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Vegetation Structure and Regeneration Status of the Western Escarpment of the Rift Valley of the Gamo Zone, Southern Ethiopia

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Abstract

Understanding the structure and regeneration of forest resources contributes to identifying the elements of diversity, endemism, threatened and endangered species. This study was conducted in the western escarpment of the Rift valley of the Gamo Zone, Southern Ethiopia. The main objective was to investigate structure and regeneration status of the study area. A systematic sampling method was used to collect vegetation data from a total 102 quadrats, each 20 × 20 m (400 m^2) and five 1 × 1 m (1 m^2) sub-quadrats were established at the four corners and at the centre for sapling and seedling estimation. Tree and shrub species were listed; Height (H ≥ 1.5 m) and DBH ≥ 2 cm were measured and recorded. R-statically software and Microsoft Excel were used to record and analyse the data. A total of 126 plant species belonging to 43 families and 90 genera were identified. The most dominant families were Fabaceae, followed by Anacardiaceae and Euphorbiaceae. Most frequent species were *Euclea divinorum* (84.3%), followed by *Rhus natalensis* (83.3%), *Terminalia brownii* (74.5%). DBH class ≤ 5cm had highest density (63.6%) and DBH ≥ 25.1 cm had the lowest density (0.87%). Three population patterns have been observed; inverted J, J-shaped and irregular shaped. 93% of species had IVI values b/n 1 - 4, 65% of species IVI values < 1% and 7% of species had IVI values ≥ 5.28. *Pappea capensis*, *Combretum molle*, *Terminalia brownii*, *Euclea divinorum* had highest IVI values. In the vertical stratification, lower story was 91.3% of the individuals. Only a few species contributed to the high density of saplings (440.2/ha) and seedlings (825.49/ha) while most had very little or no saplings and seedlings at all. Thus, in order to revert the current forest structure and regeneration to the previous natural state, it is considered important to minimize the influence of the human interference, grazing and raising awareness to surrounding community.

Keywords

Importance Value Index, Regeneration, Seedling/Sapling, Vegetation Structure

1. Introduction

Diverse physiographic, altitudinal, climatic, and edaphic differences enable Ethiopia to have various vegetation types ranging from alpine to desert plant communities [1] [2] [3] [4] and the species in that provide economic, sociocultural, and environmental benefits. As a result, Ethiopia is endowed with rich flora and fauna and that makes the country an important centre of diversity and endemism [5] [6] [7] [8]. It has the fifth highest biodiversity in Africa [9].

Forests in East Africa accounted for 21% of the forest area in Africa. However, the annual rate of deforestation in the region has increased from 0.7% during the period 1981-1990 (FAO, 1993) to 1% between 1999-2000 [10]. The annual deforestation rate in Ethiopia exceeds 0.8% [11].

Forest coverage in Ethiopia has been threatened by habitat conversion, loss, and fragmentation that occurred over the past many years [12] [13] [14]. The forest covered about 35% of the land area in the early 19^{th} century [15]; 16% in the 1950's, reduced to 3.6%, in 1980 and to 2.7% in 1989 [16] [17]. The remaining forest resources of the country are found in areas in the western and south western parts of Ethiopia, mainly not unduly affected by human settlements as well as human disturbance [12].

The threats those conversions of natural forests into grazing lands, woodlands, and wetlands to agriculture and settlement in Ethiopia [18] [19]. The overall change in forest cover leads to forest degradation, habitat loss and fragmentation, which in turn leads to changes in forest structures that affect the sustainability of the forest in the escarpment [2] [18].

The study area is facing rapid deforestation and degradation of forest resources [20] due to population pressure that forced the conversion of forest land into other forms (agriculture, settlement, etc.). There was no previous study in the area documenting the structure and regeneration status. Hence in order to address the following research objectives were provided: 1) to identify vegetation structure of woody species in the study area; 2) to assess the regeneration status of woody species in the study area.

2. Materials and Methods

2.1. Description of the Study Area

The study was carried out in the western escarpment of the rift valley of the Gamo Zone, Southern Ethiopia (**Figure 1**). Topographically, the study area consists

