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ORIGINAL ARTICLE

Vegetation structure and regeneration status of the western escarpment of the rift valley of the Gamo zone, southern Ethiopia

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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 the structure and regeneration status of the study area. A systematic sampling method was used to collect vegetation data from 102 quadrats, each 20 × 20 m (400 m^2) and five 1 × 1 m (1 m^2) sub-quadrats at the four corners and the center 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 analyze 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. The most frequent species were *Euclea divinorum* (84.3%), followed by *Rhus natalensis* (83.3%), *Terminalia brownii* (74.5%). DBH class ≤ 5cm had the 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% had IVI values ≥ 5.28. *Pappea capensis*, *Combretum molle*, *Terminalia brownii*, *Euclea divinorum* had the highest IVI values. The lower story was 91.3% of the individuals in the vertical stratification. 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, to revert the current forest structure and regeneration to the previous natural state, it is considered important to minimize the influence of human interference, grazing, and raising awareness to the surrounding community.

Keywords: Importance value index, Regeneration, Seedling/sapling, Vegetation structure.

Introduction

Diverse physiographic, altitudinal, climatic, and edaphic differences enable Ethiopia to have various vegetation types ranging from alpine to desert plant communities (Friis et al., 2010, Friis and Sebsebe, 2001; Friis, 1992; Sahle, 1984; White, 1983) and the species therein that provide economic, sociocultural, and environmental benefits. As a result, Ethiopia is endowed with rich flora and fauna, making the country an essential center of diversity and endemism (Zerihun et al., 2002 and Zewge and Healey, 2001). It has the fifth-highest biodiversity in Africa (Anonymous, 1997).

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 1981-1990 (FAO, 1993) to 1% between 1990-2000 (FAO, 2001). The annual deforestation rate in Ethiopia exceeds 0.8% (FAO, 2010).

Forest coverage in Ethiopia has been threatened by habitat conversion, loss, and fragmentation that occurred over the past many years (Logan, 1946; Bonnefille and Buchet, 1986; Darbyshire et al., 2003). The forests covered about 35% of the land area in the early 19th century (EFAP, 1994); 16% in the 1950s, reduced to 3.6% in 1980 and 2.7% in 1989 (EPA, 2002 and FOA, 2003). The remaining forest resources of the country are found in areas in the western and southwestern parts of Ethiopia, mainly not unduly affected by human settlements and a human disturbance (Gessesse and Kleman, 2007).

The threats are converting natural forests into grazing lands, woodlands, and wetlands to agriculture and settlement in Ethiopia (IBC, 2014; Tesfaye et al., 2001; 2003). 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 forest's sustainability in the escarpment (Sebsebe and Friis, 2009; NBSAP, 2005).

The study area is facing rapid deforestation and degradation of forest resources (Desalegn and Zerihun, 2005) 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 these 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.

Materials and Methods

Description of the study area

The study was carried out in the western escarpment of the rift valley of the Gamo Zone, Southern Ethiopia (Fig. 1). Topographically, the study area consists of plains and hillsides of the Gamo mountain ridge between 6°05'N to 6°12'N and 37°33'E to 37°39'E. The area's elevation ranges from 1168 m to 2535 m a.s.l, and the slope of the forest ranges between 0 to 32 degrees.

