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Research Article

Floristic Composition and Structural Analysis of Woody Plant Species in Jib Godo Natural Forest, Farta District, South Gonder Zone, Amhara Region, Ethiopia

Kassaw Awoke Wubu,[1] **Elango Matavan Ramaraj**,[2] **and Endale Adamu Anteneh**[2]

[1]*Department of Biology, Kabridahar University, Kabridahar, P.O. Box 250, Ethiopia*
[2]*Department of Biology, Debre Tabor University, Debre Tabor, P.O. Box 272, Ethiopia*

Correspondence should be addressed to Kassaw Awoke Wubu; awokek76@gmail.com

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Afromontane forests are crucial for maintaining plant diversity and reducing climate change. Even though the Jib Godo Natural Forest is subject to anthropogenic impacts such as cutting and farming, it lacks long-term conservation practices. The researchers conducted fieldwork in Jib Godo Natural Forest to investigate the floristic composition and structural analyses of woody plant species in Ethiopia. The vegetation and environmental data were collected from 50 ($20\,m \times 20\,m$) sample plots established for woody species at every 100 m along seven transect lines and $5\,m \times 5\,m$ in five subplots for saplings and seedlings using a systematic sampling procedure. In each sample plot, soil samples were obtained from 0–20 cm and mixed to generate a composite sample. A vegetative structural analysis of DBH, height, and stem IVI was computed. There were 65 species of woody plant identified, belonging to 58 genera and 41 families, with 34 species (52.30 percent) being trees, 23 species (35.38 percent) being shrubs, and 8 species (12.30 percent) being lianas. Outside of the sample plot, four other species were identified. Only eleven environmental characteristics were significant at $p < 0.05$, according to the results of canonical correspondence analysis (CCA). In conclusion, the distribution of plant communities and the composition of the species depend on altitude and topographic aspects. The forest's population structure and regeneration condition suggested that the area had experienced forest degradation and severe anthropogenic disturbances; therefore, the conservation of species and sustainable use of forest genetic resources are advocated as a result of this study's findings.

1. Introduction

1.1. Background of the Study. Forests and woods are projected to encompass 650 million hectares, or 22% of Africa's total land area, and account for around 17% of the world's forest cover. The forest in the East African region accounts for 21% of Africa's total forest area [1]. However, Ethiopia is regarded as one of the tropical African countries with the highest richness of indigenous plants and animals. Ethiopia is a mountainous nation with contrasting landscapes including rough mountains, plateaus, deep gorges and river valleys, and undulating plains. Its elevation ranges from 4,620 meters at the highest peak of the Ras Dejen to 110 meters below sea level in the Dallol valley [2]. Ethiopia is endowed with a highly diversified climatic conditions and topography with a wide range of habitats and vegetation types. Therefore, biodiversity encompasses all genes, species, and ecosystems, as well as the ecological processes that they contribute to reference [3]. The flora of Ethiopia and Eritrea is quite diverse and contains a significant amount of endemic species [4]. It is estimated to contain around 6,000 species of higher plants, of which about 10% are endemic [5]. This large number of plant species is due to a wide range of climate, geology, and terrain functioning on different time scales [6, 7].

However, the forest resource of the country is under serious threat from deforestation, forest fire, land

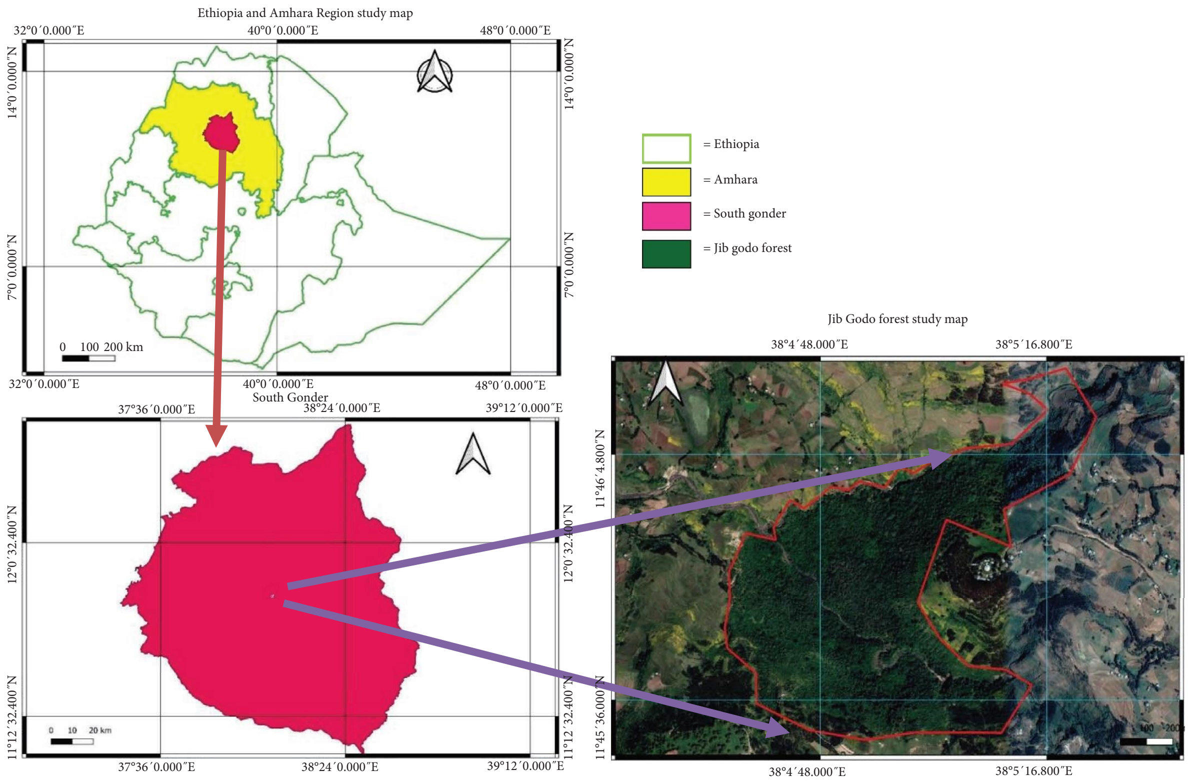

Figure 1: Location map of Jib Godo Natural Forest.

degradation, overexploitation, overgrazing, shifting cultivation, habitat loss, and invasive species. A recent analysis of the rate of deforestation shows that the country's forest resource is rapidly declining at the rate of 141,000 ha per year [8]. This extensive amount of habitat loss or destruction may have resulted in a rapid declining of the genetic resources of the country [9]. However, the country's extensive forests and woodlands are shrinking in both area and quality [10]. The variety and abundance of woody species are significantly impacted by environmental factors such as height, slope, and aspect [11]. The patterns of population structures may reveal important information regarding their regeneration and recruitment status, which can be used to develop conservation strategies [12]. Therefore, vegetation studies are essential to address ecological issues for biological conservation and management purposes, as an input to environmental impact assessments, or to provide the basis for prediction of potential future changes in plant species distributions that could be linked to human impacts on habitats directly and through land-use practices involving land-use changes [13]. Jib Godo Natural Forest is located in the highlands of northern Ethiopia, where the floristic composition and ecology were previously untouched. As a result, the study's objectives were to (a) assess the floristic composition of the forest; (b) identify plant community types in the study area; (c) analyze the structural pattern of woody plant species in the forest; (d) assess the regeneration status of woody plant species in the forest; and (e) assess the impact of soil nutrients on species distribution in the study area.

2. Materials and Methods

2.1. Description of the Study Area. The research was carried out in the Jib Godo Natural Forest in Ethiopia's Farta District, South Gondar Zone, and Amhara Region. It is roughly 690 kilometers from Ethiopia's capital, Addis Ababa (Figure 1). The forest is located between latitudes 11°45′38.1″ and 11°45′59.0″ N and longitudes 037°04′59.9″ and 038°05′09.7″ E. This forest is found between the elevations of 2,485 and 2,747 meters above sea level. The study area was 86 hectares in size. The major current land cover and land use types in the study area are crop land, sparse forest, open grassland, open shrub land, bare soil, wetland, water bodies, and settlements. *Apodytes dimidiata, Ekebergia capensis, Nuxia congesta, Juniperus procera, Olinia rochetiana, and Nuxia congesta* were more common in the area. Deforestation, grazing, and forest degradation have all contributed to the loss of forest biodiversity in this area. Furthermore, significant population densities occur, with many people relying on subsistence agriculture for a living [14]. The agricultural households are engaged primarily in crop-livestock mixed farming systems.

2.2. Climate and Soil. The average annual minimum, maximum, and mean temperatures were 6.80°C, 25.50°C, and 15.90°C, respectively, in January, April, and May. The

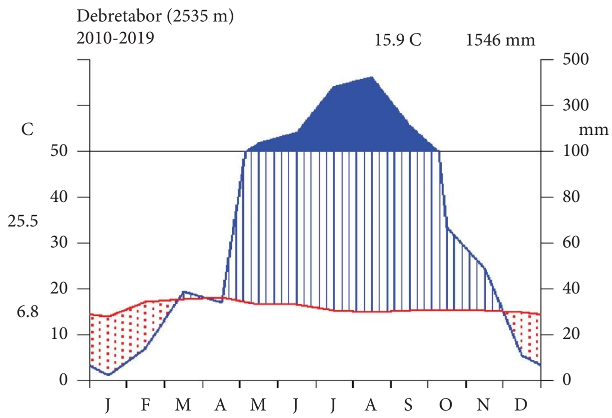

Figure 2: Climate diagram of the study area from 2010–2019 at Debre Tabor station source: National Meteorological Agency.

rainy season runs from May to October, and the pattern is unimodal. The annual rainfall ranges from 1,202 to 1,926 millimeters, with a long-term average of 1,546 millimeters (Figure 2). Cambisols, Regosols, Lithosols, and Andosols are the most common soil types, according to J. Tiruneh et al. [15], with the others spread across the district.

