research activities.

3. Results and Discussions

3.1 Floristic composition

In the GCMF, a total of 52 woody species with a DBH ≥ 1 cm were recorded. Of these, 42 species (80.7%) were trees and 10 species (19.3%) were shrubs. The identified species were distributed among 46 genera and 39 families (Table 1). The families *Euphorbiaceae and Celasteraceae* were the most species-rich, each represented by three species. The families *Anacardiaceae, Asteraceae, Fabaceae, Loganiaceae, Meliaceae, Moraceae, Myrsinaceae, Rubiaceae*, and *Rosaceae* were each represented by two species, while the remaining 28 families were represented by a single species each. Overall, the results indicate moderate taxonomic diversity, with a relatively high proportion of families represented by only one species, suggesting a heterogeneous floristic composition within the study area.

The woody species richness recorded in the GCMF (52 species) is relatively high compared to several other dry Afromontane forests in Ethiopia. For instance, lower values have been reported for Doshke Forest 15 species (Tegene et al., 2018) and other dry Afromontane sites documented by Abiyu et al. (2011) 33 species, as well as for Gera (40 species) and Menagesha (41 species) Forests (Girma and Mosandl, 2012). Such differences in species richness among Afromontane forests may be attributed to variations in altitude, rainfall patterns, soil characteristics, disturbance regimes, and management history. In particular, differences in anthropogenic pressure such as selective logging, fuelwood collection, grazing intensity, and agricultural encroachment can substantially influence floristic composition and diversity patterns.

Compared with other Afromontane forests of similar ecological settings, the species richness of Gole Forest falls within the upper range of values reported for dry Afromontane ecosystems. For example, Wof Washa Natural Forest, which represents a relatively less disturbed and ecologically stable Afromontane forest system, supports 62 woody species (Fisaha et al., 2013). The higher diversity observed in Wof Washa may be related to its broader altitudinal gradient, higher moisture availability, and relatively better conservation status. Similarly, degraded dryland Afromontane hillsides supporting 58 woody species may exhibit elevated richness due to the coexistence of pioneer, secondary, and remnant climax species, which can temporarily inflate species counts under intermediate disturbance conditions (Mengistu et al., 2004). Overall, the observed species richness in the GCMF suggests that it maintains a comparatively well-conserved dry Afromontane vegetation structure. Its diversity level indicates ecological resilience and highlights the positive role of community-based forest management in sustaining floristic diversity within Afromontane forest ecosystems.

The Shannon–Wiener diversity index (H′) for the GCMF was calculated to be 3.95, with a corresponding Pielou's evenness value (J) of 0.901. The Shannon index was computed following the approach described by Peet (1974), evenness was determined using the method of Pielou (1966), and Simpson's Index was calculated according to Gering et al. (2003). These values indicate a very high level of species diversity and a near-uniform distribution of individuals among species within the forest. The high Shannon index suggests both substantial species richness and a relatively balanced abundance distribution. An evenness value close to 1 (J = 0.901) indicates that most species contribute proportionally to the total stand structure, with limited dominance by a few taxa. Such a pattern is typically characteristic of structurally complex and relatively stable Afromontane forest ecosystems.

In comparison, lower diversity values have been reported from other Afromontane forests. For example, Wanzaye Natural Forest exhibited a Shannon index of 3.15 and an evenness of 0.81 (Asfaw, 2018), while the islands of Lake Ziway recorded even lower values (H′ = 2.60; J = 0.62) (Zegeye et al., 2011). The comparatively lower indices in these forests may reflect stronger dominance by a limited number of species, higher disturbance intensity, narrower environmental gradients, or reduced habitat heterogeneity. The markedly higher Shannon diversity and evenness observed in the GCMF may be attributed to several ecological and management-related factors. First, the presence of numerous rare or less abundant species increases the richness component of the Shannon index, thereby elevating overall diversity values. Second, effective community-based forest management may have minimized selective harvesting and overexploitation, allowing a more equitable distribution of individuals across species. Third, microhabitat heterogeneity arising from variations in topography, soil properties, and moisture availability may facilitate the coexistence of species with different ecological requirements.