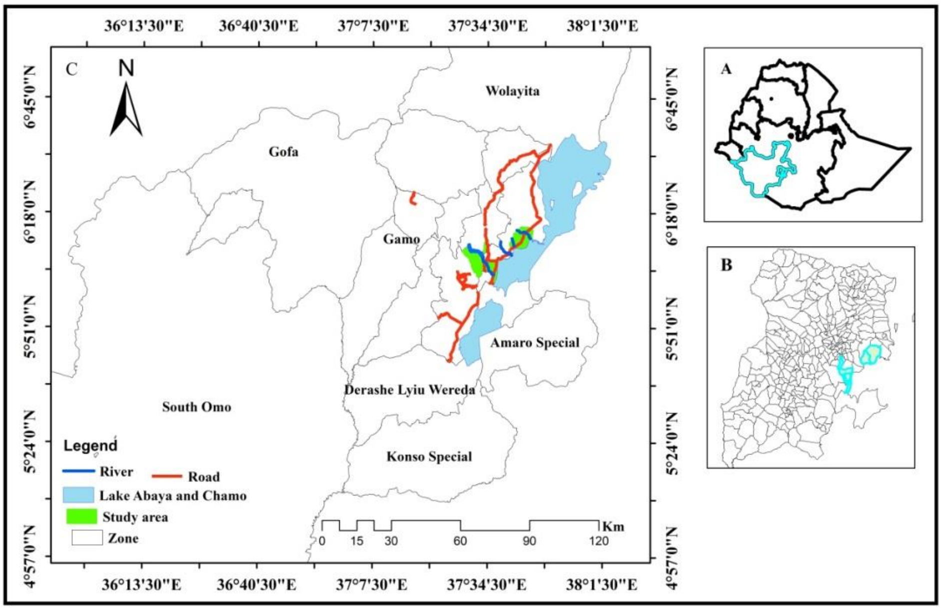

Fig. 1. Location map for the study area (A=Ethio-Region, B=Gamo Zone, C=Study area (surrounded Zone, Lakes Abaya and Chamo, Rivers and Roads all weathered)).

The Central Statistical Authority (CSA) (2019) 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.

Friis et al. (2010) described the vegetation of the study area as *Combretum-Terminalia* woodland and wooded grassland, *Acacia-Commiphora* woodland and bushland and Dry evergreen Afromontane 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 (Mateos et al., 2003). The soil types are classified into the sand, sandy clay loam, sandy loam and loam sandy.

The climate of the study area

The climate of the study area and surroundings are 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 (Fig. 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 dry deciduous forest.

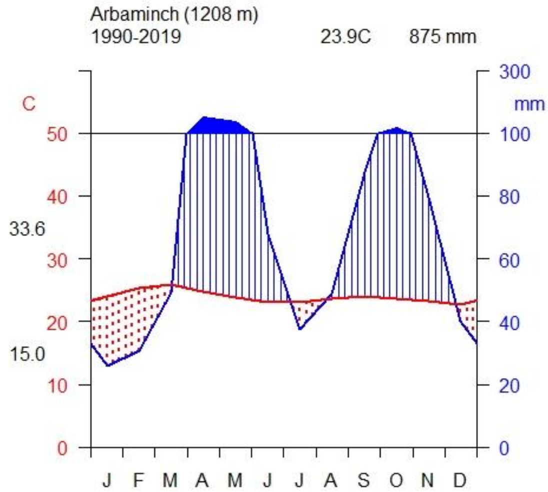

Fig. 2. Annual mean maximum and minimum and rainfall in mm (1990-2019).

Sampling design and vegetation data collection

A systematic sampling technique was used to collect vegetation data to ensure complete coverage of environmental variation and habitat heterogeneity following Kent and Coker (1992). One hundred and two main quadrats (plots) were selected to determine the various parameters of the vegetation in the study area.

A Modified-Whittaker nested vegetation sampling method (Shmida 1984) 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 m2, and (5 × 5 m) 25 m^2 within a 20 m × 20 m (400 m^2) main quadrat. 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 quadrants, each 20 m × 20 m (400 m^2) quadrats, were used. 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 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 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 saplings, while those with root collar diameter ≤0.5 cm and height ≤0.5 m were considered seedlings.

In each quadrat, anthropogenic disturbance factors, including grazing and disturbance (cutting marks, fuelwood collection, fire, and charcoal production), were recorded. Impact of grazing intensity class was estimated following Kebrom et al. (1997) and Zerihun and Backeus (1991), as 3=heavy; 2=moderate; 1=lightly; and 0=not grazed, while the state human activities were estimated following Leul et al. (2010) and Kumelachew and Tamrat (2002) 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 Venkateswaran and Parthasarathy (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 Zerhun et al. (1989) as: North=0; East=2; South=4; West=2.5 and NW=1.3.