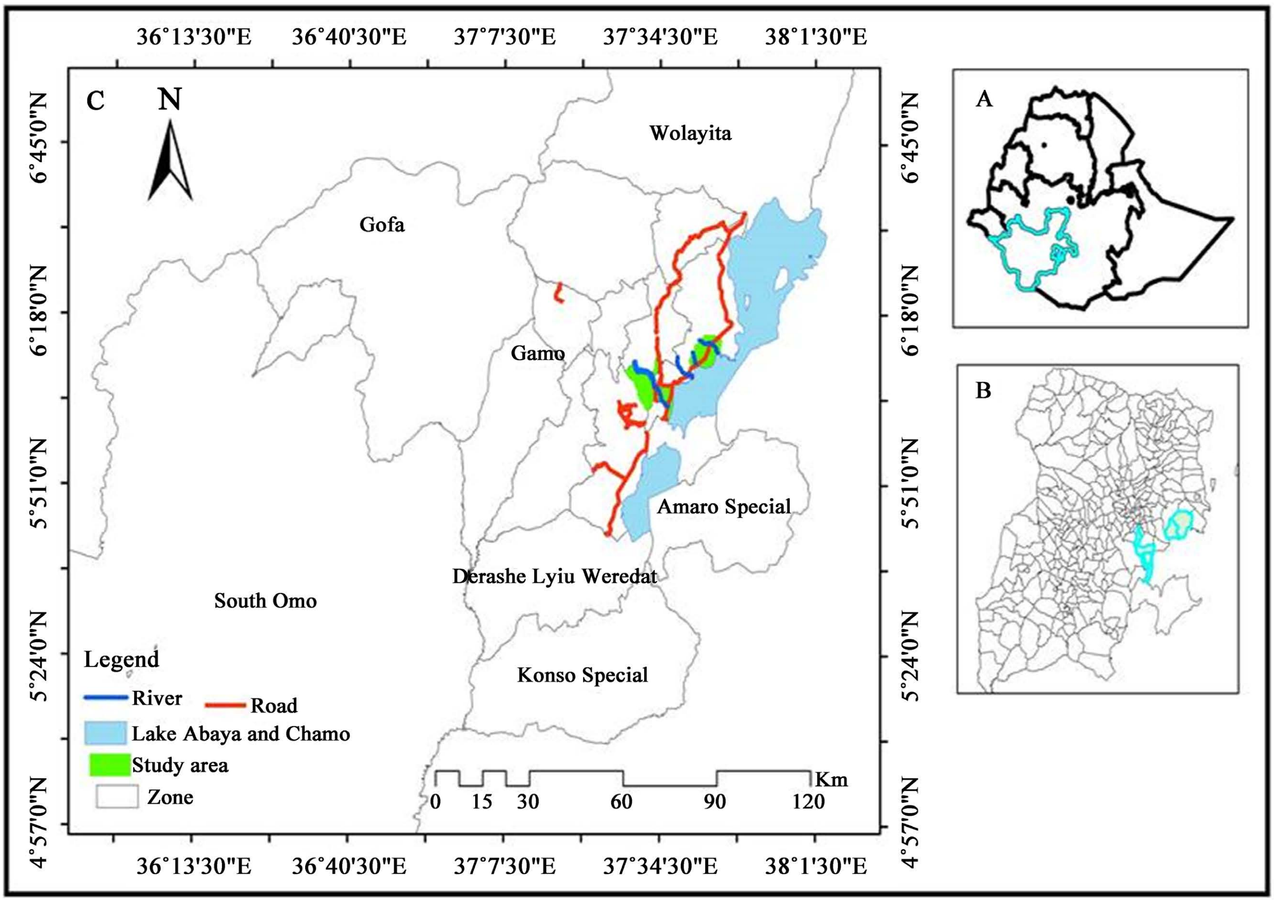

Figure 1. Location map for the study area (A = Ethio-Region, B = Gamo Zone, C =Study area (surrounded Zone, Lakes Abaya and Chamo, Rivers and Roads all weathered)).

of plains and hill sides of the Gamo mountain ridge between 6˚05'N to 6˚12'N and 37˚33'E to 37˚39'E. The elevation of the area ranging from 1168 m to 2535 m a.s.l and the slope of the forest ranges between 0 to 32 degrees.

The Central Statistical Authority [21] report shows that the total size of the population in the study area is 1,825,027 of which 857,266 are males and 967,761 are females.

[1] (2010) described the vegetation of the study area as *Combretum-Terminalia* woodland and wooded grassland, *Acacia-Commiphora* woodland and bushland and Dry evergreen Afromonatne forest. The most common tree species in the area are *Terminalia brownii, Combretum molle, Ziziphus mauritiana, Pappea capensis, Cadaba farinosa, Vachellia spp.* and *Senegalia spp. Balanites aegyptiaca, Commiphora abyssinica, Rhus natalensis, Olea europaea* subsp. c*uspidata, Psydrax schimperiana, Acokanthera schimperi and Juniperus procera.*

The geology of the Western Rift-valley Escarpment is mainly quaternary volcanic alluvial deposits and lacustrine clay [22]. The soil types are classified into sand, sandy clay loam, sandy loam and loam sandy.

The climate of the study area

The climate of the study area and the surrounding is characterized by a prolonged period of dry months and bimodal rainfall pattern which can barely support a vegetation cover that can provide the desired ecological functions and ecosystem services. The maximum and minimum mean annual rainfall for 20 years between 1990-2019 was 1141.1 mm and 491.8 mm, respectively. The maximum and minimum mean annual temperature was 33.6˚C and 15˚C, respectively (**Figure 2**). The prolonged dry periods between two short wet periods imply a high rate of evapotranspiration and desiccation of the soil leading to the predominance of deciduous dry forest.

2.2. Sampling Design and Vegetation Data Collection

A systematic sampling technique was used to collect vegetation data to ensure full coverage of environmental variation and habitat heterogeneity following [23]. One hundred and two main quadrats (plots) were selected to determine the various parameters of the vegetation in the study area.