3.2 Floristic structure

3.2.1 Density of woody species

A total of 1,257 woody individuals with a DBH $\geq$ 1 cm were recorded from 47 systematically established quadrats in the Gole Forest. The study area spans an altitudinal range of

1,837 to 2,723 m a.s.l. and covers approximately 765 ha. Of the total individuals recorded, 1,187 (94.4%) were trees, while 70 (5.6%) were shrubs. In terms of species abundance, the most dominant tree species were *Syzygium guineense* (272 individuals), *Schefflera abyssinica* (162 individuals), *Ocotea kenyensis* (137 individuals), and *Ilex mitis* (95 individuals). In contrast, *Euphorbia abyssinica* was the least represented tree species, with only a single individual recorded (Table 1).

Among the ten shrub species documented, *Geniosporum rotundifolium* had the highest abundance (15 individuals), whereas *Phytolacca dodecandra* was the least abundant, represented by only two individuals. The overall stand density for woody individuals with DBH > 5 cm was estimated at 385 stems per hectare (Table 1), indicating a relatively well-stocked forest stand within the Afromontane vegetation type.

3.2.2 Frequency

Regarding frequency, the most prevalent tree species included *Syzygium guineense***,** *Schefflera abyssinica***,** *Ocotea kenyensis***,** and *Ilex mitis***,** with occurrence values of 272, 162, 137, and 95 individuals, respectively. *Euphorbia abyssinica* emerged as the least frequent tree species, represented by a single individual. Among the 70 individuals representing the shrub species in the study area, *Geniesporum rotundifolium* had the highest count (15), while *Phytolacca dodecandra* registered the lowest (2) (Figure 4).

From the occurrence data, *Syzygium guineense* accounted for 76.5% of the tree frequency, followed by *Ilex mitis* at 61.7% and *Schefflera abyssinica* at 57.4%. In contrast, *Euphorbia abyssinica* had the lowest frequency of occurrence at 2.12%, appearing in only one out of the 47 plots. The frequency of occurrence for both tree and shrub species within the Gole Community Forest is visualized in Figure 4, where the three most frequently occurring tree species were *Syzygium guineense* (76.5%), *Ilex mitis* (61.7%), and *Olea capensis* (57.4%). Conversely, *Euphorbia abyssinica* had the lowest occurrence at 2.12% (Figure 4).

