Floristic Composition of Harla-Ija Aneni Valley and Mountain Complex in the Semi-arid Ecosystem of Dire Dawa, Eastern Ethiopia

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Abstract

Background: The landscape of Harla-Ija Aneni Valley and Mountain Complex are inhabited by rich floristic diversity with endemism. However, the recurrent drought and over-exploitation of plant resources, coupled with increasing human population in the area, has been severely affecting the vegetation of these complex semi-arid ecosystems, which require research-based intervention.

Objective: The objective of this study was to analyse the floristic composition, vegetation structure and diversity of Harla-Ija Aneni valley and mountain complex landscapes to support the on-going dry land restoration efforts undertaken in the study area.

Material and Methods: A total of 58 quadrats each measuring 20 m x 20 m for trees, 5 m x 5 m for shrubs and woody climbers, and 1m x 1m for herbs and grasses were used to collect floristic data such as height and diameter at breast height (DBH) of woody species and type and number of plant species. Shannon-Weiner Diversity Index, richness, and evenness were used to analyse the vegetation data.

Results: A total of 121 plant species belonging to 91 genera, and 48 families were identified, of which 10 species (8.3%) were endemic. Poaceae and Fabaceae were represented by higher number of species (11 species = 9.09%) each. Species richness, Shannon-Wiener Diversity Index (H`), and evenness values for the entire study area were 121, 3.12 and 0.38, respectively. Average basal area of woody species in the study area was 2.10 m^2 ha^{-1}, higher density at lower diameter class. The diameter and height class distribution of the woody species exhibited inverted J-shaped distributions, which indicate a continuous and good regeneration status. The three community types were: *Acacia tortilis-Rhus natalensis*, *Ficus vasta-Acacia brevispica* and *Psychotria orophila-Canthium pseudosetiflorum*.

Conclusions and Implications: It is concluded that the study area harbours many native endemic plant species and taxonomic diversity. The results indicate that this unique landscape possesses ecologically and economically important plant species, which could be used as a provenance to establish semi-arid natural vegetation genetic resource centers in eastern Ethiopia. Therefore, the floristic diversity should be conserved to enhance ecosystem services.

Keywords: Basal area; Dry land restoration; Endemic plant species; Genetic resource; Ecosystem services

1. Introduction

Natural vegetation provides a wide range of ecological, economic, social, and cultural services and processes (Lewis *et al*., 2015). However, the natural ecosystems are severely threatened by climate change and population pressure which have resulted in severe biodiversity loss at the global level and substantial loss in the tropics (FAO, 2022; Taylor *et al*., 2022). The tropical vegetation systems have been known to exhibit multi-stability and structural dynamics due to a broad ranges of drivers and impacts such as climate change, land degradation, biodiversity loss, and desertification (Winkler *et al*., 2021; Bert and Jan, 2023).

Ethiopia is known as an important global centre of origin of biodiversity and diversity for a significant number of natural and cultivated plant species and their wild relatives as well as animals due to its dramatic geological history, broad latitudinal spread, and vast altitude ranging from 125 m below sea level to 4,533 m above sea level (Friis *et al*., 2011; Sebsebe Demissew *et al*., 2021). These diverse physiographic, altitudinal, climatic, and edaphic variation allow the country to have various vegetation types ranging from alpine to desert plant communities (Friis *et al*., 2011). The flora of Ethiopia encompasses above 6,027 vascular plant species 647 of which are endemic (Sebsebe Demissew *et al*., 2021). The country is the fifth largest

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floral composition in tropical Africa (Motuma Didita *et al.*, 2010) and the diversified vegetation provides varied economical, socio-cultural, and environmental benefits. Nonetheless, regardless of the economic and environmental benefits, the natural vegetation cover of Ethiopia has generally declined from 13.78% to 11.40% from 1990 to 2015 mainly due to different anthropogenic activities (FAO, 2015).