3. Methods

3.1. Sampling Design. To obtain vegetation data for this investigation, a systematic sampling design was used. Along the altitude gradient, seven transect lines were created, each oriented east-west. Following the systematic establishment of the initial sampling plot, subsequent independent sampling plots were spread out along line transects at 100 m intervals between sampling plots and 100 m between each line transect [16]. To gather the woody species, 20 m × 20 m (400 m^2) plots were laid out. The regeneration status of woody species was determined by counting all seedlings and saplings inside 5 m × 5 m subsample plots, one in the center and four in the corners. The latitude, longitude, and altitude were measured using GPS from the center of each main plot.

3.2. Vegetation Data Collection. The data were collected during November and December, 2020. The species composition and cover value of each species were reported by Kent, M. [16].

To collect woody plant species, 50 major plots were laid out. Seedlings were defined as undergrowth of woody species with a height less than 1 m; trees were defined as single-stem individuals with a height greater than 2 m and a DBH of 2.5 cm; and saplings were defined as those in between seedlings and trees or shrubs (with a height of 1-2 m) [13].

The specimens were identified using the flora of Ethiopia and Eritrea as well as the expertise of a botanical expert. DBH (Diameter at Breast Height) was measured by a caliper at a height of roughly 1.30 m above the ground and recorded for all woody species with DBH of 2.5 cm and height of 2 m to assess biomass and the size-class distribution of trees in a sampling plot.

3.3. Environmental Data Collection. Following reference [2], environmental parameters (altitude, slope, and aspect) of the Jib Godo Natural Forest were measured. The global positioning system was used to determine altitude. The clinometer and compass were used to determine the slope and aspect, respectively. In the sampled plots, ecological disturbances such as grazing and human influences were noted and reported as present or missing. The authors of reference [17] calculated the intensity of grazing as follows: 0 = none; 1 = slight; 2 = moderate; and 3 = heavy. In reference [18], the degree of human interference was calculated and codified using a 0–3 subjective scale to record the impacts (from fuel wood collecting, chopping, and signs of trampling) as follows: 0 = nil; 1 = low; 2 = moderate; and 3 = heavy.

3.4. Soil Sampling. Composite soil samples were collected at a depth of 0–20 cm from four deliberately designated places at the corner and one in the center of each of the 50 plots. Prior to chemical and physical analysis, the samples were air-dried and sieved with a screen size of 2 mm to eliminate coarse gravels, roots, and debris. A 1.5 kg composite soil sample was collected and transported in plastic bags [19].

4. Data Analysis

4.1. Community Type Analysis. The authors of reference [20] employed hierarchical cluster analysis in R for Windows version 3.6.1 [21] to classify the vegetation into plant community kinds. The analysis was based on the species' abundance. The community types discovered by cluster analysis were refined further in a synoptic table, which summarized species occurrences as synoptic cover-abundance values [2]. The Jaccard similarity coefficient was used to compare the similarity between the community types. The Shannon–Wiener diversity index was calculated for the four plant community types in Jib Godo Natural Forest's woody vegetation.

4.2. Vegetation Structural Analysis. The following factors made up the structural analysis of the vegetation: stem density, DBH, height, basal area, frequency, and important value index (IVI). Microsoft Excel was used to compute and summarize the data. The possibility of discovering a species in a specific area in a specific trial sample is known as "frequency." The sum of relative dominance (RDO), relative density (RD), and relative frequency (RF) was used to compute the IVI of a species [16]. By comparing seedling to sapling and sapling to mature tree data, the regeneration status of sample species in the forest was determined [22]. Priority classes for conservation efforts were determined by comparing the numbers of mature, sapling, and seedling trees. Using R software, canonical correspondence analysis (CCA) is a crucial component for analyzing the link between environmental variables and vegetation data. Based on the methodologies provided by Estefan, G. et al. [23], soil analysis was performed in the organic matter, organic carbon, calcium, electrical conductivity, available phosphorus laboratories, and pH of the Amhara Design and Supervision Works Enterprise Soil Chemistry and Water Quality section.

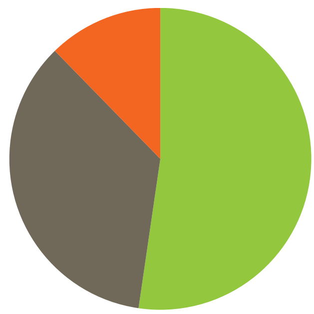

Figure 3: Growth forms of species.

5. Results

5.1. Floristic Composition. A total of 65 woody plant species belonging to 58 genera and 41 families were identified. Of these, 34 tree species (52.31) were followed by 23 shrub species (35.38%) and 8 liana species (12.3%) (Figure 3).

Appendix 1 has a detailed list of the species' scientific name, family, habit, and vernacular name. In Figure 4, the most dominant family in terms of species number was Fabaceae, with 5 species (7.7%), followed by *Celastraceae*, *Euphorbiaceae*, and *Oleaceae*, each with 4 species (6.2%), and *Asteraceae*, *Myrsinaceae*, and *Rubiaceae*, each with 3 species (4.6%); the remaining 39 species accounted for 60%.

In this study, six (9.23%) different plant species were identified that were not registered in the Gonder floristic zone. There are five families and six genera represented by species. Three trees, two bushes, and one liana are also included (Table 1).

5.2. Endemic Plant Species. The Jib Godo Natural Forest is home to six Ethiopian endemic species (Table 2). Three of these are trees, while the other three are shrubs. Two species were classified as "least concern" (LC), three species as "near threatened" (NT), and one species as "vulnerable" (VU), according to the [24] standard.

5.3. Plant Community Classification. Four plant community types were discovered using hierarchical cluster analysis (Figure 5). Two distinctive species with the highest mean cover abundance value in each community were used to name the plant community types. The synoptic value of cover abundance is more popular and better represents the determination of community type. The cophenetic correlation coefficient between the four community types was 0.87. This value indicates that the correlation between the four community types was good.

5.3.1. Maesa lanceolata-Pittosporum abyssinicum. This community was found between the elevations of 2,485 and 2,677 meters above sea level. It consisted of 19 plots, 60 species, 55 genera, 39 families, and 0.76 ha, with 47 species shared with communities 2 and 3 and 34 species shared with community 4. In addition to the main species utilized in the community's name, the tree layer of the community was dominated by *Maesa lanceolata*, *Pittosporum abyssinicum*, and *Prunus africana*. The shrub layer of the community was dominated by *Carissa spinarum*, *Acanthus sennii*, and *Vernonia hymenolepis*. The dominant species in the liana layer of the community was *Clematis hirsuta*.

5.3.2. Apodytes dimidiata-Ekebergia capensis. In the vegetation, this community was found between the altitudinal ranges of 2,511 m.a.s.l. and 2,693 m.a.s.l. It had 14 plots, 49 species, 45 genera, 31 families, and 0.56 ha of land, with 44 species shared with community 3 and 32 species shared with community 4. The dominating species in the community's tree layer were *Apodytes dimidiata*, *Ekebergia capensis,* and *Nuxia congesta*. The shrub layer of the community was dominated by *Vernonia hymenolepis*, *Carissa spinarum*, and *Discopodium penninervium*.

5.3.3. Carissa spinarum-Olinia rochetiana. This community was found between the elevations of 2,664 and 2,747 meters above sea level. It consisted of four plots, 48 species, 43 genera, thirty families, and 0.16 ha, with 31 species in common with community four. Along with the community's major species, *Olinia rochetiana*, *Apodytes dimidiata*, and *Galiniera saxifraga*, the major species in the community's tree layer were *Prunus africana*, *Nuxia congesta*, *Pittosporum abyssinicum*, and *Rhus glutinosa*. The shrub layer of this community was dominated by *Carissa spinarum*, *Maytenus arbutifolia*, *Solanecio gigas*, and *Acanthus sennii.*

5.3.4. Juniperus procera-Vernonia hymenolepis. This community was found between the elevations of 2,490 and 2571 meters above sea level. There were 13 plots, 37 species, 36 genera, 28 families, and 0.52 ha in all. The main species in the community's tree layer were *Juniperus procera*, *Olinia rochetiana*, *Nuxia congesta*, and *Apodytes dimidiata*, in addition to the dominant species used in the community's designation. The shrub layer of the community was dominated by *Vernonia hymenolepis*, *Clutia abyssinica*, *Acanthus sennii*, *Buddleja polystachya*, and *Calpurnia aurea*.