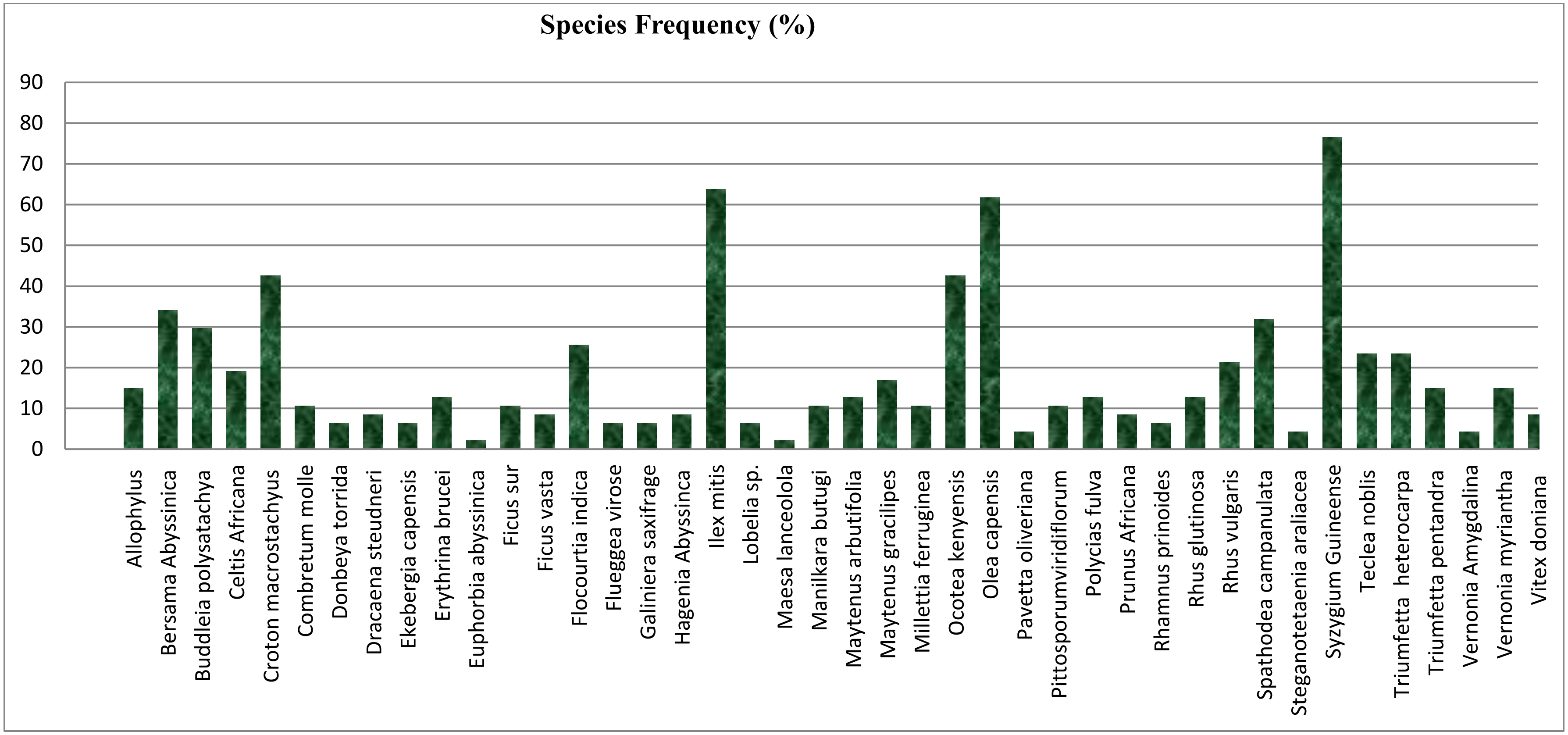

Figure 4. Frequency of occurrence of tree species in the forest

Regarding, shrub species, *Embelia schimper* (14.89%) (Appeared in 7 plots) and *Geniesporum rotundifoli* 10.6% (appeared in 5 plots) were the top two frequently appeared shrub species whereas the three most abundant woody plant species in the forest were *Syzigium guineese Ocotea kenyensis* and *Schefflera abyssinica*. *Schefflera volkensii, Schefflera abyssinica, Ocotea kenyensis* and *Ilex mitis were* four most dominant woody plant species in the forest. *Acanthus sennii, Ricinus communis* and *Phytolacca dodecandra* (4.25%) were the least appeared in 2 plots (Figure 5).

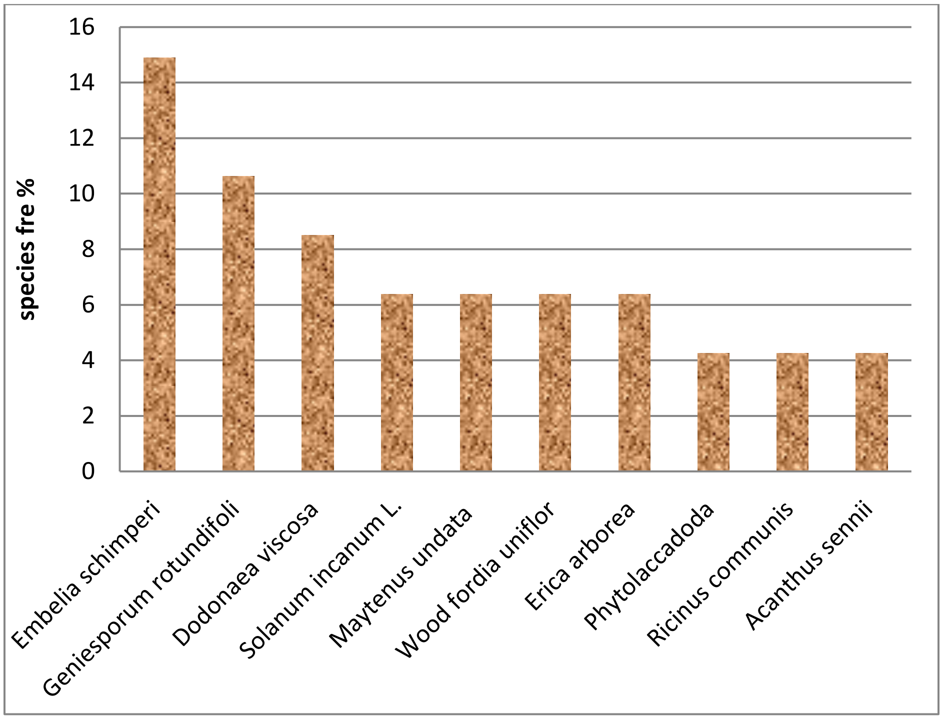

Figure 5. Frequency of occurrence of shrub species in the Gole Community Managed Forest