Voucher specimens of each species encountered in the quadrats and sub-quadrats were collected, pressed, and identified in the National Herbarium of Ethiopia, Addis Ababa University, and deposited in the Herbarium Arba Minch University. Taxonomic nomenclature follows Volumes 2-8 of the Flora of Ethiopia and Eritrea (Hedberg and Edwards, 1989; Edwards et al., 1995; 1997;m2000, Hedberg et al. 2003; 2006; Mesfin, 2004).

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 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 computed using Equation 1.

$$H' = \sum_{i}^{S} \mathrm{pi} \ln(pi) \text{ ....(1)}$$

Where *pi* 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.

Equitability (J) $=\frac{\mathrm{H}}{\mathrm{Hmax}}=\frac{H}{lnS}$ ......(2)

Vegetation structural

Structural data were analysed using Microsoft Excel, R software and performed based on density, DBH, height, frequency, basal area per hectare and IVI were calculated Equations 3-10.

Density is the 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:

Density$=\frac{Total\ number\ of\ individuals\ of\ a\ species\ in\ all\ quadrats}{Total\ number\ of\ quadrats\ studied}$ ....(3)

Frequency is calculated by the equation:

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

Abundance is represented by the equation:

Abundance$=\frac{Total\ number\ of\ individuals\ of\ a\ species\ in\ all\ quadrats}{Total\ number\ of\ quadrats\ in\ which\ the\ species\ occurred}$ ....(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 occupy at ground level (Kent & Coker, 1992).

BA$=\frac{¼\ \pi d2}{4}$ ......(6)

Where: BA=Basal Area in $m^2\ ha^{-1}$, d=diameter at breast height (m), and π=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 (Kent and Coker, 1992; Curtis, 1959).

IVI=Relative density+Relative frequency+Relative dominance (7)

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

Relative density$=\frac{Total\ number\ of\ individual\ s\ of\ the\ species}{Sum\ of\ all\ individual\ s\ of\ all\ species}$*100 (9)

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

Vertical structure

The vertical stratification of the tree in the study area was examined using IUFRO classification scheme (Lamprecht, 1989). According to this scheme, trees with height above 2/3m top height represent upper story, trees with height between 1/3 and 2/3 represent middle story, and trees 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 Khan et al. (1987) as:

i. Good regeneration if seedlings>saplings>adults;
ii. Fair regeneration if seedlings>or≤saplings≤adults;
iii. Poor regeneration if the species survives only in the sapling stage, but no seedlings (saplings may be or=adults).
iv. No regeneration if a species is present only in adult form.
v. New regeneration if the species has no adults but only seedlings or saplings.

Results and Discussion

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 significant 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.

Vegetation structure

Frequency

Based on the percentage frequency values, woody plant species were classified into five frequency classes: A=81-100, B=61-80, C=41-60, D=21-40, E=0-20%. 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) (Fig. 3).

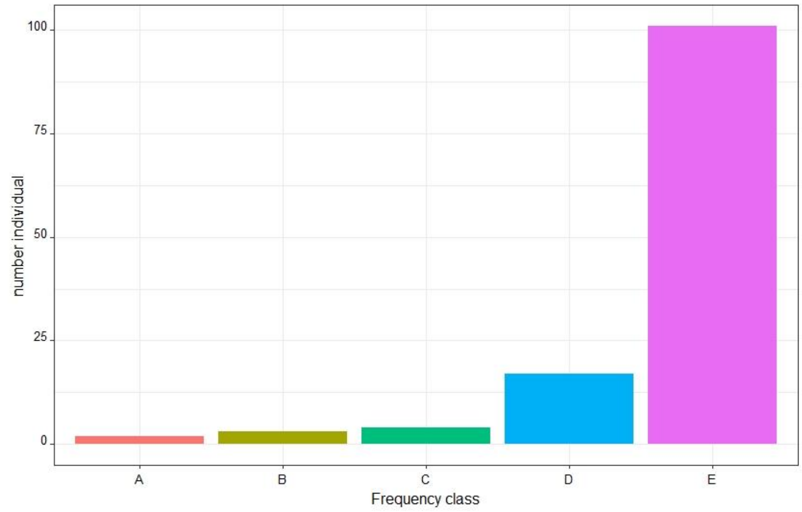

Fig. 3. Distribution of species by frequency class.