5.4. Soil Properties of Plant Community Classification. In the study area, the physical and chemical properties of the soil were determined. Physical properties of texture include sand, silt, and clay, whereas chemical properties include pH, available phosphorus, exchange of calcium, exchange of potassium, exchange of sodium, exchange of magnesium, total nitrogen, organic matter, organic carbon, electrical conductivity of soil, and cation exchange in soil. These properties were determined in each plot of a community.

5.5. Species Richness, Evenness, and Diversity of the Four Communities. The Shannon–Wiener diversity index was

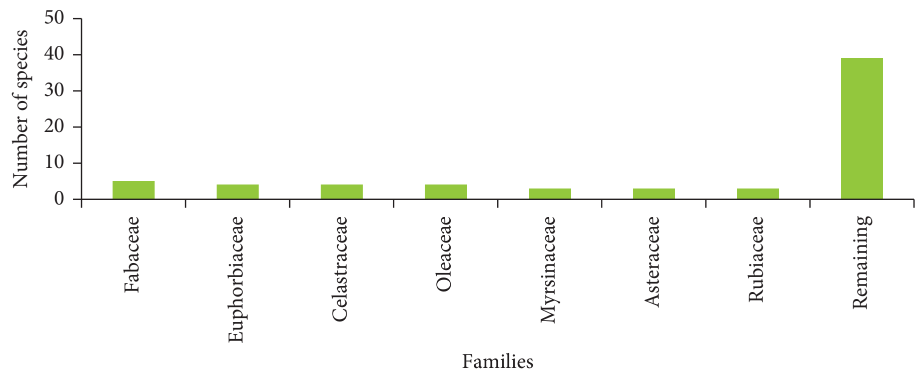

Figure 4: Number of species with the distribution of families.

Table 1: Six plant species identified were not registered in Gonder floristic region of Ethiopia.

Species name	Family	Habit	Local name
Albizia gummifera (J. F. Gmel.) C.A. Sm.	Fabaceae	T	Kachena/sessa
Discopodium penninervium Hochst.	Solanaceae	S	Almit
Jasminum fluminense Vell.	Oleaceae	L	Tbteba hareg
Maytenus addat (Loes.) Sebsebe	Celastraceae	T	Kermo aderk
Olea welwitschii (Knobl.) Gilg & Schellenb.	Oleaceae	T	Wegeda
Vernonia hymenolepis A. Rich.	Asteraceae	S	Kotkoto

Table 2: Endemic plant species in Ethiopia occurring in Jib Godo Natural Forest. Key: LC = least concern; NT = near threatened; VU = vulnerable.

Species name	Family	Habit	IUCN category
Rhus glutinosa A. Rich.	Anacardiaceae	T	VU
Maytenus addat (Loes.) Sebsebe	Celastraceae	T	NT
Erythrina brucei Schweinf.	Fabaceae	T	LC
Acanthus sennii Chiov.	Acanthaceae	S	NT
Solanecio gigas (Vatke) C. Jeffrey	Asteraceae	S	LC
Laggera tomentosa (Sch. Bip. exA. Rich.) Oliv. & Hiern,	Asteraceae	S	NT

calculated for the four plant community types in Jib Godo Natural Forest's woody vegetation. The most diverse community was community one, followed by community two, while community three had the least diverse community. Community one and two, however, had the highest equitability (evenness) rating, which assesses the relative abundance of different species present in each community (Table 3).

5.6. Woody Plant Species of Diversity and Evenness Analysis. Shannon–Weiner diversity is high when it is above 3.0, medium when it is between 2.0 and 3.0, low when it is smaller than 1.0 [16]. The study forest's overall Shannon–Weiner diversity index was 3.07. This implies that study forest has high diversity. The species evenness value ranges between 0 and 1. When it is 0, the area is dominated by single species and when it is 1, the species are evenly distributed in the area. The average evenness value of the study forest was 0.74, according to the data analysis. This indicates that the species in the study forest are more or less evenly distributed.

5.7. Similarity between the Four Community Types. To find commonalities between plant communities, the Jaccard's similarity coefficient was utilized. The overall species composition similarity values between the communities ranged from 0.26 to 0.31. Community types 2 and 3 had a higher similarity coefficient ($Sj = 0.31$), while community types 1 and 4 had a lower similarity coefficient ($Sj = 0.26$) (Table 4).

6. Analysis of the Vegetation Structure

6.1. Frequency. According to their total frequency expressed as percentage, species were grouped in to five frequency classes following reference [2]: 1 = 81–100, 2 = 61–80, 3 = 41–60, 4 = 21–40, and 5 = 0–20%. The frequency distribution of woody plant species in Jib Godo Natural Forest revealed that the first frequency class had the highest proportion of species, followed by the third frequency class, and the last frequency class had no species distribution (Figure 6).

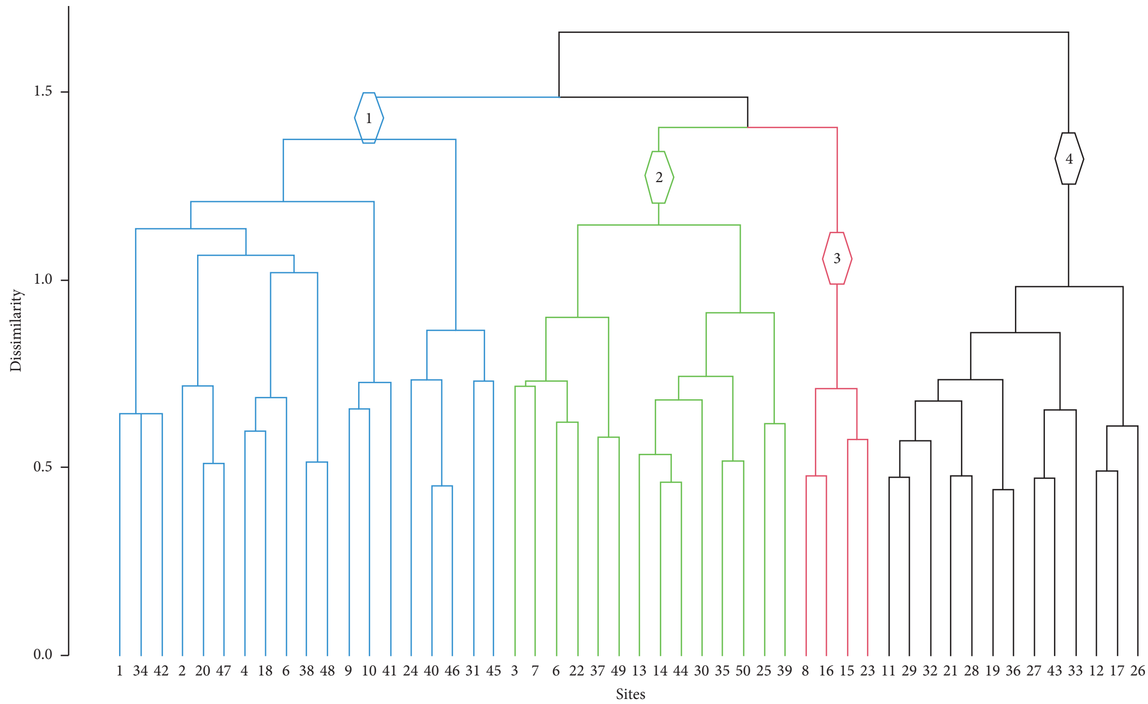

Figure 5: Dendrogram of the vegetation data obtained from hierarchical cluster analysis.

Table 3: Shannon–Wiener indices, species richness, and evenness of the plant communities.

Community	Species richness	Shannon diversity index	Shannon evenness	H'max	Altitudinal range
1	61	3.64	0.89	4.11	2485–2677
2	50	3.46	0.89	3.91	2511–2693
3	39	3.09	0.84	3.66	2664–2747
4	49	3.35	0.86	3.89	2490–2571

Table 4: Jaccard's similarity coefficient between four plant communities.

Community	1	2	3	4
1	1			
2	0.30	1		
3	0.30	0.31	1	
4	0.26	0.27	0.27	1

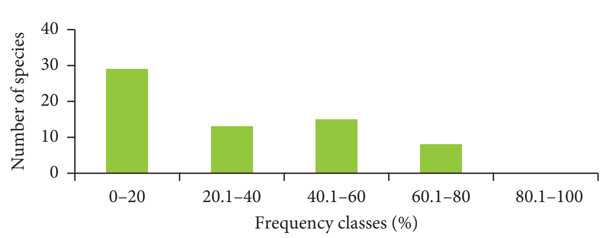

Figure 6: Frequency distributions of woody plant species in Jib Godo Natural Forest.

6.2. Stem Density. According to their stem density expressed as a percentage, species were classified into five density classes as follows [25]: (1) = >100; (2) = 50.1–100; (3) = 10.1–50; (4) = 1.1–10; and (5) = <1. Individuals of woody species with a DBH of less than 2.5 cm had a total stem density of 3,322 ha^{-1}. Sixteen species from density class 1 supplied 78.37% of the overall density, with *Carissa spinarum* (25.45%) and *Acanthus sennii* (7.76%) leading the way (Figure 7).

6.3. DBH Class Distribution. According to their DBH class distribution, species were classified into five classes [26]: (1) 2.5–10 cm; (2) 10.1–20 cm; (3) 20.1–30 cm; (4) 30.1–40 cm; and (5) >40 cm. The majority of woody plant species were found in the first class (10.1 cm), which had a total of 5,792 individuals, 2,896 (87.17%) individuals per hectare, and 45 species, according to the DBH study. The fourth-class least woody plant species (30.1–40 cm) has a total of 80 individuals, with 40 (1.2%) individuals per hectare and 1 species (Figure 8).