In Ethiopia, factors such as deforestation, overharvesting, invasive/alien species and land use/land cover changes were leading to reduction of natural vegetation resources (Samson *et al.*, 2020). In rural areas of Ethiopia, where 83% of the population lives and depend on renewable natural resources (Tinsae Bahru *et al.*, 2021), the pressure on natural vegetation resources is very high. The pressure has caused depletion and deterioration of the natural vegetation, which have resulted in increased vulnerability of the local community to climate change impacts and reducing ecosystem services and agricultural productivity (Samson Tsegaye *et al.*, 2020). Regardless of the declining vegetation cover, Ethiopia still hosts rich biological diversity due to extremes and divers ecosystems and landscapes (Zewdie Kassa *et al.*, 2016; Zerihun Tadesse *et al.*, 2017). The Harla-Ija Aneni valley and Mountain Complex is one of these diverse landscapes where visible floristic composition and diversity of vegetation covers with endemism are apparent in eastern Ethiopia (Anteneh Belayneh and Nigussie Bussa, 2014). This area is part of the Somali-Masai centre of endemism in East Africa, which is known for high-level of vegetation diversity, distinct floristic communities, and endemism (Friis *et al.*, 2011).

The natural vegetation of Harla-Ija Aneni Valley and Mountain landscape is characterized by grassland, scattered woodlands, scrublands, and bush lands (Anteneh Belayneh and Nigussie Bussa, 2014). It has contributed much to reducing vulnerability of the local community to climate change impacts and the prevailing ground water scarcity in this semi-arid ecosystem (Seyoum Bezabih and Hayal Derb, 2022; Tessema Toru *et al.*, 2023). However, the current extensive amount of habitat destruction and shrinking of the natural vegetation may have resulted in a rapid declining of the genetic resources and reduced ecosystem services (Sintayehu Workneh *et al.*, 2020; Tessema Toru *et al.*, 2023). The nearby port city of Dire Dawa is severely affected by recurrent flood and scarcity of ground water balance in the Dengego sub-basin (Seyoum Bezabih and Hayal Derb, 2022). In addition, there is an increasing invasive woody plant species (Tessema Toru *et al.*, 2023) and overexploitation of woody plant species for firewood selling along the roadsides of Dengego Valleys (daily observation). These extensive amounts of resource exploitation and habitat destruction may have resulted in a rapid decline in the genetic resources of the native woody plant species in this complex landscape in the semi-arid ecosystem.

The patterns of vegetation structures may reveal an important attribute of floristic composition and regeneration status, which can be used to develop proper conservation strategies (Jian *et al.*, 2015). In addition, floristic studies are essential to address ecological issues for biodiversity conservation and management purposes, as well as provide the basics for prediction of potential future changes in plant species distributions that could be linked to human impacts on habitats (Sintayehu Workneh *et al.*, 2020). Moreover, knowledge of floristic composition and diversity of vegetation is valuable in identifying endemic species, ecologically and economically important plant species, and their diversity (Addo-Fordjour *et al.,* 2009), which could contribute much to enhancing the on-going conservation activities. Such information could ultimately give the clue on resources prioritization and protecting threatened, endemic, and socio-economically valuable plants species (Naveh and Whittaker, 2007; Balemlay Sewale and Siraj Mammo, 2022). In this respect, the study area was hypothesized to harbour high level of floristic diversity with endemism. It is important to analyse the vegetation resources upon which sound management plan of conservation and sustainable utilization can be based. Therefore, the objective of this study was to analyse the floristic composition, species identity and quality, diversity level, and vegetation types along the gradient to fill the gap of limited report on the Harla-Ija Aneni Complex valleys and Mountains landscape in the semi-arid ecosystem.

2. Materials and Methods

2.1. Study Area Description

The study was conducted in the valley and mountain complex of Harla and Ija Aneni *Kebeles* (the smallest administrative unit in Ethiopia), which is found near to the town of Dire Dawa in eastern Ethiopia. The study area is located at the distance of 515 km East of Addis Ababa, the capital city of Ethiopia (Figure 1).