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^2ha^{-1}. The total basal area of stems in the study area is low compared to other sites in Ethiopia (Semegnew, et al, 2021). The basal area of the ten most essential species in the study area accounted for 65.64% of the total basal area (Table 1).

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

	Scientific Name	Basal area m^2ha^{-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

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 (Fig. 4).

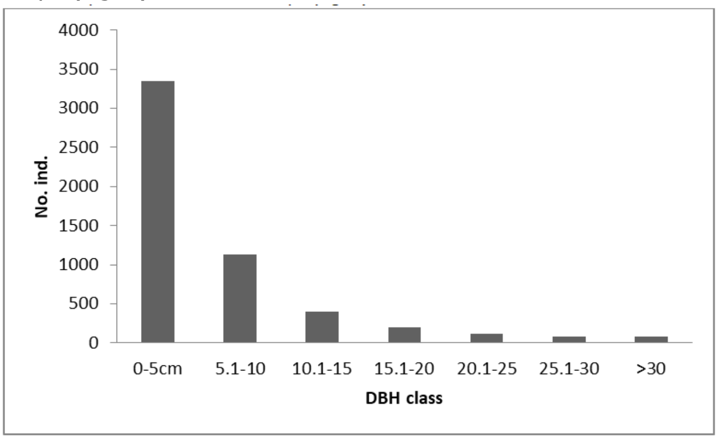

Fig. 4. DBH class distribution in the study area.

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%) (Table1). 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 (Fig. 5). The ten species with the highest DBH Pappea capensis are

Combretum molle, Terminalii brownii, Euclea divinorum, and *Olea europaea subsp. cuspidata, Senegalia mellifera* manifested inverted J shape. *Balanites aegyptiaca* manifested J shape and *Scrocarya birrea* manifested irregular shape.

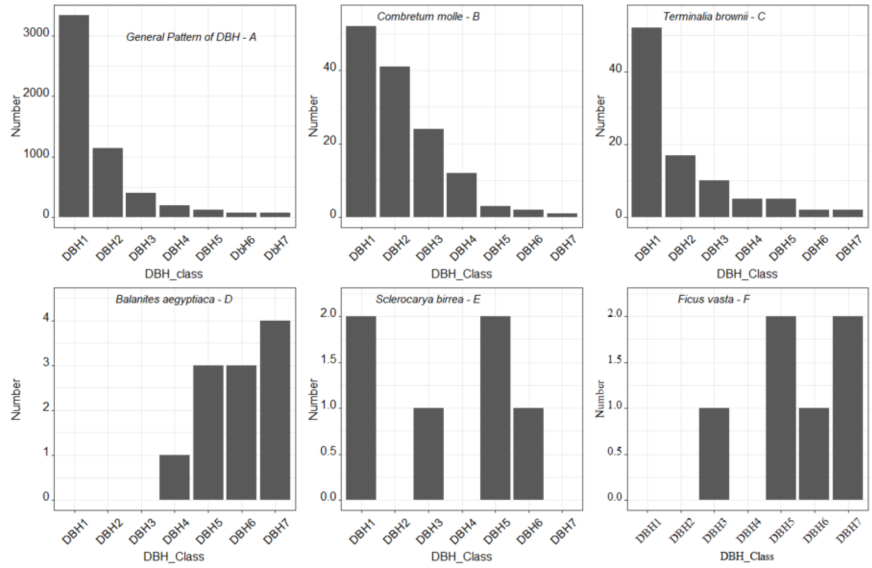

Fig. 5. Selected six species DBH class distribution.