6.4. Height Class Distribution. The height distribution of the forest was classified into six height classes [25], such as 1, 2–6 m; 2, 6.1–10 m; 3, 10.1–14 m; 4, 14.1–18 m; 5, 18.1–22 m; and 6, >22 m. The first height class (2–6 m) had the most individuals, with 2,821 individuals and 1,410.5 (42.4%)

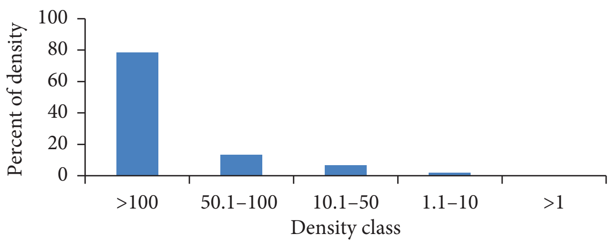

Figure 7: Percent of density with distribution of different classes.

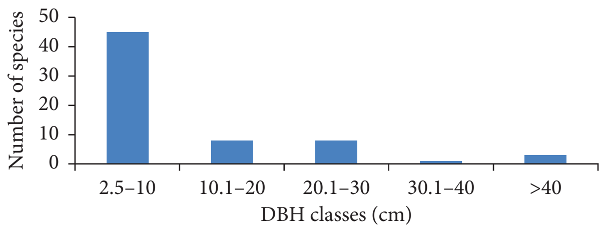

Figure 8: DBH class with number of species.

individuals per hectare, followed by the second height class (6.1–10 m), which had 2,262 individuals and 1,131 (34.04%) individuals per hectare, contributing to a higher proportion (>76.49% and 41 species for height 10 m). In the highest height class (18.1–22 m), only a few individual trees (1.61 percent of the total) were recorded (Figure 9).

6.5. Basal Area. According to their DBH class distribution, species were classified into five classes [26]: (1) 2.5–10 cm; (2) 10.1–20 cm; (3) 20.1–30 cm; (4) 30.1–40 cm; and (5) >40 cm. In Jib Godo Natural Forest, the total basal area of all woody plant species was 25.18 $m^2 \cdot ha^{-1}$ DBH >2.5 cm (Table 5). Individuals 2.5–10 cm had 1.32 $m^2 \cdot ha^{-1}$, 10.1–20 cm had 1.75 $m^2 \cdot ha^{-1}$, 20.1–30 cm had 2.9 $m^2 \cdot ha^{-1}$, and individuals >30 cm had 19.2 $m^2\ ha^{-1}$ in DBH.

The basal area of Jib Godo Forest was compared to the basal area of five Ethiopian dry montane forests. Only Ylat Forest has a lower basal area than Jib Godo Forest, whereas the rest of the forests have higher basal areas than the forest under study. In descending order, the trend of basal area for the comparison forests was shown (Table 6).

6.6. Importance Value Index (IVI). Carissa spinarum (9.78%), *Apodytes dimidiata* (8.56%), *Rhus glutinosa* (5.58%), *Galiniera saxifraga* (4.35%), and *Acanthus sennii* (3.75%) were the plant species with the greatest percentage importance value index. In Jib Godo Natural Forest, five most prominent woody species accounted for 32% of the total percentage important value index (Table 7).

Furthermore, based on their IVI scores for conservation priority, the forest's total tree species were divided into six classes according to Bantiwalu, S. [10]. IVI values: (1) >20, (2) 15.1–20, (3) 10.1–15, (4) 5.1–10, (5) 1.1–5, and (6) <1. In Table 8, the percentages of species in the IVI classes were (1) (3.08%), (2) (1.54%), (3) (7.69%), (4) (23.08%), (5) (29.23%), and (6) (35.38%), respectively. Class 6 (35.38%) and 23

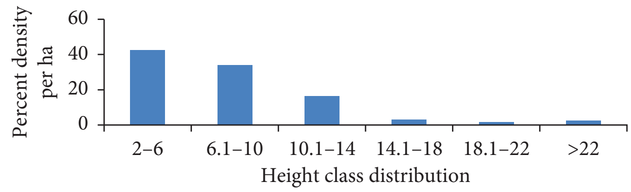

Figure 9: Percent density per hectare of Jib Godo Forest in different height classes.

species had the highest dominance percentage. Class 2 (1.54%) had the lowest level (1.54 percent), which represented a single species.

6.7. Population Structure. The examination of chosen woody species based on the number of individuals' distributions by diameter classes for tree species in the research region yielded three alternative population structural patterns (Figures 10(a)–10(c)). The interrupted pattern represents the first population pattern (Figure 10(a)). The frequency of this pattern is the highest in the upper DBH classes, the lowest in the middle DBH classes, and significantly diminished (missing) in the lower DBH classes. The I shape reflected the second population pattern, which was only seen in the middle DBH classes and was not found in the lower or upper DBH classes (Figure 10(b)). The third pattern was generated by species with a high frequency distribution of individuals in the lower DBH classes followed by a steady drop towards the higher DBH classes, forming an inverted J-shaped distribution (Figure 10(c)).

6.8. Regeneration Status of the Jib Godo Natural Forest. Seedling density was 3,362.5 per hectare, with 50 (76.92%) woody species comprising 46 genera and 33 families recorded. Similarly, 53 (81.53%) woody species with saplings, 48 genera, and 35 families had a sapling density of 1,926.5 per hectare. There were 3,362.5 seedlings per hectare, 1,926.5 saplings per hectare, and 3,322 mature individuals per hectare. Seedlings to mature trees and shrubs ratios were 1.01 : 1, saplings to mature trees and shrubs ratios were 0.57 : 1, and seedlings to saplings ratios were 1.74 : 1, indicating that there were fewer saplings than mature trees and shrubs.

Three main patterns emerge from the distribution of seedlings, saplings, and mature trees and shrubs (Figures 11(a)–11(d)). The first kind includes species from all three stages; the second type only includes species from mature trees and shrubs; and the third type includes species from saplings and mature trees and shrubs or seedlings and mature trees and shrubs. Only a limited number of mature trees or shrubs were observed for eight species (12.3 percent) that were not represented by both seedlings and saplings (Figure 11(b)). Seven species (10.76%) and four species (6.15%), on the other hand, had no seedlings or saplings (Figures 11(c) and 11(d), respectively). These findings led to the classification of woody species into three priority classes for conservation efforts [10]. There are no seedlings or saplings in Class 1 species; no seedlings in Class 2 species; and no saplings in Class 3 species (Tables9 and 10).

Table 5: Contribution of different DBH classes to the total density and basal area per hectare in Jib Godo Natural Forest.

DBH classes (cm)	Density (ha)	% of density	Basal area m^2ha^{-1}	% of basal area
2.5–10	2906	87.48	1.32	5.24
10.1–20	211.5	6.37	1.75	6.95
20.1–30	96	2.89	2.90	11.52
30.1–40	40	1.2	2.63	10.44
>40	68.5	2.06	16.58	65.85
	3322	100	25.18	100

Table 6: Comparison of the BA of Jib Godo Forest with BA of other forests in Ethiopia.

Forests	Basal area (m^2 ha^{-1})	Source
Alemsaga	75.37	[27]
Dindin	49	[28]
Sanka meda	34.71	[10]
Chilimo	30.1	[29]
Jib Godo	25.18	This study
Ylat	1	[26]

Table 7: IVI value of woody plant species in Jib Godo Natural Forest.

Nos.	Species name	IVI value	Percentages
1	*Carissa spinarum* L.	29.35	9.78
2	*Apodytes dimidiata* E. Mey. ex Arn.	25.67	8.56
3	*Rhus glutinosa* A. Rich.	16.73	5.58
4	*Galiniera saxifraga* (Hochst.) Bridson.	13.05	4.35
5	*Acanthus sennii* Chiov.	11.19	3.73 32

Inverted J shape (Figure 11(a)): This pattern has a large number of individuals at the seedling stage and a smaller number of individuals at the sapling and adult stages, with typical inverted J-shape curves.

I form (Figure 11(b)): In this pattern, seedlings and saplings are not present, and only the adult plant stands in for them.

J-shape (Figure 11(c)): In this group, the pattern of distribution shows a greater number of mature plants than saplings and no seedlings. It has a J-shaped regeneration curve, with recruitment being higher than regeneration.

U-shape (Figure 11(d)): This regeneration pattern represents the species with only seedlings and mature individuals. There is a gap between the floristic composition of mature stands and the seedling.

6.9. Impacts of Environmental Variables on Vegetation Distribution. A one-way ANOVA was used to assess the significance of differences in environmental factors throughout the distribution of plots. Only eleven of the twenty parameters considered for the current study, such as altitude, slope, OM, OC, sand, pH, Ca, aspect, cutting, EC, and available phosphorus, had significant differences $p < 0.05$, according to the results obtained using analysis of variance (ANOVA) in conjunction with canonical correspondence analysis (CCA) (Appendix 2). The association between significant environmental variables and the plots was determined using canonical correspondence analysis (CCA) (Figure 12).