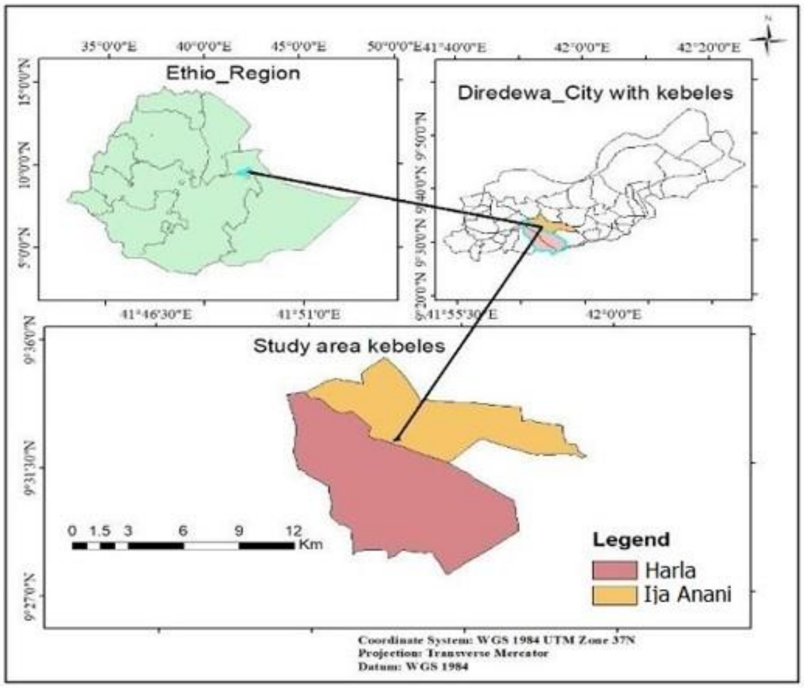

Figure 1. Map of study area, the Harla-Ija Aneni Valley and Mountain landscape.

The area is found within 9°27' and 9°39' N latitude and 41°38' and 42°20' E longitude and the elevation ranges between 950–2260 meters above sea level. The physiographic feature includes mountain ranges, hills, valleys, river terraces and flat plains (Rediat Takele, 2012). The mean annual temperature is about 22.8 °C, ranging from a mean minimum of 16.2°C to mean maximum of 30.4 °C. May to June are the hottest months, whereas November to January are the coldest months. The mean annual rainfall in the study areas ranges between 500 to 600 mm with a mean minimum of 228.3 mm and mean maximum of 719.7 mm (Rediat Takele, 2012). Rainfall is bimodal, occurring from February to April (short rainy season) and June to September (long rainy season) (Anteneh Belayneh and Nigussie Bussa, 2014).

2.2. Sampling Method

A reconnaissance survey was conducted in the study areas to get an impression of the site conditions and identify the sampling sites for vegetation data collection. Then a systematic transect line sampling technique was used for sample quadrat establishment, in which the line transects were laid along the mountain from bottom to top (Mueller-Dombois and Ellenberg, 1974). Along each line transect, nested quadrats were established in which 20 m x 20 m (400 m^2) main quadrats were laid at interval of 100m for trees measurement. Sub-quadrats of 5 m x 5 m (25 m^2) were laid in the main quadrat (at four corners and one at the centre) for shrubs and climbers. Sub-quadrats of 1 m x 1 m (1 m^2) were used for grass and herbs within the 25 m^2 to collect data on the individual species number per quadrat including estimate of percentage cover (Kent, 2011). The distance between each transect line was 1000 m in a zigzag pattern, which was believed to maximize the representation of different vegetation types of the study area. A total of 58 sampling quadrats from 12 transect lines were established. The locations and altitude of the quadrats were marked by Garmin GPS.

2.3. Data Collection

In each quadrat, data on the taxonomic identity of all plant species, number of individuals per species, height, frequency of occurrence, diameter at breast height (DBH) and diameter at stump height (DSH) were recorded for tree, tree/shrub, and shrub species. The DBH of individual tree species was measured using diameter tape and height was measured using hypsometer. The diameter of trees that were branched at the stamp height was measured separately above the swelling and average measurement was recorded. Whereas, for tree species forked below 1.3 m, individual stems were separately measured and treated as single tree (Tesfay Atsbeha *et al.*, 2019). In the case of multi-stemmed shrub, each stem was measured, and diameter equivalent of the plant calculated as the square root of the sum of diameter of all stems per plant (Snowdon *et al.,* 2002):

$$d = \sum_{i}^{n} \sqrt{di^2}$$

Where, d = diameter equivalent height and di = diameter of the i^{th} stem at the measurement height.