Thirteen transects parallel to each other and approximately 500 m apart from each other were laid along the altitudinal gradient in the western escarpment of the Rift valley. The sampling quadrats were placed at a regular interval of 200 m between each other beginning from the lowest altitude of the escarpment and extending to the highest altitude. One hundred and two main quadrats, each 20 m × 20 m (400 m^2) quadrats were used. A Modified-Whittaker nested vegetation sampling method [24] was used to collect species richness, cover-abundance, population, height and diameter at breast height (DBH) of tree species at multiple spatial scales, using 1 m^2, and (5 × 5 m) 25 m^2 within a 20 m × 20 m (400 m^2) main quadrat. Data on trees and shrubs were collected in the main quadrats. Data on seedlings and saplings were collected in 25 m^2 sub-quadrats. The sub-quadrats were placed at the four corners and one at the center of the main quadrat.

Height was measured using a Suunto Clinometer and Compass, and DBH was measured using a caliper. Individuals with DBH ≥ 2 cm and height ≥ 1.5 m were

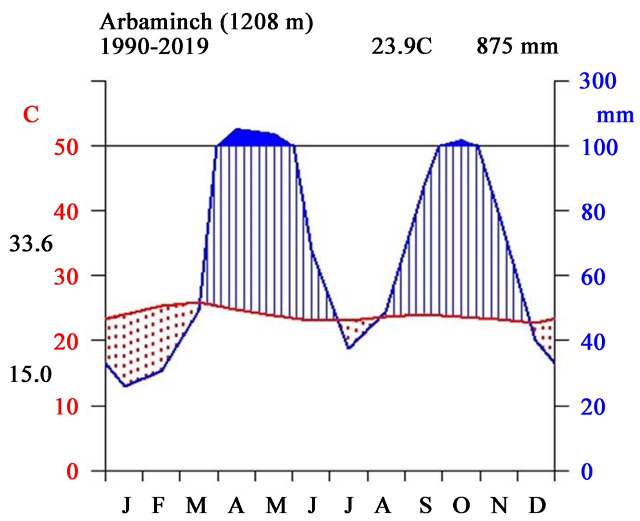

Figure 2. Annual mean maximum and minimum and rainfall in mm (1990-2019).

considered as trees/shrubs. Individuals with DBH between 0.5 cm and 2 cm and height between 0.5 m and 1.5 m were considered as saplings while those with root collar diameter ≤ 0.5 cm and height ≤ 0.5 m were considered as seedlings.

In each quadrat anthropogenic disturbance factors including grazing and disturbance (marks of cutting, fuelwood collection, fire, and charcoal production) were recorded. Impact of grazing intensity class was estimated following [25] [26], as 3 = heavy; 2 = moderate; 1 = lightly; and 0 = not grazed, while the state human activities were estimated following [27] [28] using modified 0 - 3 subjective scale to determine the degree of the impacts of fuelwood collection, charcoal production, selective tree cutting and fire. The sum of all scores for each quadrat was determined following an overall ranking of human disturbances index in each quadrat following [29], (2003).

Geographical location, altitude, slope and aspect (the direction of the slope of the sample quadrat faces) were recorded using a Garmin GPS 72 (±3 m accuracy). Slope (%) was recorded using a Suunto Clinometer and Compass. Aspect was coded following [30] as: North = 0; East = 2; South = 4; West = 2.5 and NW = 1.3.

Voucher specimens of each species encountered in the quadrats and subquadrats were collected, pressed and identified in the National Herbarium of Ethiopia, Addis Ababa University and deposited in the Herbarium of Arba Minch University. Taxonomic nomenclature follows Volumes 2 - 8 of the Flora of Ethiopia and Eritrea [31]-[36].

2.3. Data Analysis

Diversity

Species diversity and evenness of the clusters identified were calculated using the Shannon-Wiener diversity index. The Shannon-wiener diversity index is commonly used to characterize species diversity in a community. Shannon-Wiener's index accounts for both the abundance and evenness of the species present. The proportion of species i relative to the total number of species (p_i) is calculated and then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product is summed across species, and multiplied by −1 compute using Equation (1).

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

where p_i is the proportion of individuals that belong to species i and S is the number of species in the sample.

Shannon's equitability (J) Shannon's equitability (E_H) can be calculated by dividing H by $H_{\max}$ (here $H_{\max} = \ln S$). Equitability assumes a value between 0 and 1 with 1 being complete evenness calculated by Equation (2).

$$\text{Equitability}\left(J\right) = \frac{H}{H_{\max}} = \frac{H}{\ln S} \quad (2)$$

Vegetation Structural

Structural data were analysed using Microsoft excel, R statistical software and performed on the bases of density, DBH, height, frequency, basal area per hectare and IVI were calculated Equation (3)-(10).