7. Discussion

7.1. Floristic Composition. The findings of this study suggest that Jib Godo Forest has a high diversity of plant species, as evidenced by the presence of 65 species within a total of a plot, and confirm Shannon–Weiner diversity, which is high when it is above 3.0, medium when it is between 2.0 and 3.0, and low when it is smaller than 1.0. The overall Shannon–Weiner diversity index of the study forest was 3.07. It implies that the study forest has high diversity. As a result, the species richness of Jib Godo Natural Forest is higher than that of other Ethiopian forests, such as Ylat Forest (60 species) [26], and much lower than that of Alemsaga Forest (82 species) [27], Sanka Meda Forest (98 species) [10], Chato Natural Forest (119 species) [13], and Ilu Gelan [25]. These outcomes could be influenced by factors such as small area sizes, human participation, and environmental variability. Furthermore, forests that have long been subjected to a great deal of human influence and disturbance have lower species diversity than others [30].

The Fabaceae family of woody plants is the most common in Jib Godo Natural Forest. Fabaceae dominance was discovered in various floristic investigations conducted by different researchers at different times in the Bore–Anferara–Wadera Forest [2] and Ilu Gelan Forest [25]. Fabaceae may have dominated Bale Mountain National Park in the past due to strong pollination and seed dispersal systems that adapted them to a wide range of ecological conditions [31].

In comparison to other Ethiopian montane forests, this study demonstrates a high taxonomic diversity; for example, no new plant species have been identified in the Alemsaga and Jibta woods in the Gonder floristic zone.

7.2. Endemic Plant Species. Ethiopia is one of the countries in East Africa with a high level of plant endemism [32]. Ethiopia's remarkable biodiversity is attributed to the country's diverse geographic terrain and climate conditions [22]. Six Ethiopian endemic species have been discovered in the Jib Godo Natural Forest (Table 2). According to IUCN standards, two species were categorized as "least concern"

Table 8: IVI classes and number of species in each class in Jib Godo Natural Forest.

IVI values and classes	No of species	Percentages	Total IVI
6. (<1)	23	35.38	10.16
5. (1.1–5)	19	29.23	54.43
4. (5.1–10)	15	23.08	108.63
3. (10.1–15)	5	7.69	55.03
2. (15.1–20)	1	1.54	16.73
1. (>20)	2	3.08	55.02

List of species in each class

Class 6	Class 5	Class 4
Rhamnus prinoides	*Maytenus undata*	*Clausena anisata*
Rumex nervosus	*Maytenus obscura*	*Calpurnia aurea*
Rhamnus staddo	*Phytolacca dodecandra*	*Juniperus procera*
Pterolobium stellatum	*Brucea antidysenterica*	*Dombeya torrida*
Lobelia giberroa	*Jasminum abyssinicum*	*Discopodium penninervium*
Olea welwitschii	*Periploca linearifolia*	*Pittosporum abyssinicum*
Ficus sur	*Osyris quadripartita*	*Solanecio gigas*
Salix subserrata	*Embelia schimperi*	*Prunus africana*
Vernonia amygdalina	*Myrica salicifolia*	*Maesa lanceolata*
Croton macrostachyus	*Clutia abyssinica*	*Ekebergia capensis*
Ritchiea albersii	*Bridelia micrantha*	*Olinia rochetiana*
Cassiporea malosana	*Buddleja polystachya*	*Erythrina brucei*
Erica arborea	*Pavetta abyssinica*	*Maytenus arbutifolia*
Dodonaea angustifolia	*Albizia gummifera*	*Nuxia congesta*
Eucalyptus globulus	*Maytenus addat*	*Vernonia hymenolepis*
Zehneria scabra	*Rosa abyssinica*	
Jasminum fluminense	*Urera hypselodendron*	
Euphorbia abyssinica	*Clematis hirsuta*	
Hypericum revolutum	*Teclea nobilis*	
Dregea abyssinica		
Olea europaea		
Myrsine africana		
Acacia polyacantha		
Class 3	Class 2	Class 1
Dovyalis abyssinica	*Rhus glutinosa*	*Carissa spinarum*
Schefflera abyssinica		*Apodytes dimidiata*
Bersama abyssinica		
Acanthus sennii		
Galiniera saxifraga		

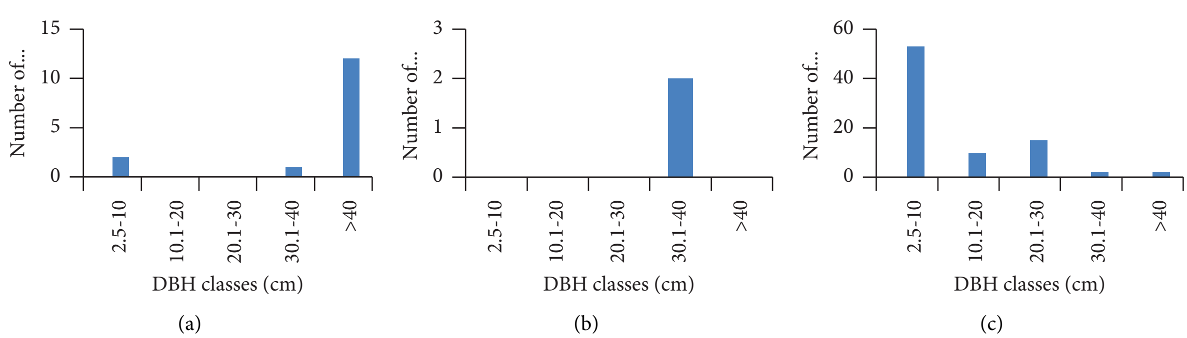

Figure 10: Three representative patterns of population structure in Jib Godo Natural Forest. (a) Interrupted shape, (b) I shape, and (c) inverted J shape.

(LC), three species as "near threatened" (NT), and one species as "vulnerable" (VU).

Jib Godo Natural Forest has a low diversity of endemic plant species. Jib Godo Natural Forest, on the other hand, has only six endemic plant species, compared to twelve endemic plant species in Chato Natural Forest [13]. This could be because of the region's small size or the interaction of humans and animals. Other Afromontane Forests in Ethiopia feature a high percentage of endemic plant species, ranging from 11% to 15% of total species [33]. The authors of reference [34] discovered that

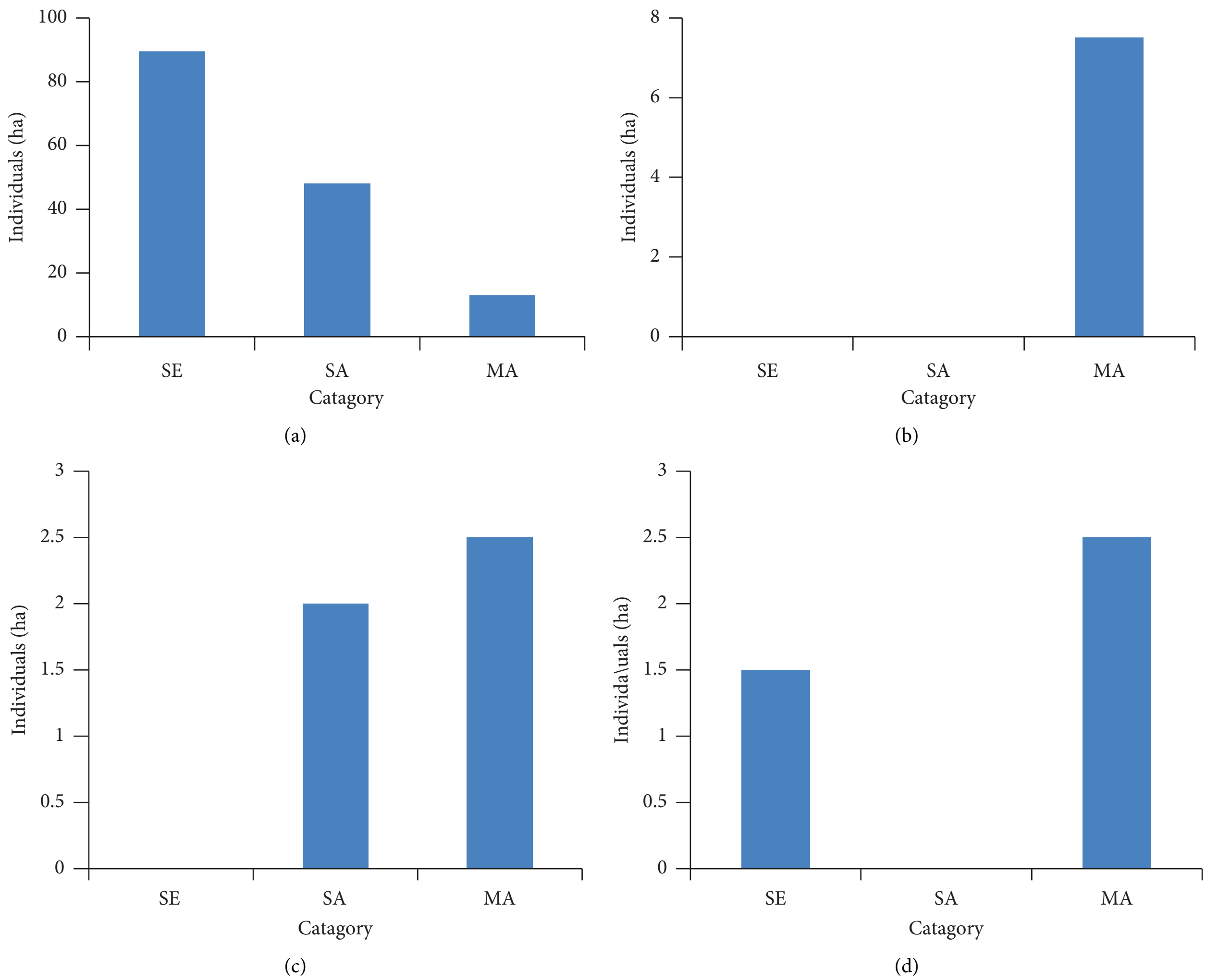

Figure 11: Four regeneration patterns of selected species in Jib Godo Natural Forest. Key: seedling (SE), sapling (SA), and mature (MA) distributions. (a) Inverted J shape, (b) I shape, (c) J shape, and (d) U shape.