3.2.3 DBH and height class distribution

In this study, the DBH of trees was categorized into nine distinct classes: ≤ 1cm, ≥5-20 cm, >20-40 cm, >40–60 cm, >60–80 cm, >80–100 cm, >100–120 cm, >120-140 cm, and >140 cm (Figure 6).

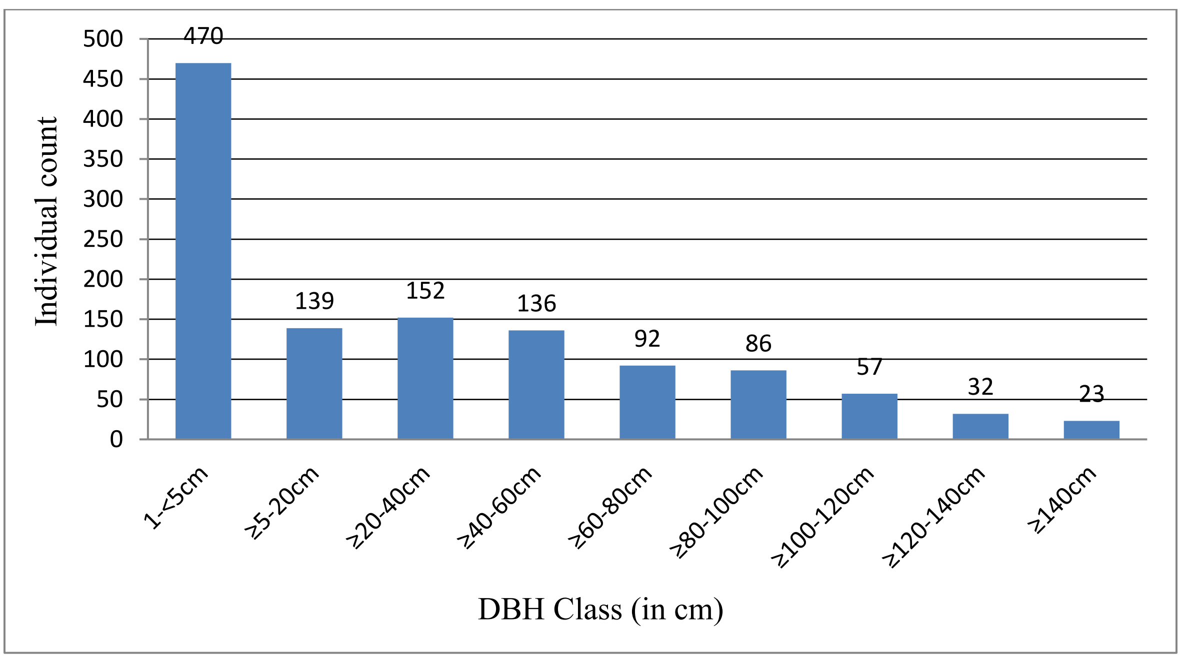

Figure 6. Diameter distribution of tree species in the forest

As illustrated in Figure 6, approximately 51.3% (609 stems per hectare) of the individuals fall within the first two DBH classes. The remaining seven classes collectively account for 48.7% of the total individuals observed. The species with the highest mean DBH in the study area was *Euphorbia abyssinica*, which recorded an average DBH of 78.0 cm. It was followed by *Flacourtia indica,Merr and Ilex mitis*, which had average DBH values of 70.57 cm and 69.58 cm, respectively. On the other end of the spectrum, the species with the lowest mean DBH was *Pittosporum viridiflorum* Sims, with a mean value of 22.20 cm, and *Triumfetta heterocarpa* Sprague & Hutch, which had a mean DBH of 24.72 cm.