Density is a total number of individuals of each species in all the quadrats is divided by the total number of quadrats studied. Density is calculated by the equation:

$$\text{Density} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats studied}} \tag{3}$$

Frequency is calculated by the equation:

$$\text{Frequency}(\%) = \frac{\text{Number of quadrats in which the species occured}}{\text{Total number of quadrats studied}} \times 100 \tag{4}$$

Abundance is represented by the equation:

$$\text{Abundance} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats in which the species occurred}} \tag{5}$$

Basal area (BA): It is the cross-sectional area of tree stems at breast height (1.3 m above ground level). Generally, it is a measure of dominance, which refers to the degree of coverage of species that occupies at ground level [23].

$$\text{BA} = \frac{\frac{1}{4}\pi d^2}{4} \tag{6}$$

where: BA = Basal Area in $m^2\ ha^{-1}$, d = diameter at breast height (m), and $\pi = 3.14$.

Dominance (DO) = total cover or basal area of species A/area sampled.

Importance Value Index is used to determine the overall importance of each species in the community structure. In calculating this index, the percentage values of the relative frequency, relative density and relative dominance are summed up together and this value is designated as the Importance Value Index or IVI of the species [23].

$$\text{IVI} = \text{Relative density} + \text{Relative frequency} + \text{Relative dominance} \tag{7}$$

$$\text{Relative frequency} = \frac{\text{Number of quadrats in which species occurred}}{\text{Total number of quadrats occupied by all species}} * 100 \tag{8}$$

$$\text{Relative density} = \frac{\text{Total number of individuals of the species}}{\text{Sum of all individuals of all species}} * 100 \tag{9}$$

$$\text{Relative Dominance} = \frac{\text{Dominance of given species}}{\text{Total dominance of all species}} * 100 \tag{10}$$

Vertical Structure

The vertical stratification of the tree in the study area was examined using IUFRO classification scheme [37]. According to this scheme, tree with height above 2/3m top height represent upper story, tree with height between 1/3 and 2/3 represent middle story and tree with height < 1/3 represent lower story.

Regeneration status

The regeneration status of some tree species was determined based on the population size of seedlings and saplings following [38] (1987) as:

1) good regeneration if seedlings > saplings > adults;

2) fair regeneration if seedlings > or ≤ saplings ≤ adults;

3) poor regeneration if the species survives only in sapling stage, but no seedlings (saplings may be or = adults).

4) no regeneration if a species is present only in adult form.

5) new regeneration if the species has no adults but only seedlings or saplings.

3. Results and Discussion

3.1. Floristic Composition

A total of 126 species belonging to 90 genera and 43 families were encountered. The floristic composition of the vegetation at the family level includes 10 major families such as Fabaceae (15.87%) Anacardiaceae (5.6%), Euphorbiaceae and Capparidaceae (5.6%) Rubiaceae and Tiliaceae represented (4% each) Acanthaceae, Asteraceae, Celastraceae and Combretaceae represented by 4 (3.2% each) and 32 minor families represented by 0.8% - 2.4% of the total species number. Trees, shrubs and herbs, climbers and lianas constituted 55.6%, 26.2%, 11.9% herbs, 3.2% climbers and 3.2% respectively.

3.2. Vegetation Structure

Frequency

Based on the percentage frequency values, woody plant species were classified into five frequency classes: A = 81 - 100 (2), B = 61 - 80 (3), C = 41 - 60 (4), D = 21 - 40 (16), E = 0 – 20% (101). The most frequently distributed species in the escarpment forest was *Euclea divinorum* (84.3%), followed by *Rhus natalensis* (83.3%), *Terminalia brownie* (74.5%), *Combretum molle* (71.6), *Pappea capensis* (62.8) and *Dodonaea angustifolia* (54.9) (Figure 3).

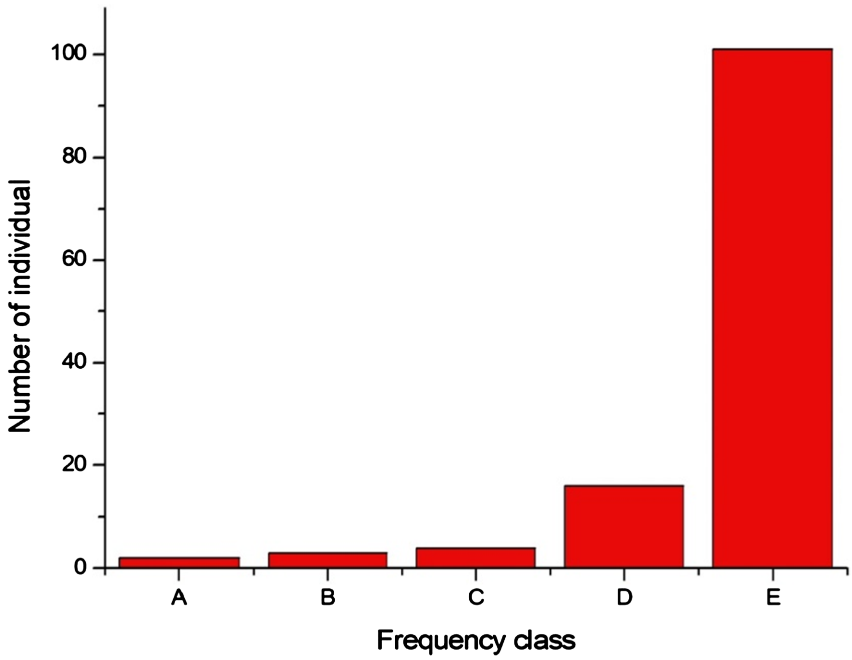

Figure 3. Distribution of species by Frequency class.