Table 9: Classification of woody species in the different conservation priority classes.

Class 1	Class 2	Class 3
Acacia polyacantha	*Ekebergia capensis*	*Cassipourea malosana*
Croton macrostachyus	*Lobelia giberroa*	*Olea welwitschii*
Erica arborea	*Maytenus obscura*	*Ritchiea albersii*
Erythrina brucei	*Myrica salicifolia*	*Juniperus procera*
Eucalyptus globulus	*Schefflera abyssinica*	
Pterolobium stellatum	*Vernonia amygdalina*	
Rhamnus staddo	*Zehneria scabra*	
Salix subserrata		

8.7% of the plant species detected in Borena Saint National Park were native to the area (31 species).

7.3. Plant Community Classification. Plant community distribution is mainly the manifestation of environmental gradients [30]. Plant community type clusters were determined by combining the k means of the cluster with the species' synoptic cover abundance value. The mean values for slopes and aspects on which the four plant communities occurred varied among plant communities. The result from cluster analysis showed that there are differences among the four plant communities in species composition. The differences could be attributed to variations in environmental gradients that can limit the ecological distributions of plant species. The vegetation classification was done using the cover abundance value estimate of each species included in the analysis. Distribution of the four plant community types (C1 = Community Type 1 with altitudinal range between 2,485 and 2,677, which accounted for 19 plots, C2 = Community Type 2 with altitudinal range between 2,511 and 2,693, which accounted for 14 plots, C3 = Community Type 3 with altitudinal range between 2,664 and 2,747, which accounted for 4 plots; and C4 = Community Type 4 with altitudinal range between 2,490 and 2,571, which accounted for 13 plots). The main factors of community separation are based on species

Table 10: List of seedling species.

Seedling species lists	Family names
Acanthus sennii Chiov.	Acanthaceae
Albizia gummifera (I.F.Gmel.) C.A.Sm.	Fabaceae
Apodytes dimidiata E. Mey. ex Arn.	Icacinaceae
Bersama abyssinica Fresen.	Melianthaceae
Bridelia micrantha (Hochst.) Baill.	Euphorbiaceae
Brucea antidysenterica J. F. Mill.	Simaroubaceae
Buddleja polystachya Fresen	Loganiaceae
Calpurnia aurea (Ait.) Benth.	Fabaceae
Carissa spinarum L.	Apocynaceae
Cassipourea malosana (Baker). Alaston.	Rhizophoraceae
Clausena anisata (Willd.) Hook.	Rutaceae
Clematis hirsuta Perr. & Guill.	Ranunculaceae
Clutia abyssinica Jaub. & Spach.	Euphorbiaceae
Discopodium penninervium Hochst.	Solanaceae
Dodonaea angustifolia L.f.	Sapindaceae
Dombeya torrida (J. F. Gmel.) P. Bamps	Sterculiaceae
Dovyalis abyssinica (A.Rich)Worb.	Flacourtiaceae
Dregea abyssinica (Hochst.) K. Schum.	Asclepiadaceae
Embelia schimperi Vatke	Myrsinaceae
Euphorbia abyssinica Gmel.	Euphorbiaceae
Ficus sur Forssk	Moraceae
Galiniera saxifraga (Hochst.) Bridson.	Rubiaceae
Hypericum revolutum Vahl	Hypericaceae
Jasminum abyssinicum Hochst Ex.DC.	Oleaceae
Jasminum fluminense Vell.	Oleaceae
Juniperus procera L.	Cupressaceae
Maesa lanceolata Forssk	Myrsinaceae
Maytenus addat (Loes.) Sebsebe	Celastraceae
Maytenus arbutifolia (A. Rich.) Wilczek	Celastraceae
Maytenus undata (Thunb.) Blakelock	Celastraceae
Myrsine africana L.	Myrsinaceae
Nuxia congesta R. Br. Ex Fresen.	Loganiaceae
Olea europaea (Wall. ex DC.) Cifferri	Oleaceae
Olea welwitschii (Knobl.) Gilg & Schellenb.	Oleaceae
Olinia rochetiana A. Juss.	Oliniaceae
Osyris quadripartita Decn.	Santalaceae
Pavetta abyssinica Fresen.	Rubiaceae
Periploca linearifolia Quart.-Dill. & A. Rich.	Asclepiadaceae
Phytolacca dodecandra L'Her.	Phytolaccaceae
Pittosporum abyssinicum Del.	Pittosporaceae
Prunus africana (Hook. f.) Kalkm.	Rosaceae
Rhamnus prinoides L'Herit.	Rhamnaceae
Rhus glutinosa A. Rich.	Anacardiaceae
Ritchiea albersii Gilg	Rubiaceae
Rosa abyssincia Lindley.	Rosaceae
Rumex nervosus Vahl	Polygonaceae
Solanecio gigas (Vatke) C. Jeffrey	Asteraceae
Teclea nobilis Del.	Rutaceae
Urera hypselodendron A. Rich.	Urticaceae
Vernonia hymenolepis A. Rich.	Asteraceae

composition, but they could also be related to the effects of environmental factors such as altitude, aspect, soil contents, moisture, and human impacts. Lower altitudinal ranges, aspects more exposed to sun light directions, soils with sufficient moisture content, and parts of vegetation less exposed to disturbance accesses can all support more biodiversity than the inverse of each component. The main factors of community separation are based on species

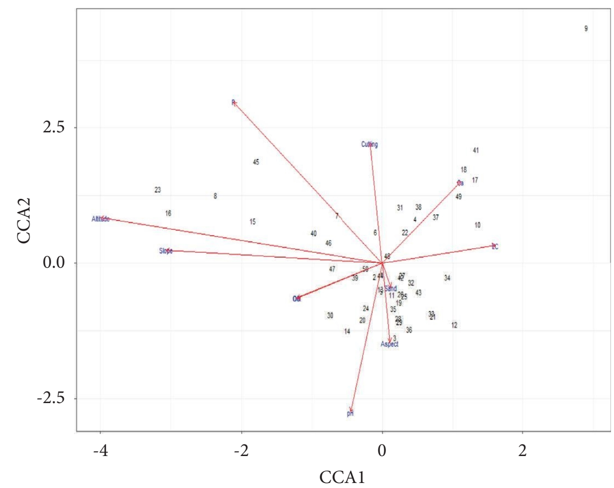

Figure 12: Impacts of environmental variables on vegetation distribution in the study area. Keywords: OM = organic matter, P = available phosphorus, Ca = calcium, pH = potential hydrogen, EC = electrical conductivity, OC = organic carbon, and CEC = cation exchange capacity.

composition due to environmental variables of altitude and slope indifference. The community's one and two have high species richness, whereas the community three has low species richness. The effects of environmental factors on species variation are similar to those on community change. According to canonical correspondence analysis, sandy soil texture influenced communities 4 and 5. Calcium exchange has a significant impact on plots 18 and 41 in community 1. Organic matter significantly affected plots 3 and 50 under community 2. Electrical conductivity significantly affected plot 10 under community 1, whereas the availability of phosphorus significantly affected plot 45 under community 1.

7.4. Species Richness, Evenness, and Diversity of the Four Communities. Cluster analysis revealed that the four plant communities have different species compositions. Variations in environmental gradients could explain the inequalities by limiting plant species' ecological ranges [35]. Environmental factors such as height, aspect, soil content, moisture, human influences, and grazing intensity could all influence species composition [36].

The difference in the Shannon diversity index between community 1 ($H' = 3.64$) and community 3 ($H' = 3.09$) could be explained by the bigger anthropogenic disturbances in these forest sections. Community 3 has been negatively impacted by local residents removing trees for firewood and grazing (Appendix 3). The authors of reference [20] identify local climate changes and forest disturbances as two of the most important factors influencing species diversity and evenness in a forest.

Community 1 has the most diversified and rich species composition when compared to the other groups. On typical plots, this could be attributable to the interaction of topographic, climatic, and disturbance factors. Changes in terrain, gradient, and slope orientation, according to Suratman,

M. N. [37], result in variances in soils, water, and microclimate conditions, as well as disparities in species adaption. Species evenness represents a species' relative abundance in the sample plot. *Apodytes dimidiata, Ekebergia capensis, Nuxia congesta, Galiniera saxifraga, Rhus glutinosa, Maesa lanceolata,* and *Dovyalis abyssinica* have lower evenness values in community 3.