The height measurements were categorized into six classes: <1-5m, ≥5–15m, >15–25m, >25–35m, >35–45m, and >45m. Among these, the height class <1-5m exhibited the highest density of trees, comprising 40.8% (485 stems per hectare), closely followed by the ≥5–15m class at 39.2% (465 stems per hectare), as illustrated in Figure 7.

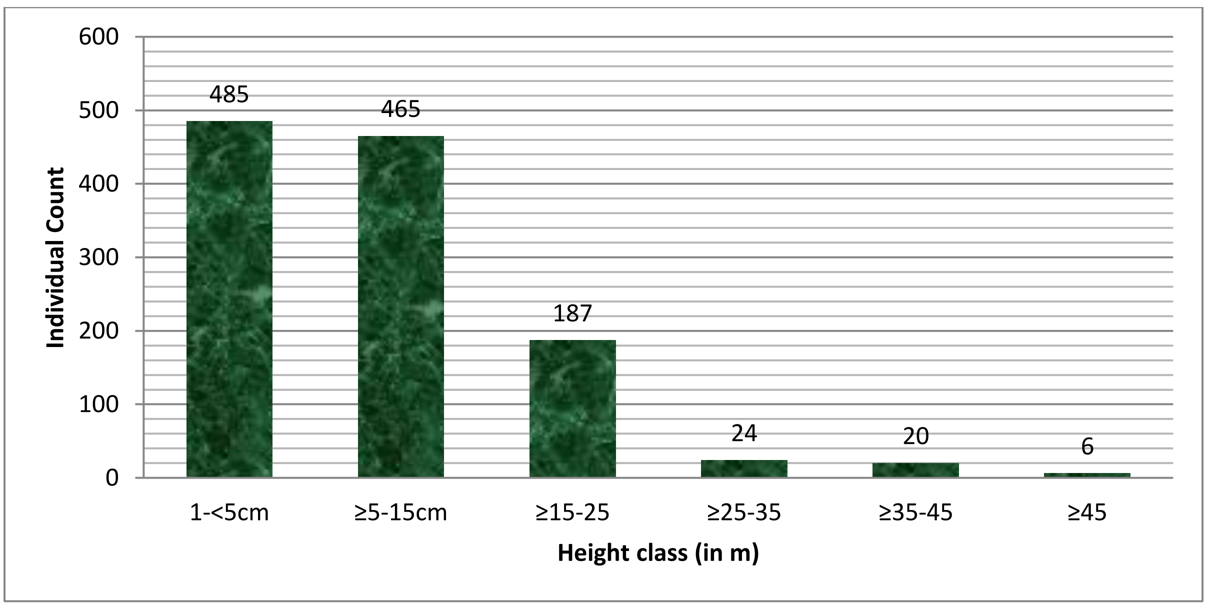

Figure 7. Height distribution of tree species the forest

3.2.4 Basal area

In the GCMF, the total basal area of woody plants with a DBH ≥ 5 cm was estimated at 168.153 m²/ha, representing 0.654% of the total study area. A small subset of tree species dominated the stand: *Ficus sur*, *Syzygium guineense*, *Ilex mitis*, *Celtis africana*, and *Olea capensis* collectively accounted for 58.01% of the total basal area. Conversely, species such as *Rhamnus prinoides*, *Lobelia* spp., *Donbeya torrida*, and *Triumfetta heterocarpa* contributed only 6.36%, reflecting their limited structural dominance. Basal area distribution is a key indicator of stand maturity and forest structural development, often used to classify forest types and assess successional status (Sokpon and Biaou, 2001). The mean basal area recorded for Gole Forest is considerably higher than values reported in other dry Afromontane forests of Ethiopia. For example, Doshke Forest recorded 103.7 m^2/ha for woody plants >2.5 cm DBH (Tegene et al., 2018), Bale Mountain National Park (Boditi Forest) had 23 m^2/ha (Yineger et al., 2008), woodland and riverine vegetation of Sire Beggo showed 19.3 m^2/ha (Dibaba et al., 2014), Zengena Forest reported 22.3 m^2/ha (Tadele et al., 2013), and Hugumburda Forest exhibited 9.23 m^2/ha (Aynekulu, 2011). The comparatively high basal area of Gole Forest indicates a structurally well-developed stand with a higher proportion of mature and canopy-dominant trees.