Plant species in each plot were counted and recorded at individual level, and voucher specimens were collected, pressed, and dried properly for herbarium specimen. All plant species were identified using the respective volumes of the Flora of Ethiopia and Eritrea entails the Families identified in this study and authenticated by comparing with specimens' sheets at the Herbarium of Haramaya University (HHU).

2.4. Data Analysis

The most common diversity indices like Shannon Wiener diversity index (H') and Shannon evenness index (E_H) were used to determine the evenness and diversity of trees, shrubs, climbers, herbs and grass species. Species richness and Jaccard's similarity index, frequency, basal area (BA), and Importance Value Index (IVI) were computed. R software program (version 3.5.1.) with permute, lattice, and vegan packages (R Core Team, 2018) was used for data analysis.

2.4.1 Shannon - Wiener diversity index

Shannon - Wiener diversity index (H') accounts for both richness and evenness of the species (Magurran, 2004) and calculated using the formula:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

Where, S = a total number of species, P_i = the proportion of individuals or the i^{th} species expressed as a proportion of total cover, and ln = log base n.

Shannon's equitability or Evenness is calculated as follows:

E_H = H/Hmax = H/lns Equitability assumes a value between 0 and 1 with 1being complete evenness (Magurran, 2004).

2.4.2 Jaccard's similarity index

Jaccard's similarity index was used to determine the pattern of species turnover among the different community types. It was calculated as follows (Shem and Arjun, 2022).

$$J = \frac{a}{a+b+c}$$

Where, J = Jaccard's similarity coefficient, a = Number of species common to both samples, b = number of species present in the first site, and c = number of species present in the second site. Often, the coefficient is multiplied by 100 to give a percentage similarity index.

2.4.3 Frequency and density

Frequency (relative frequency), diameter at breast height (DBH), density (relative density), height, basal area (BA) and importance value index (IVI) were analysed for woody species following the methods of Kent (2011). Density (D) is defined as the number of plants of a certain species per unit area such as a hectare. It is closely related to abundance but more useful in estimating the importance of a species (Mueller-Dombois and Ellenberg, 1974).

$$D = \frac{\text{Number of individual species}}{\text{Sample size in hectar}}$$

Frequency is the number of times a particular species is recorded in the sample area (Kent, 2011). It was obtained by using quadrats and expressed as the number of quadrats occupied by a given species per number thrown or more often, as percentage. The high frequency value of a given plant species in the community indicates that it is widely distributed in the area under the study (Kent, 2011).

$$\text{Frequency}(\%) = \frac{\text{Number of plots with individual species}}{\text{Total number of plots}} \times 100$$

2.4.4 Importance value index

Importance Value Index (IVI) is used to calculate ecological importance or significance of woody plant species. The percentage values of the relative frequency (RF), relative density (RD), and relative dominance (RDo) were summed up together and this value was designated as the Importance Value Index (IVI) of the species (Kent, 2011). As Anne (2021) indicated, it is useful to compare the ecological significance of species.

$$IVI = RF + RD + RDo$$

$$RF = \frac{\text{Frequency of aspecies}}{\text{Total frequency of all species}} \times 100;$$

$$RD = \frac{\text{Total number of individuals of aspecies}}{\text{Total number of individuals of all species}} \times 100;$$

$$RDo = \frac{\text{Total basal area of a species}}{\text{Total basal area of all species}} \times 100$$

2.4.5 Basal area

Basal area (BA) is used to estimate tree volumes and stand competition. It is also the cross-sectional area of all of the stems in a stand at breast height (1.3 m above ground level) expressed in square meter/hectare (Mueller-Dombois and Ellenberg, 1974). The basal area was calculated using the DBH values of woody plant species using an equation (Kent, 2011):

BA = $\pi d^2/4$; where, BA = Basal area, d = DBH/DSH, and π = 3.14

2.4.6 Plant community types

A plant community was categorized based on essential homogenous physiognomy, ecological structure and by floristic composition. In this study, a hierarchical cluster analysis was made by using PC-ORD 5.31 window versions based on their similarity values (McCune and Grace, 2002) to classify the vegetation into plant community types. The name for each community type was given based on high synoptic values of the species in the vegetation cover estimate (Mueller-Dombois and Ellenberg, 1974).