7.5. Woody Plant Species of Diversity and Evenness Analysis. The Shannon–Weiner diversity index for the study forest was 3.07. This revelation has numerous ramifications. The research forest was compared to the Ylat Forest using average diversity and evenness values [26]. For the analyzed forest, the average Shannon–Weiner diversity index value and average evenness value are 3.07 and 0.74, respectively. Ylat Natural Forest has a Shannon–Weiner diversity index of 2.94 and an average evenness score of 0.84. According to the data analysis, the study forest's average evenness value was 0.74. The species evenness value ranges between 0 and 1. When it is 0, the area is dominated by a single species, and when it is 1, the species are evenly distributed in the area. This indicates that the species in the research forest are generally evenly distributed.

The Shannon–Weiner diversity index varies from 1.5 to 3.5, with a score of 4.5 being highly unusual. When the Shannon–Weiner diversity reaches 3.0, it is termed "high," "medium" when it is between 2.0 and 3.0, and "bad" when it is less than 1.0 [16]. Thus, Jib Godo Forest's H value is within the expected range, indicating that the research region includes a wide variety of plant species, which could be due to the area's unusually high degree of topographic, climatic, and edaphic component (structure and composition of soil) changes.

7.6. Similarity between the Four Community Types. Communities 1 and 4 (26%) resemble each other more closely than communities 2 and 4 (27%) and 3 and 4 (27%) do. This could be because the communities have virtually equivalent altitudinal ranges, resulting in similar species compositions. The higher number of related species in communities 2 and 3 may be attributed to the near geographic distance between them, with most plots in both communities having similar environmental parameters. According to Pyke, C. R, et al. [38], environmental variables alter with geographic distance, resulting in floristic dissimilarity.

7.7. Frequency, Stem Density, DBH Class Distribution, Height Class Distribution, Basal Area, Importance Value Index (IVI), and Population Structure. According to Rey, P. J. et al. [39], a species' high frequency is always influenced by factors such as habitat preferences, adaptation, degree of exploitation, and the availability of favorable environmental conditions for regeneration. As a result, lower frequency classes have a high value, while higher frequency classes have a low value, according to this study. This indicates that Jib Godo's Natural Forest has a wide species composition. A similar result was reported in the Sanka Meda Forest Arsi zone [10].

The majority of plant species in the study area were represented by a small number of individuals distributed across numerous plots, which is a common pattern in tropical forests. Jib Godo Natural Forest had a relatively high woody species density (3,322 individuals ha^{-1}) when compared to other Ethiopian forests such as Bore–Anferara–Wadera Forest (1047 individuals ha^{-1}) [2], Chato Natural Forest (980 individuals ha^{-1}) [13], and Ylat (1227.77 individuals ha^{-1}) [26], while its density was found to be lower than Ilu Gelan Forest (5145.83 individuals ha^{-1}) [25]. Variations in topographic gradients, forest species' habitat preferences, environmental variables, and the degree of anthropogenic disturbances could all be the factors [40]. In the study area, we faced a high number of woody plant species, which were caused by altitude, slope, and the availability of phosphorus in the soil.

The four most common plant species detected in class one were *Carissa spinarum* 1691 (25.45%), *Acanthus sennii* 516 (7.76%), *Maytenus arbutifolia* 416 (6.26%), and *Vernonia hymenolepis* 384 (5.77%). This finding is similar to that of a study conducted in Oromia's Ilu Gelan West Shewa Zone [25], which indicated that few people cover the majority of vegetation density classifications. *Carissa spinarum, Acanthus sennii, Maytenus arbutifolia,* and *Vernonia hymenolepis* were counted as high stem density species due to protected anthropogenic disturbance and their adaptability to the environment. On the other hand, the stem density of two woody species with density classes less than one is only 1 ha^{-1} (0.03%). This demonstrates that a single individual rarely represents a species in the vegetation.

The results of the DBH class distribution of trees and shrubs throughout the five DBH classes in Jib Godo Forest demonstrate an inverted J-shape distribution. However, as the DBH class grew, the density declined, indicating that higher DBH classes had a smaller number of big trees than lower DBH classes, which had more shrubs and little trees. This aids in the formation of the inverted J shape. Dindin Woods [28], Menagesha Amba Mariam Forest [41], and Sanka Meda Forest [10] all followed the same pattern.

This pattern indicates that the vegetation has a high rate of reproduction but a low rate of recruitment, which may be due to tree clearance (Figure 8). According to the DBH survey, the majority of woody plant species were identified in the first class (10.1 cm), which contained 5,792 individuals, 2,896 (87.17%) individuals per hectare, and 45 species.

Jib Godo Natural Forest (2.08) showed a higher ratio of trees and shrubs with DBH >10 cm to DBH >20 cm than Chato (1.71) [13] and Bore–Anferara–Wadera (2.03) [2], indicating a higher preponderance of small-sized individuals. Jib Godo Woods have been subjected to a long history of anthropogenic disturbance, as evidenced by the absence of large individuals.

Individual trees were less than 10 meters more numerous. This finding is similar to those of studies conducted in the Chato Natural Forest Horo Guduru Wollega Zone [13]; Bore–Anferara–Wadera Forest in southern Ethiopia [2]; Sanka Meda Forest Guna district, Arsi Zone [10]; and Ilu Gelan West Shewa Zone, Oromia region [25]. The density ha^{-1} of woody plants dropped as the height classes climbed, with the exception of the gaps recorded at the 6th height class.

Only a few trees (1.61% of the total) were reported in the highest height class (18.1–22 m). This could indicate that individuals of lesser stature governed the Jib Godo Natural Forest. When such patterns, also known as reverse J-shape distributions, are examined separately, they reveal stable population structures, but there is variation among species. A higher frequency of large-sized individuals in the top height class in the natural forest implies the presence of a sufficient number of mature tree species for reproduction [42]. This logic does not apply to Jib Godo Natural Forest. This is due to the presence of a large-scale charcoal production facility as well as construction materials.

The total basal area of all woody plant species in Jib Godo Natural Forest was $25.18\,m^2{\cdot}ha^{-1} > 2.5$ cm in DBH. According to [10], Africa's typical virgin tropical forest area is $23–37\,m^2{\cdot}ha^{-1}$. According to the study, the basal region of Jib Godo Natural Forest is typical, indicating the existence of woody species. The basal area of this forest is compared to that of other Ethiopian forests. Only Ylat Forest ($1\,m^2{\cdot}ha^{-1}$) [26] has a smaller basal area than the study forest, while Alemsaga Forest ($75.37\,m^2\ ha^{-1}$) [27], Dindan Forest ($49\,m^2{\cdot}ha^{-1}$) [28], Sanka Meda Forest ($34.71\,m^2{\cdot}ha^{-1}$) [10], and Chilimo Forest ($30.1\,m^2{\cdot}ha^{-1}$) [29] have a greater basal area.

According to Lewis, S. L. et al. [43], the density of woody plants in African montane forests is relatively high when compared to other tropical montane forests. However, these individuals contributed just a modest amount to the basal area. This indicates that species with the largest basal area do not necessarily have the highest density, but that size differences exist between species [28]. A species' basal area, rather than a simple stem count, is a better predictor of its relative importance [44]. The most important woody species in the forest are those with the greatest basal area contribution.

Moreover, the most significant species are those that dominate particular vegetation [28]. According to the IVI data, *Carissa spinarum* (9.78%) and *Apodytes dimidiata* (8.56%) were the plant species with the highest percentage significant value index compared to other species in the research region.

The huge basal area values of these species were the primary contributors to the high IVI levels. This finding suggests that IVI is mostly caused by a small number of species with a broad basal area. IVI values less than 5 were found in 21.54% of woody species, indicating the need for conservation management. The IVI data validated these two species (*Carissa spinarum* and *Apodytes dimidiata*) as the most important and dominant species in the study region. From a structural point of view, the two species represented a more realistic figure of dominance. It is useful to compare the ecological significance of species, where a high IVI value indicates that the species' sociological structure in the community is high. IVI values were the sum of relative frequency, relative density, and relative dominance value.

The population structure could provide useful information regarding the population's regeneration and recruitment status, as well as its viability, which could be used to develop evidence-based conservation and management policies [45]. The number of individuals' distributions by diameter classes for chosen woody species in the study area resulted in three different patterns of population structures (Figures 10(a)–10(c)).

The J shape indicated the first population pattern (Figure 10(a)). *Schefflera abyssinica*, *Erythrina brucei*, and *Juniperus procera* were among the species that displayed this pattern. The species with this pattern have huge individuals who are less capable of reproducing and are in a poor regeneration position [2]. The I shape reflected the second population pattern, which was only seen in the middle DBH classes and was not found in the lower or upper DBH classes (Figure 10(b)). *This pattern can be seen in Croton macrostachyus and Ficus sur.*

The third pattern was generated by species with a high frequency distribution of individuals in the lower DBH classes followed by a steady drop towards the higher DBH classes, forming an inverted J-shaped distribution (Figure 10(c)). *Dombeya torrida*, *Maesa lanceolata*, *Nuxia congesta*, *Pittosporum abyssinicum*, *Prunus africana*, *Rhus glutinosa*, and *Dovyalis abyssinica* were among the species that appeared in this pattern. This pattern of population indicates a steady population structure and healthy forest regeneration [45, 46]. This sort of population structure is found in species with strong reproductive capacity and shade-tolerant canopy trees with a rather steady recruitment rate.