Basal area and Dominance

Basal area is the total cross-sectional area of all stems in a stand measured at breast height and expressed as per unit of land area. The total basal area in the study area was 266.01 $m^2 \cdot ha^{-1}$. The total basal area of stems in the study area is low compared to other sites in Ethiopia [39]. The basal area of the ten most important species in the study area was account for 65.64% of the total basal area (**Table 1**).

DBH classes

The DBH data of the woody species were categorized into seven classes (DBH1 = 0 - 5 cm; DBH2 = 5.1 - 10 cm; DBH3 = 10.1 - 15 cm; DBH4 = 15.1 - 20 cm; DBH5 = 20.1 - 25 cm; DBH6 = 25.1 - 30 cm and DBH7 ≥ 30.1 cm). The general pattern of the DBH class distribution in the study area was inverted J shape (**Figure 4**).

Table 1. Basal area and density of the of the ten most important species in the study area

	Scientific Name	Basal area $m^2 \cdot ha^{-1}$	Rank	Density	Rank
1	*Pappea capensis*	36.86	1	44.36	9
2	*Combretum molle*	30.30	2	76.96	6
3	*Terminalii brownii*	25.88	3	89.95	4
4	*Euclea divinorum*	24.09	4	185.78	1
5	*Mystroxylon aethiopicum*	14.08	5	28.68	12
6	*Olea europaea* subsp. cuspidata	12.83	6	72.55	7
7	*Senegalia mellifera*	9.89	7	22.55	14
8	*Balanites aegyptiaca*	9.52	8	4.90	41
9	*Sclerocarya birrea*	5.60	9	7.35	36
10	*Cadaba farinosa*	5.58	10	21.57	15

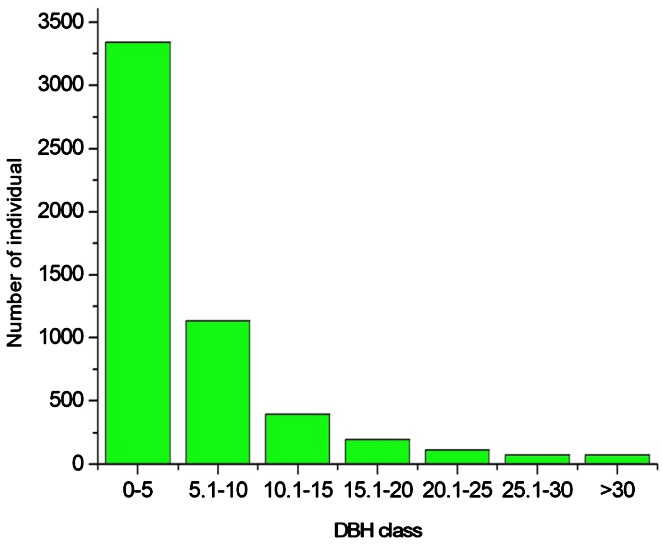

Figure 4. DBH class distribution in the study area.

Stems with DBH ≤ 5 cm constituted the highest density (6462.04/ha^{-1} or 62.5%) while those with DBH ≥ 25 cm had the lowest density with 88.4/ha^{-1} (5.1%) (Table 1). Three different patterns (Inverted J-shape, J-shape, and Irregular shape) were manifested by nine species with high basal area in the five community types (Figure 5). Among the ten species with the highest DBH *Pappea capensis, Combretum molle, Terminalii brownii, Euclea divinorum, Olea europaea subsp. cuspidata, Senegalia mellifera* manifested inverted J shape*. Balanites aegyptiaca* manifested J shape and *Scrocarya birrea* manifested irregular shape.

Height distribution

The height classes were classified into six categories (H_1 = 0 - 2.5 m; H_2 = 2.6 - 5.0 m; H_3 = 5.1 - 7.5 m; H_4 = 7.6 - 10 m; H_5 = 10.1 - 12.5 m and H_6 ≥ 12.6 m). The height distribution of the species in the study area is suggestive of scattered trees with short to medium-high trees breaking the uniformity of the low sclerophyllous vegetation cover (Figure 6).

Importance Value Index

Importance Value Index (IVI) analysis of all woody species distribution of the study areas were grouped in to four IVI classes based on their total IVI values (IVI_1 ≤ 1, IVI_2 between 1.1 - 5; IVI_3 between 5.1 - 10 and IVI_4 ≥ 10.1). The results revealed that IVI_1 ≤ 1 had 65% of total species and IVI ≥ 5.1 had contained only 8 species and contributed 6.34%. Species with high IVI value *Pappea capensis* (17.73), *Combretum molle* (15.75), *Terminalia brownie* (14.23), *Euclea divinorum* (14.18). On the other hand, about eighty two (82) species each has less than 1% IVI values, for example, *Abutilon figarianum* (0.17), *Polyscias fulva* (0.17), *Calpurnia aurea* (0.11) and *Aloe calidophila* (0.11).