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 $H_6 \geq$ 12.6 m). The height distribution of the species in the study area suggests scattered trees with short to medium-high trees breaking the uniformity of the low sclerophyllous vegetation cover (Fig. 6).

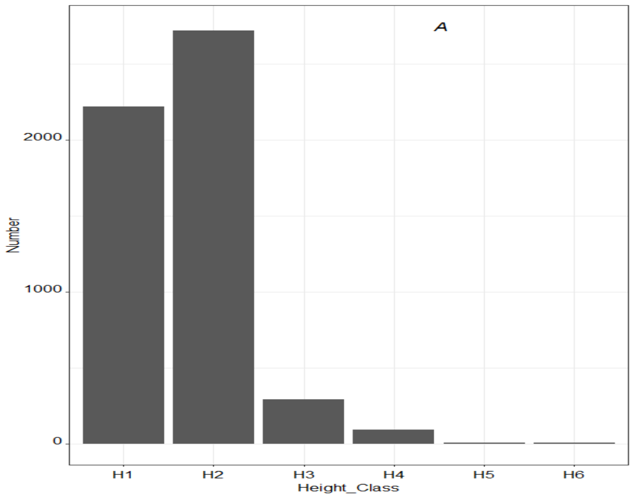

Fig. 6. Height distribution of the study area.

Importance value index

Importance Value Index (IVI) analysis of all woody species distribution of the study areas were grouped into four IVI classes based on their total IVI values ($IVI_1 \leq 1$, IVI_2 between 1.1-5; IVI_3 between 5.1-10 and $IVI_4 \geq 10.1$). The results revealed that $IVI_1 \leq 1$ had 65% of the total species and IVI ≥ 5.1 had 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 have less than 1% IVI values, for example, *Abutilon figarianum* (0.17), *Polyscias fulva* (0.17), *Calpurnia aurea* (0.11) and *Aloe calidophila* (0.11).

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).

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

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^2ha^{-1}), *Olea europaea* subsp. *cuspidata* (48.78 m^2ha), *Pappea capensis* (41.2 m^2ha^{-1}), *Mystroxylon aethiopicum* (29.7 m^2ha^{-1}) and *Dichrostachys cinerea* (17.9 m^2ha^{-1}). The total mature tree, sapling and seedling density in the study area is shown in Fig. 7. The result shows that not all seedlings are recruited to maturity due to the constraints imposed by browsing, desiccation, and other biological, climatic, edaphic, and anthropogenic influences.

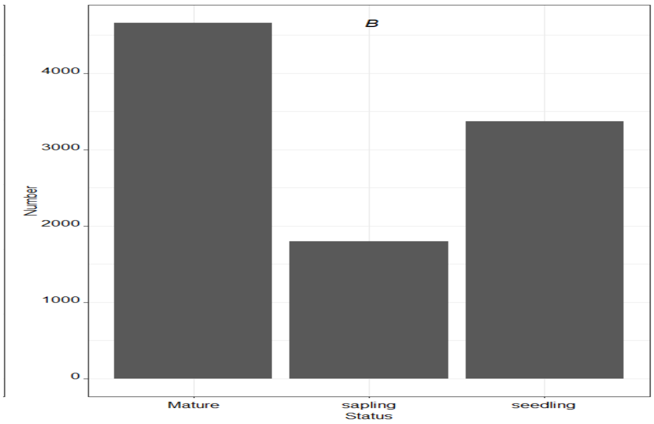

Fig. 7. Regeneration status of the study area.

Discussion

Species in families Fabaceae and Anacardiaceae were the most frequently occurring species in the vegetation of the study area. These plant families are among the families with high species richness in the Flora of Ethiopia and Eritrea (Enserum and Sebsebe, 2014). Most species in the family Fabaceae and Asteraceae are drought-tolerant, deciduous, and well adapted to the climatic conditions of Ethiopia's ecological and agro-ecological zones. 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 (Enserum and Teshome, 2008).