3. Results and Discussion

3.1. Floristic Composition

A total of 121 plant species belonging to 91 genera and 48 families were recorded in the study area, of which 10 (8.3%) species are endemic. In terms of their growth habits, trees accounted for 22 (18.18%), shrubs 54 (44.62%), climbers 13 (10.75%), herbs 19 (15.70%), and grasses 13 (10.75%) in the floristic composition (Figure 2). The most probable reason for the domination of shrub species may be specialization of the different species to different dispersal agents. The higher numbers of grasses and herbs (26.5%) could be attributed to the wet season data collection period. Some of the plant species may have a wide range of dispersal mechanisms and/or rapid reproduction strategies. Sorensen *et al.* (2022) also suggested that since the fruits of most shrubs are dispersed by birds, they can colonize vegetation of the study area. The semi-arid mountainous landscape and rocky surface feature could support shrubs and lower canopy species like annual and perennial herbs rather than trees (Demel Teketay, 1995). Rugged terrains and rocky surfaces are the dominant features of the Harla-Ija Aneni Valley and Mountain Complex landscape (HIVMC) (Anteneh and Nigussie, 2014).

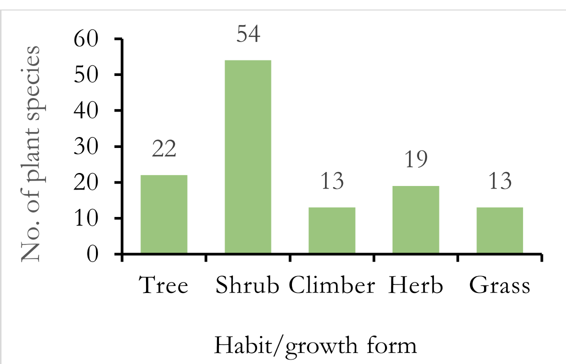

Figure 2. The proportion of plant species with their growth habit.

Poaceae and Fabaceae were the most dominant family with nine and four Genera, respectively and 11 species each. Euphorbiaceae was the third dominant Family with five genera and eight species. Three Families, namely Asteraceae, Ascelepiadaceae and Tiliaceae has six species each; Oleaceae has five species; Acanthaceae, Asphodelaceae, and Lamiaceae has four species each; and Rhamnaceae, Rubiaceae, and Vitaceae has three species each. The rest 12 Families were represented by two species while 23 Families were represented by one species each. Poaceae, Fabaceae, and Euphorbiaceae were the three most dominant families with a total of 30 species that accounted for 24.8% of the floristic composition. Fabaceae and Euphorbiaceae contain drought tolerant, deciduous and spiny species, which are well adapted to the prevailing drought conditions of the study area (Tessema Toru *et al.*, 2023). The ten endemic plant species identified were *Aerva javanica* (Burm.f.), *Aloe harlana* Reynolds, *Aloe mcloughlinii* Chris., *Aloe trichosantha* subsp. *longiflora, Gomphocarpus purpurascens* A. Rich., *Indigofera ellenbeckii* Bak. f., *Leucas stachydiformis* (Hochst. ex Benth.) Briq., *Myrsina africana* L., *Pittosporum abyssinicum* Del., and *Rhynchosia erlangeri* Harms. Among these endemic species, the genus *Aloe* accounted for the higher number of endemic species (three), which could attract interest on *Aloe* conservation centre in eastern Ethiopia (Anteneh Belayneh *et al.*, 2020).

3.2. Density and Frequency of Woody Species

Overall average density of woody species i.e. trees and shrubs from HIVMC landscape were estimated at 5,101 individuals whereas climber species was 633.1 individuals per hectare. This figure is comparable with woodland vegetation of Ilugelan district (5,145.83 individuals h-1), (Zerihun Tadesse *et al.*, 2017) and much greater than dry woodland vegetation of west Shewa (538 individuals h^{-1}) (Gadisa Demie, 2019) and Hirmi woodland vegetation (528.4 individuals h-1) (Mehari Girmay *et al.,* 2020). However, it is much less than the semi-arid woodland vegetation of Erer Valley of the Babile District (19,991 individuals ha^{-1}) (Anteneh Belayneh *et al.*, 2011). This variation may be because of the differences in agro-ecological zones, management practices, and other ecological factors such as soil and moisture.