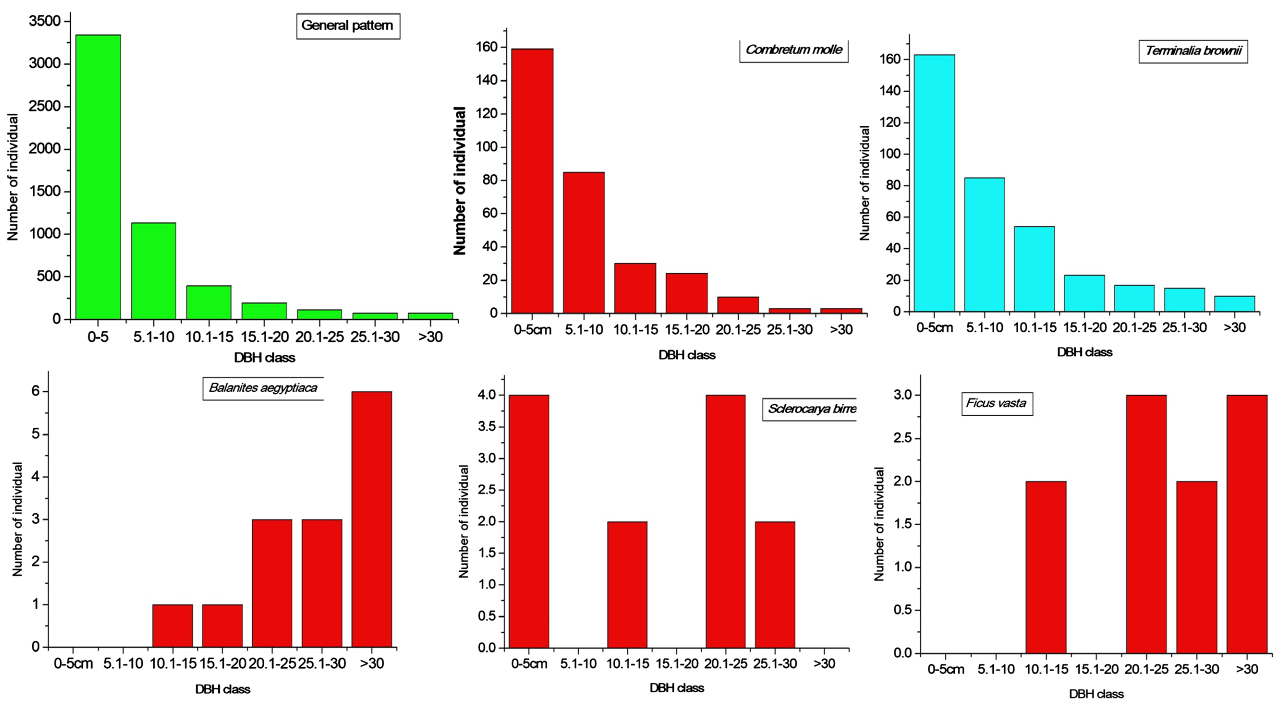

Figure 5. Selected six species DBH class distribution.

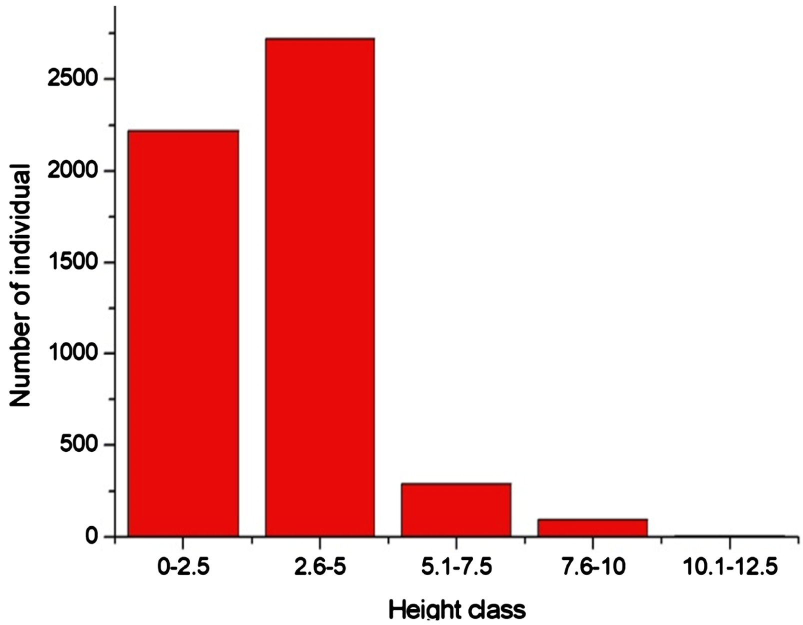

Figure 6. Height distribution of the study area.

Table 2. Density and species number in the western escarpment.