This pattern aligns with findings from other relatively undisturbed or well-managed Afromontane forests, where a few dominant species contribute disproportionately to the basal area, reflecting competitive exclusion and niche specialization (Yineger et al., 2008; Tadele et al., 2013). The substantial basal area in Gole Forest may also result from effective community-based management practices that reduce selective logging, allow canopy closure, and facilitate the persistence of large-diameter trees, thereby maintaining both forest structure and ecological function. Compared to more degraded or heavily exploited forests, the Gole Forest's basal area suggests a high conservation value and a relatively mature Afromontane vegetation profile.

3.2.5 Importance value index

The Importance Value Index (IVI) was calculated for 42 species within the GCMF. The five species with the highest IVI were *Syzygium guineense* (37.534), *Olea capensis* (25.511), *Ilex mitis* (21.469), *Ocotea kenyensis* (21.041), and *Crotonmacrostachyus* (12.150), collectively accounting for 117.7 of the total IVI value of 300. Conversely, the species with the lowest IVI scores included *Pavetta oliveriana* (1.672), *Steganotetaenia araliacea* (1.912), Lobelia sp. (1.999), and *Maesa lanceolata* (2.048). In this forest, species with a higher IVI are considered to hold greater ecological significance than those with lower IVI values (Zegeye et al., 2005).

3.4 Regeneration status of Gole Forest

The regeneration status of the Gole Forest was evaluated across 52 representative woody species, revealing a total of 17,622 seedlings per hectare, 4,127 saplings per hectare, and 385 mature individuals per hectare recorded from 47 quadrants. Based on criteria established by Dhaulkhadi et al. (2008) and Chauhan et al. (2008), the regeneration status indicates that both seedlings and sapling populations outnumber mature individuals, classifying the species as having good regeneration potential. Notable species showing robust regeneration included *Syzygium guineense, Donbeya torrida, Rhus glutinosa,* and *Schefflera abyssinica*. Overall, the distribution data demonstrate that seedlings are more than saplings, and saplings exceed mature trees. The regeneration pattern in the Gole Forest, where seedling density > sapling density **>** mature density**,** is consistent with *healthy regeneration trends reported in recent Ethiopian forest studies*. It aligns with the ecological expectation that elevated densities of younger life stages indicate ongoing recruitment and a dynamic population structure capable of sustaining forest continuity (Awoke et al., 2025).

The GCMF is characterized by a diverse array of woody species, including *Syzygium guineense***,** *Schefflera abyssinica***,** *Ocotea kenyensis***,** and *Ilex mitis.* These species exhibit varying levels of composition, DBH, height, density, and frequency across the altitudinal gradient from 1837 to 2723 meter above sea level and an annual average rainfall ranging from 700 to 1712 mm yr^{-1}. Based on these parameters, the forest can be classified as a moist evergreen afromontane forest (1500-3400 m) (Friis *et al*., 2010). In the present study, a total of 42 different woody species belonging to 46 genera and 39 families were identified within 47 quadrats, resulting in a density of 385 trees/ha. Measurements of DBH and height ranged from 5 to 410 cm and 5 to 46 m, respectively. These findings align closely with findings from similar studies conducted in Achera Natural Forest, where a density of approximately 392.5 trees/ha was recorded (Habtam and Ali, 2018), and in Gezha Forest, which reported a density of 340 trees/ha (Biruk, 2019). However, the density observed in this study is lower than that reported in the Lake Hawassa Watershed (482 trees/ha) (Wondrade et al., 2019) and Belete Moist Evergreen Montane Forest (760 trees/ha) (Abebe *et al*., 2021).

The total woody plant species reported in this study (42 species) is lower than figures from other afromontane forests in Ethiopia, which have been reported as high as 87 species (Haile, 2020), 70 species (Semere, 2019), and 44 species (Kidanemariam et al., 2019). Nonetheless, the species richness observed in this study (42 species) is comparable to the 34 species reported by Adugna et al. (2021) and exceeds the 24 species recorded by Biniam (2020).