The trend line showed that the lower density classes have relatively higher number of tree species whereas, the higher density classes with less number of tree species (Figure 3). The vegetation characterized by diversified woody species were found highly exploited for various use values by the local communities (Mehari Girmay *et al.,* 2020), which tends to count less individuals per woody plant species. Higher density classes with a few woody plant species are related to the dominance of less valuable plant species, which might be invasive plant species in the given landscape. The lower density classes are related to mature woody species, affected by selective cutting, which could promote conservation concern in this valleys and mountainous landscape. The highest average density of some tree species in the study area were recorded for

Acacia bussei (95.3 individuals per hectare) followed by *Acacia tortilis* (74.7 individuals per hectare), *Acacia nilotica* (59.7 individuals per hectare), *Acacia senegal* (44.7 individuals per hectare) and *Canthium pseudosetiflorum* (39.3individuals per hectare) whereas, the lowest average density of tree species were recorded in *Grewia velutina*, *Clerodendrum* sp. and *Ficus vasta* (0.3 individuals per hectare each) and *Bridelia micrantha* (0.6 individuals per hectare).

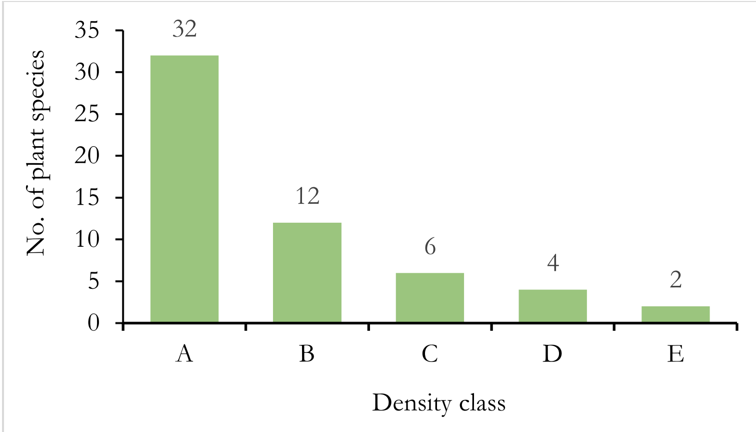

Figure 3. Density class distribution and number of tree species (Density classes of individual total count per ha: A ≤ 20; B=20.1—40; C=40.1—60; D=60.1—80; E=80.1—100.

Similar to the tree species, the lower density class has relatively higher number of shrub species (Figure 4). However, the higher density classes have a few shrub species like, *Aloe megalacantha* subsp. *megalacantha* (1,902.3 individuals per hectare), *Croton dichogamum* (1761.7individuals per hectare), *Lanthana camara* (1,748 individuals per hectare), *Cadia purpurea* (1481.3 individuals per hectare) and *Grewia erythraea* (1,410.3 individuals per hectare). These shrub species were found dominant in some degraded landscapes which might be less valuable and unexploited by the local communities.

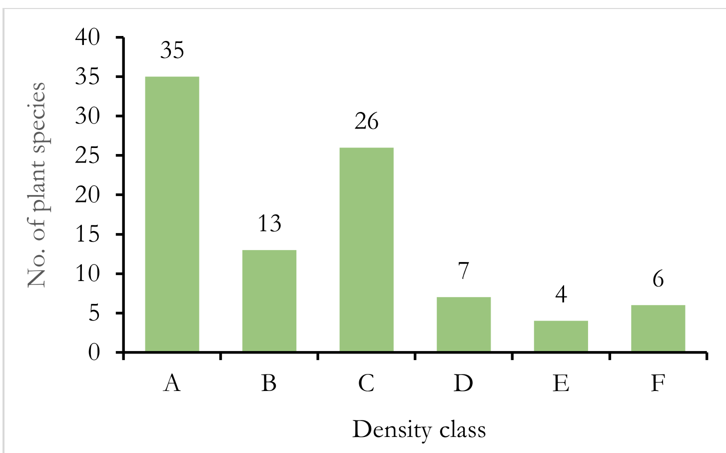

Figure 4. Density class distribution and number of shrub species (Density classes of individual total count per ha: A = ≤ 50; B = 50.1—100; C = 100.1—500; D = 500.1—1000; E =1000.1—1500; F= 1500.1—2000.