Stratum	Height (m)	Density (steam/ha)	%	No species	%	ratio
Lower	2 - 5	4131	91.3	68	54	60:1
Middle	5.1 - 10	388	8.5	49	38.9	7:1
Upper	≥10.1	9	0.2	9	7.1	1:1

Vertical stratification of the western escarpment

The vertical stratification of the trees and shrubs in the study area represent mainly lower story which is 91.3% of the individuals followed by the middle (8.5%) and upper (0.2%) (Table 2).

Regeneration status

The seedling and sapling stages were represented by 49 species belonging to 39 genera and 23 families in the study area. Only a few tree species in the study area had saplings and seedlings underneath them. The species with high sapling and seedling density include *Terminalia brownie* (77.45 $m^2 \cdot ha^{-1}$), *Olea europaea* subsp. *cuspidata* (48.78 m^2ha), *Pappea capensis* (41.2 $m^2 \cdot ha^{-1}$), *Mystroxylon aethiopicum* (29.7 $m^2 \cdot ha^{-1}$) and *Dichrostachys cinerea* (17.9 $m^2 \cdot ha^{-1}$). The total mature tree, sapling and seedling density in the study area is shown in Figure 7. The result shows that not all seedlings are recruited to maturity as a result of the constraints imposed by browsing, desiccation, and other biological, climatic, edaphic, and anthropogenic influences.

4. Discussion

Species in families Fabaceae and Anacardiaceae were the most frequently occurring species in the vegetation of the study area. Most species in the family Fabaceae and

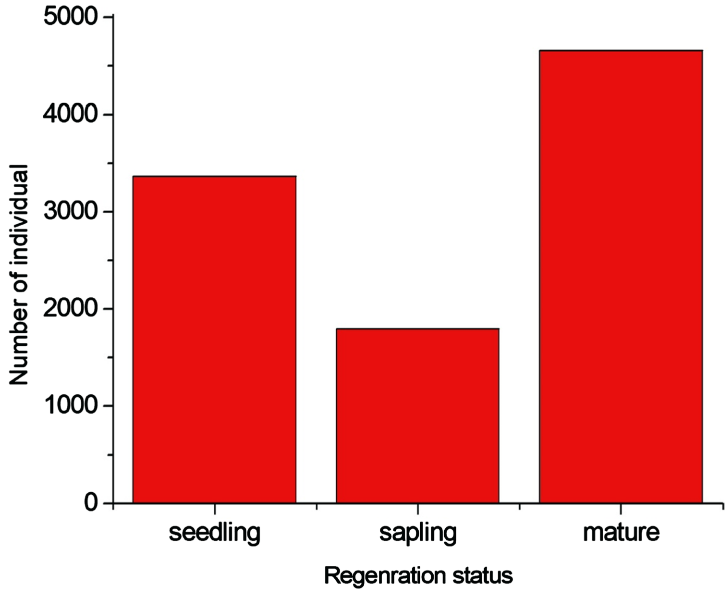

Figure 7. Regeneration status of the study area.

Asteraceae are drought-tolerant, deciduous, and well adapted to the climatic conditions of the ecological and agro-ecological zones of Ethiopia. Both these plant families are among the families with high species richness in the Flora of Ethiopia and Eritrea [40]. Fabaceae and Asteraceae show frequent occurrence in vegetation probably due to their efficient pollination and successful seed dispersal mechanisms that might help them to adapt to a wide range of ecological conditions [41].

The frequency gives an approximate indication of the homogeneity and heterogeneity of a stand. The escarpment forest has 80.15% of species in the lower frequency class E, in the middle class (D) 12.69% of species presented and in the higher frequency classes (A, B and C) 7.14% of species were presented. Two species belongs to the frequency class A; frequency class B, C and D, 3, 4 and 16 species represented respectively. On the other hand, the lower frequency class (E) comprised 101 species. Based on the description of [37], the percentage frequency of the present study revealed high degree of floristic heterogeneity. This might be associated with a bimodal rainfall patterns and to reduced reproduction (that is, flower production, pollination and seed production).

The cumulative DBH class distribution of the western escarpment of the Rift valley showed that inverted J-shaped pattern. The lower density of DBH individuals (DBH ≤ 5 cm) has large proportion than large sized individuals (DBH ≥ 25.1 cm). These were showed that western escarpment of the Rift valley has high density, which indicated that there are more dominance of lower and medium sized DBH class. This might be associated with the selective cutting of species for fuel wood collection, local house building (hat house), charcoal production and others. Similar results were observed in [21] [42] [43] [44] [45].

Selected six species showed that three pattern of vegetation structure of the study area. The first pattern was inverted J-shape pattern, *Combretum molle,* *Euclea divinorum, Ochna inermis*, *Olea europaea subsp. Cuspidata, Pappea capensis* and *Terminalia browni*, this means high number of individuals in the lower DBH size classes and low number of individuals in the higher DBH size classes.