The frequency gives an approximate indication of the homogeneity and heterogeneity of a stand. Two species belong to the frequency class A; frequency class B, C and D, 3, 4 and 16 are represented, respectively. 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. On the other hand, the lower frequency class (E) comprised 101 species. Based on the description of Lamprecht (1989), the percentage frequency of the present study revealed a high degree of floristic heterogeneity. This might be associated with bimodal rainfall patterns and reduced reproduction (that is, flower production, pollination, and seed production).

The cumulative DBH class distribution of the western escarpment of the Rift valley showed an inverted J-shaped pattern. 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. The lower density of DBH individuals (DBH ≤ 5cm) has a large proportion than significant-sized individuals (DBH ≥ 25.1 cm). This might be associated with selective species cutting for fuelwood collection, local house building (hat house), and charcoal production. Similar results were observed in Girma and Melesse, 2020; Ahmed et al., 2017; Fikadu et al., 2014; Feyera et al., 2007; Feyera and Demel, 2001.

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

The second pattern was J-shape and displayed by *Balanites aegyptiaca*, with a low number of individuals in the lower DBH size classes and a 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 regions of Ethiopia, for example, Feyera et al. (2007) in the Sheko forest; Ahmed et al. (2017) in the Hallideghie wildlife reserve; Debissa et al. (2017) Vegetation Ecosystem of Ethiopia; Fikadu et al. (2014) in the boda dry evergreen Montana forest; Teshome et al. (2012) in the rangeland of Southeast Ethiopia and Feyera and Demel, (2003) in the Kimphe Forest.

Last but not least, species, such as *Scrocarya birrea* showed relatively irregular-shape with an 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 seems inverted J-shaped. This shows that the lower height class of large-sized individuals and the upper height classes a few numbers of individuals. This implies that the western escarpment of the Rift valley presence of a 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 agrees with those of Feyera et al. (2014); Debissa et al. (2017); Ahmed et al. (2017) and Tensay et al. (2020) 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 well adapted to the high pressure of disturbance, natural and environmental factors, and the effect of local communities. In contrast to this idea, almost all species in this study showed variation in terms of their IVI, showing the different ecological importance of each species in the escarpment forest. 6.34% of 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 very few species had high dominance. A species with a value of IVI ≥ 5.00 can be considered dominant because of its relative ecological role in the ecosystem (Kent and Coker 1992). As indicated in IUFRO classification scheme (Lamprecht, 1989), IVI value is used for comparison of the ecological significance 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 (Lamprecht, 1989).

The composition, distribution, and density of seedlings and saplings indicate future habitat conditions, geographical distribution, composition, successful regeneration, and survival and growth within space and time (Khumbongmayum et al., 2005; Good and Good, 1972). The density of saplings (440.2 ha^{-1}) and seedlings (825.49 ha^{-1}) were dominated by a few species. Both seedlings and saplings did not represent 50 species (48.5%) but were represented by mature individuals. On the other hand, 3 species (2.9%) were not represented by seedlings and/or saplings. A finding of this work showed seedlings were more significant than that of the sapling but less than mature trees. Similar findings were also reported by Dereje (2007), Simon and Girma (2004), and Teshome (2009). 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 fewer saplings were recorded than that of the seedling and mature trees and shrubs. Even though the density of seedlings greater than that of the saplings and less than mature trees and shrubs indicates that the vegetation is in a fair regeneration status, the density of saplings has not followed a 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 (Khan et al., 1987). The density of seedlings obtained from the study area was less than the report made by Annissa and Eyasu (2020); Nesibu et al. (2019), Abiyou (2018), Abiyot et al. (2017), and Gebremicael et al. (2013). 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.

Conclusion

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 the 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 species number represented by 20 (15.87%). DBH class ≤ 5 cm had the highest density (63.63%), and DBH ≥ 25.1 cm 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 divinorum* (14.18). In the study area, three vertical structures were classified, and the lower story was represented by 91.3% of the individuals, followed by the middle (8.5%) and upper (0.2%).

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

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