The lowest average density of some shrub species were recorded in *Secamone* spp., *Jasminum floribundum, Thesium schweinfurthii* (6.3 individuals per hectare each) and *Cadaba farinose*, *Teclea nobilis*, *Osyris quandripartita* and *Opuntia stricta* (7 individuals per hectare each). The higher average density for *Lanthana camara* could be an indicator of increasing invasion by this alien species, which was invaded the lowlands and mid altitude dry montane ecosystems of eastern and western Hararge midlands (Bekele Firew, 2018). The frequency of species occurrence per sample plots indicates the probability of finding a species in a series of quadrats examined in an area of interest (Haileab Zegeye *et al*., 2005). The frequency of species occurrence analysis was grouped into five major classes: A≥80.1; B = 60.1-80; C = 40.1-60; D =10.1-40; E≤10 for tree and shrub species (Figure 5).

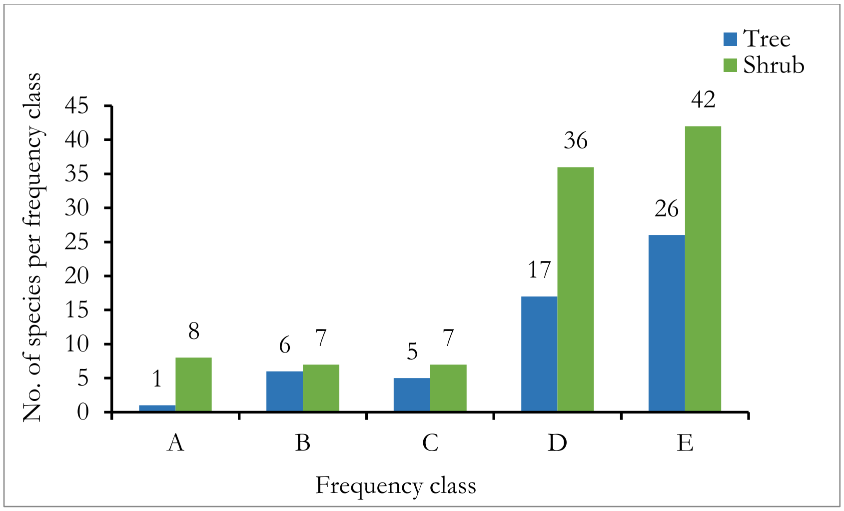

Figure 5. Distribution of woody species in the frequency classes (Frequency classes in %: A = >80.1; B = 60.1—80; C = 40.1—60; D =10.1—40; E = <10).

There were relatively a greater number of woody species in lower frequency and less in higher frequency classes. This might be an indicator of heterogeneous species composition, which is one of a signal for healthy vegetation types. However, the potential anthropogenic factors like selective exploitation as well as dominance of less valuable and invasive plant species might be resulted in a smaller number of woody plant species in higher frequency classes. An invasive plant species resulted in the disturbance of floristic composition on the natural vegetation beyond its socio-economic impacts (Ketema Bekele *et al.*, 2018). The greater number of species in higher frequency and less in lower frequency classes indicated constant or similar species composition whereas the greater number of species in lower frequency classes and less in higher frequency indicated high degree of floristic heterogeneity (Lamprecht, 1989).