The second pattern was J-shape and displayed by *Balanites aegyptiaca*, with low number of individuals in the lower DBH size classes and high number of individuals in the higher DBH size classes. This might be species are harvested at an early growth stage by the local people for charcoal production, live fence and construction of houses. Several studies were reported in the different region of Ethiopia for [46] in the Sheko forest; [43] in the Hallideghie wildlife reserve; [47] Vegetation Ecosystem of Ethiopia; [44] in the boda dry evergreen Montana forest; [48] in the rangeland of Southeast Ethiopia and [49] in the Kimphe Forest.

Last but not least, Species, such as *Scrocarya birrea* showed relatively irregular-shape with irregular number of individuals in the different DBH classes. Those species which manifested irregular patterns indicate that stems of these species are harvested for various domestic uses at any stage as found fit for the purpose.

The height distribution of the study area is seems like inverted J-shaped. This shown that lower height class of large-sized individuals and the upper height classes a few number of individual. This implies that the western escarpment of the Rift valley presence of small number of adult trees for reproduction and clearing mature trees for different purposes such as house construction, charcoal production and expansion of agriculture and settlement. This agree with those of [43] [47] [50] [51] in the afromontane forests of Ethiopia, Vegetation Ecosystem of Ethiopia, Hallideghie wildlife reserve and Shello Giorgis dry Afromontane forest, respectively.

The result indicates that high IVI was attributed to few species. These species are those which are well adapted to the high pressure of disturbance, natural and environmental factors as well as the effect of local communities. In contrast to this idea, almost all species in this study showed variation in terms of their IVI, showing different ecological importance of each species in the escarpment forest. 6.34% Species were recorded IVI values between 5.1 - 10 and ≥10.1, 28.57% of species were recorded in IVI between 1.1 - 5 and the rest of 65.08% species with IVI values < 1. In our study, basal area analysis across individual species revealed that very few species had high dominance. A species having value of IVI ≥ 5.00 can be considered dominant because of the relative ecological role it plays in the ecosystem [23]. As indicated in IUFRO classification scheme [37], IVI value is used for comparison of ecological significant of species in which high IVI values indicate that the species structure in the community is high.

The results revealed that the lower story was representing 91.3% of the individuals followed by the middle (8.5%) and upper (0.2%)). This type of distribution might be explained by the fact that species with overlapping size distributions can coexist as a result of differences in maximum attainable size. The presence of difference in tree height is one of the adaptive morphological bases for their high degree of floristic heterogeneity. This suggests that short species are likely to allocate more to radial growth, thereby acquiring the physical stability needed to survive in the western escarpment [37].

The composition, distribution and density of seedlings and saplings are an indicator for the future habitat conditions, geographical distribution, composition, successful regeneration and survival and growth within space and time [52] [53]. The density of saplings (440.2 ha^{-1}) and seedlings (825.49 ha^{-1}) were dominated by few species. 50 species (48.5%) were not represented by both seedlings and saplings but, it was represented by mature individuals. On the other hand, 3 species (2.9%) were no seedlings and/or saplings represented. Finding of this work shown seedlings were greater than that of sapling, but less than mature trees. Similar findings were also reported by [54] [55] [56] Ratios of seedlings to saplings = 1.88:1, seedlings to mature trees and shrubs = 0.72:1, saplings to mature trees and shrubs = 0.39:1. This indicated that less number of saplings was recorded than that of the seedling and mature trees and shrubs. Even though the density of seedlings which is greater than that of the saplings and less than mature trees and shrubs indicates as the vegetation is in a fair regeneration status, the density of saplings has not followed similar trend. Accordingly, the distribution pattern where the density of the mature trees and shrubs exceeded the total density of the seedling and saplings shows that the regeneration status of the studied vegetation is at a fair state [38].The density of seedlings obtained from the study area was less than the report made by [57] [58] [59] [60]. This could be due to the high exposure of the escarpment for grazing, selective tree cutting, agriculture expansion and settlement. Those species without saplings and seedlings are vulnerable to local extinction in the escarpment and if conservation measures are not introduced shortly, a loss of species diversity and the associated components of biodiversity could be inescapable.

5. Conclusions

The results of the study indicated that the study in the western escarpment of the Rift valley had relatively high woody species diversity and was dominated by small sized tree and shrub species in secondary stage of development, indicating that the western escarpment of the Rift valley was heavily exploited and affected in the previous periods and now going on pressure.

Fabaceae is the most dominant family in terms of species number represented by 20 (15.87%). DBH class ≤ 5 cm had highest density (63.63%) and DBH ≥ 25.1cm had the lowest density (0.87%). The density of woody species decreases with increasing DBH and height, indicating the predominance of small-sized individuals in the area.

Three population patterns have been observed; inverted J, J-shaped and irregular shaped. Species with high IVI values were recorded like *Pappea capensis* (17.73), *Combretum molle* (15.75), *Terminalia brownie* (14.23), *Euclea divi-*

norum (14.18). In the study area three vertical structures were classified and lower story was represented by 91.3% of the individuals followed by the middle (8.5%) and upper (0.2%).

Regeneration analyses of woody species were dominated by few species and most of the tree species were without seedling and sapling stage. However, some tree species are represented by all stages (seedling, sapling, and mature trees).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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