The observed low species richness in the Gole forest may be attributed to the dominance of a few key species, such as Olea europaea subsp. Cuspidate and Acacia albida, which could inhibit the competitive abilities of less dominant species (Chao et al., 2023). Additionally, external factors such as human activities and animal disturbances may further exacerbate this issue. Understanding the species structure and composition of forests is critical for effective management strategies, as it informs economic valuations, regeneration potential, and ultimately aids in the conservation of biological diversity (Verma et al., 1999).

Among woody species**,** Syzygium guineense was recorded at the highest frequency, appearing in 36 plots (n=272) (Table 1). A study conducted in the Humbo forest also reported the highest dominance of *Syzygium guineense* with n=1,807 individuals (Abebe *et al.,* 2021). In comparison to mature tree species (n=385), the present study found a significantly higher density of saplings (n=4,127) and seedlings (n=17,622), indicating that the forest possesses a robust regeneration capacity (i.e., good regeneration with seedlings > saplings > adults). Moreover, studies from various regions have reported similarly high densities of seedlings and saplings. For instance, the Afromontane Forest of Gara Ades recorded seedlings at 16,290 ha^{-1} (Dereje et al., 2022), while the Munessa-Shashemene Forest had saplings at 1,000 ha^{-1} and seedlings at 31,600 ha^{-1} (Hailu et al., 2023). In the Menagesha Suba Forest, seedlings were noted at a staggering density of 32,650 ha^{-1} (Tadesse et al., 2024).

Analysis based on DBH and height classes carried out for tree species of the forest site exhibited distinct patterns. Variations in species population structure can indicate underlying differences in population dynamics (Adugna et al., 2013; Asare et al., 2021). In the Gole community-managed forest, woody species were classified into nine DBH and six height classes to illustrate the size and age distribution of tree species in the area. Of the total 1,257 trees measured, over 50% were located in the first two DBH classes (DBH 1-<5 cm and ≥5–20 cm). Generally, the distribution of DBH classes in the study area indicated that tree density decreased as DBH class size increased, with the exception of the DBH class >20-40 cm. Correspondingly, over 80% of woody species were found in the lower height class (<15 cm), and only a small fraction, around 0.5%, attained a height of 45 m or above. Thus, tree density demonstrated a decreasing trend as height increased. The distribution patterns of DBH and height classes reflected an inverted J-shaped curve, denoting a predominance of individuals in lower size classes.

Similar patterns have been reported in various studies across different forest types, including community forests in the Mid Hill Region (Anup et al., 2013; Kumar et al., 2020), Gera Moist Montane Forest (Yohannes et al., 2015; Tura et al., 2022), and Gesh Moist Afromontane Forest (Admassu et al., 2019; Menale et al., 2023). Furthermore, the DBH and height class distribution suggested a high rate of regeneration; however, the minimal density of trees in higher DBH and height classes may be attributed to selective thinning practices prevalent in the area.

4. Conclusions

The GCMF has revealed a diverse array of plant species, comprising a total of 52 different species across 46 genera and 39 families, with *Euphorbiaceae* and *Celasteraceae* identified as the predominant families. The presence of 52 woody species indicates a relatively rich floral composition. The structural analysis of the GCMF reveals that both DBH and height class distributions exhibit a predominantly inverted J-shaped pattern, characterized by a high abundance of small and short individuals and progressively fewer medium and large trees. This pattern is a strong indicator of active regeneration, a stable age/size structure, and a dynamic forest with continuous recruitment. Similarly, the regeneration status, with seedling density exceeding that of saplings and saplings outnumbering mature trees, reinforces the evidence of healthy population dynamics and long-term sustainability. The total basal area for the GCMF was measured at 168.1532 m^2/ha, but only a few species showed significant basal area and density. Notably, *Olea europaea* subsp. *cuspidata, Acacia albida, Pittosporum viridiflorum*, and *Allophylus abyssinicus* accounted for approximately 62.45% of the IVI. In contrast, many woody species exhibited low IVI, such as *Grewia bicolor* and *Leucaena leucocephala*, indicating a need for focused conservation and management efforts. Despite this, anthropogenic pressures pose threats to forest integrity. Conservation strategies should focus on sustainable resource use, community participation, and protection of rare and ecologically important species to maintain biodiversity and forest resilience.

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Competing Interests

There is no conflict of interest regarding this research.

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