7.8. Regeneration Status of the Jib Godo Natural Forest. The density values of seedlings and saplings are regarded as the species' regeneration capability by Dhaulkhandi, M. A. et al. [47]. The presence of good regeneration potential indicates the species' environmental stability. Although the density of seedlings is greater than that of saplings and old trees and shrubs, the density of saplings in Jib Godo Natural Forest is less than that of mature species, indicating that the vegetation is in good regeneration status. *Acacia polyacantha*, *Croton macrostachyus, Erica arborea, Erythrina brucei, Eucalyptus globulus, Pterolobium stellatum, Rhamnus staddo,* and *Salix subserrata* were all represented by a small number of mature trees or shrubs, indicating that these species may be on the verge of local extinction because there are no individuals at the seedling stage. Unfavorable environmental variables such as rocky land and poorly developed soil, seed predation, seedlings, and human disturbances such as livestock grazing and trampling contribute to seed predation.

Inverted J shape (Figure 11(a)): This pattern has a large number of individuals at the seedling stage and a smaller number of individuals at the sapling and adult stages, with typical inverted J-shape curves. *Burcea antidysenterica, Clausena anisata, Clutia abyssinica, Euphorbia abyssinica, Maytenus arbutifolia, Myrsine africana, Pavetta abyssinica, Rhamnus prinoides,* and *Rumex nervosus* are among the plant species listed in this regeneration group. The inverted J-shape pattern indicates that these species have a high capacity for regeneration. This happens in the case of environmental factors when increase to stimulate germinating and they have selective cutting in the area.

Inverted J shape (Figure 11(a)): This pattern has a large number of individuals at the seedling stage and a smaller number of individuals at the sapling and adult stages, with typical inverted J-shape curves. *Burcea antidysenterica, Clausena anisata, Clutia abyssinica, Euphorbia abyssinica, Maytenus arbutifolia, Myrsine africana, Pavetta abyssinica, Rhamnus prinoides,* and *Rumex nervosus* are among the plant species listed in this regeneration group. The inverted J-shape pattern indicates that these species have a high capacity for regeneration. This occurs when environmental factors are increased to stimulate germinating and selective cutting is performed in the area.

I-shaped individuals (Figure 11(b)): Individuals in this pattern are missing seedlings and saplings, leaving just the mature plant. Because there are no juveniles, which tend to become adult plants, species with this pattern have low reproduction and recruitment potential. This could be due to anthropogenic disturbances such as the selective cutting of *Erythrina brucei* trees for their timber qualities. *Acacia polyacantha, Croton macrostachyus, Erica arborea, Erythrina brucei, Eucalyptus globulus, Pterolobium stellatum, Rhamnus staddo,* and *Salix subserrata* were among the other species in this pattern. As a result, these species must be prioritized for protection.

J-shape (Figure 11(c)): In this category, the distribution pattern indicates more mature plants than saplings and no seedlings. It has a J-shaped regeneration curve, with recruitment being higher than regeneration. *Ekebergia capensis, Lobelia giberroa, Maytenus obscura, Myrica salicifolia, Schefflera abyssinica, Vernonia amygdalina*, and *Zehneria scabra* are among the species with this sort of regeneration curve. This pattern demonstrates that juvenile performance is heavily influenced by external variables. These could be anthropogenic or environmental disturbances that affect seedling survival.

U-shape (Figure 11(d)) illustrates the species with only seedlings and mature individuals. The floristic composition of developed stands differs from that of seedlings. This could indicate that environmental factors such as slope, aspect, and altitude and anthropogenic factors such as selective cutting have an impact on the saplings. *Cassipourea malosana, Olea welwitschii, Ritchiea albersii,* and *Juniperus procera* are examples of species with this regeneration pattern.

7.9. Impacts of Environmental Variables on Vegetation Distribution. Plot distribution is primarily an expression of environmental gradients. The effects of environmental factors on species variation are similar to those on community change, i.e., species variations are significantly correlated with time since altitude, elevation, soil type, slope, and aspect. Altitude, slope, and aspect are among the important environmental factors that determine species composition and the distribution of plots across landscapes. Variation in the exposure (aspect) of the two oppositely facing hills with respect to the position of the sun resulted in variation in the patterns of plot formation. In addition, considerable variation in slopes between the two hills might result in variation in soil characteristics, which in turn determine the pattern of the plot's formation [3].

Analysis with CCA confirms that there is a relatively high correspondence between plots and soil or topography factors. The CCA results showed that altitude, slope, available amounts of phosphorus, nitrogen, calcium, pH, organic matter, and soil texture, including sand and clay, were the most important factors for the distribution of the plots.

According to Whittaker, R. J. et al. [40], differences in environmental gradients are the best explanation for vegetation patterns among populations. The length of the arrows from the origin (center) to the points representing the environmental variable indicated the relationship between the vegetation represented by plots on the current study area and the environmental parameters (Figure 12).

The most significant limiting factor is the environmental element with the longest arrow. The two most important variables determining the change in patterns in species composition at this height were available phosphorus and slope. Sand has a smaller impact on species composition variance when compared to other environmental factors. Altitude is a significant environmental component that influences atmospheric pressure, moisture, and temperature, all of which have a significant impact on plant growth and dispersion [1]. This conclusion is reinforced by Ahmed, S. D. et al. [2], who found that altitude played a larger role in determining the spatial distribution of vegetation in both situations than the other environmental variables studied. Most environmental variables are controlled indirectly by altitude. As a result, most factors are affected by altitude. Altitude, for example, has an inverse relationship with temperature and a direct relationship with precipitation.

Depending on the angle between the arrows, the different environmental variables were connected in different ways. Because the arrows were heading in opposing directions, Ca and OM were negatively connected, but altitude and slope with a middle angle were positively correlated.

The steepness or degree of incline of a surface is indicated by its slope. As a result, steep slopes exacerbate the circulation of surface water, washing away the resources available to plants. Aspect refers to the plot's orientation, which influences precipitation and temperature levels as well as wind, which reduces the amount of moisture available. The connection between altitude and EC and Ca was negative ($p < 0.05$), as evidenced by the ordination diagram, in which the two variables' arrows were practically pointing in opposing directions. In the Benishangul Gumuz Region, there was likewise a negative association between altitude, calcium, and EC [48].

Except for Ca, all exchangeable bases such as Mg, K, and Na were not important. It was found to have a positive x-axis direction and a negative association with plot numbers 30, 39, and 50, but a positive correlation with plot numbers 18, 17, 49, and 41. The positive connection of slope, OM, OC, and P with altitude ($p < 0.05$) was also confirmed in the ordination diagram (Figure 12). In the dry, evergreen Afromontane Forests of southeastern Ethiopia, plant communities, and species composition were influenced by altitude. Altitude is a complicated mixture of related climate variables that are strongly linked to a variety of other environmental features, such as soil texture, nutrients, and substrate stability. Temperature changes over short vertical distances can be influenced by changes in altitude. This has an impact on the growth, distribution, and diversity of species in forest communities [1].

8. Conclusion and Recommendations

Jib Godo Natural Forest is part of the Dry Afromontane Forest, which contains sensitive and near-threatened plant species in northern Ethiopia. Sixty-five wood species were identified, and four plant community types were identified by cluster analysis using the synoptic cover abundance value of species. Altitude and topographic aspects mainly determine the distributions of these woody species compositions and communities. In general, the diversity of woody species indicates that the forest is clearly the source of forest gene pools for some endemic and indigenous species in the country. The large ratio of size class distribution shows that the forest is dominated by small-sized woody species. In terms of total basal area, the forest is poorer than other dry Afromontane Forests, but it is richer than the Ylat Forest. The forest is also dominated by low-height and DBH individuals. There are few woody species that could contribute to the densities of both the DBH and height class distributions. Woody plant species had a high value in the first frequency class, a low value in the next frequency class, and then, a simple fall in the last frequency class. This shows the heterogeneity of species composition.

According to the findings, the occurrence of significant plant variety, species composition, and richness in the research area could be linked to habitat heterogeneity and the availability of adequate environmental gradients that fit distinct plant species associations. Despite the limited number of indigenous plant species identified, the floristic region has a considerable number of newly recorded plant species in the area that have not been listed in the Gonder floristic region in the past. This could have a significant impact on the Gonder floristic region. Different causes, such as environmental and anthropogenic, could explain the variance in species composition and diversity among community types. The population structure of typical tree and shrub species also shows that certain species have anomalous population structures, with no or few individuals in different size classes, as a result of local people selectively removing desired sized individuals for various purposes. A substantial number of species require monitoring and conservation activities based on the overall IVI value. Altitude, phosphorus, and slopes, among other environmental conditions, influenced patterns of plant species distribution and plant community formation. The following recommendation was given for the stakeholders related to forest resources: (i) more research into forest management is recommended, as are conservation systems and soil seed banks.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Supplementary Materials

Appendix 1: List of plant species collected in Jib Godo Natural Forest. Appendix 2: ANOVA test to check the level of significance for environmental variables. Appendix 3: Grazing activity in the study area. (*Supplementary Materials*)

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