Similar results were also obtained in other areas in Ethiopia like Gra-Kahsu, Northern Ethiopia, natural vegetation where only two woody species were recorded at the higher frequency class of A =>81 and B = 60–80% (Tesfay Atsbeha *et al.*, 2019) and Hirmi woodland vegetation where four woody species recorded at the higher frequency class of A = > 81 and B = 60–80% (Mehari Girmay *et al.*, 2020). The high frequency shown even distribution of the species and variation in frequency between species may be attributed to habitat differences, habitat preferences among the species, species characteristics for adaptation, degree of exploitation and conditions for regeneration (Demel Teketay, 1995). Highest average frequencies were recorded for some tree species like, *Acacia tortilis* (54.84%), followed by *Acacia nilotica* (54.65%) and *Acacia brevispica* (51.96%). However, the least were recorded for *Salvadora persica* and *Ficus vasta* where each of them were recorded only in one plot. The highest average shrubs' frequencies were recorded for *Grewia erythrae* (91.46%), *Cadia purpurea* (75.04%) and *Aloe megalacantha* subsp. *megalacantha* (73.76 %). The least shrubs' frequencies were record for species like, *Rumex nervosus, Sarcostemma viminale*, *Secamone* spp., *Jasminum floribundum* and *Thesium schweinfurthii,* in which each were recorded only in one plot. Species of such least frequency need to be given priority in conservation depending on their socio-ecological values.

3.3. Basal Area

The total average basal area of woody species in HIVMC was 2.10m^2/ha. This is much lower than the basal area of the nearby upper catchment of Dengego Mountain (Tessema Toru *et al.*, 2023). The basal area of woody species is basically determined by the distribution of density and DBH classes (Kent, 2011). The basal area was lower, indicating the lower density of woody species and the smaller number of larger diameter class stands, which could be related to selective cutting of woody species for firewood selling prevalent at the road sides of the study area. Three native plant species have covered 67.85% of the average basal area among trees, i.e., *Acacia tortilis* (36.28%), *Acacia nilotica* (17.93%), and *Acacia bussei* (13.64%). Similarly, three species have covered 78.76% of average basal area of shrubs, i.e., *Aloe megalacantha* subsp. *megalacantha* (66.96%), *Lanthana camara* (6.9%) and *Psycotria orophila* (4.9%). An increasing basal area of *Lanthana camara* in this ecosystem could be a signal for its potential invasion as alien species in the study area, which raise critical concern of impact on the native plant species. The presence of *L. camara* at high cover condition significantly decreased native species diversity, cover and composition (Sheunesu, 2020).

3.4. Importance Value Index

The importance value index (IVI) measures how dominant a species is in a given natural ecosystem and landscape. The average IVI for tree species showed that *Acacia tortilis* (72.95), *Acacia nilotica* (52.91), and *Acacia bussei* (43.83) were the three tree species with higher IVI (Table 1).

Table 1. Importance value index of some tree species with average higher and lower IVI values in Harla-Ija Aneni Valleys and Mountains complex.

Scientific name	Local Name/AO	BA(m²)	RD	F%	RF	D	RDo	IVI
Acacia tortilis	DHEDACHA	0.616	35.6	54.84	14.67	74.66	23.02	73.3
Acacia nilotica	SERKEMA	0.305	17.1	54.65	15.88	59.67	19.95	52.9
Acacia bussei	HALLO	0.232	14.7	25.13	8.21	95.33	20.93	43.8
Acacia brevispica	HAMMAREEYSA	0.009	0.6	51.96	15.87	27.67	7.85	24.3
Canthium pseudosetiflorum	TIMIRO	0.076	4.6	33.21	8.54	39.33	10.26	23.4
Acacia senegal	SOBENSA	0.050	2.9	28.09	6.61	44.67	13.23	22.7
Clerodendrum spp.		0.012	0.8	1.85	0.59	0.33	0.09	1.5
Bridelia micrantha	DHARKENA	0.001	0.1	3.34	0.92	0.66	0.27	1.3
Barbeya oleoides	JAJABA	0.001	0.1	1.85	0.59	1.66	0.39	1.1
Salvadora persica	ADE	0.001	0.1	1.75	0.37	7.00	0.13	0.6
Ficus vasta	ODA	0.001	0.1	1.75	0.37	0.33	0.13	0.6

Note: *AO = Afan Oromo; BA = Basal Area; RD = Relative Density; F = frequency; RF = Relative Frequency; D = Density; RDo = Relative Dominance; and IVI = Importance Value Index.*

The native tree species found relatively dominant with higher IVI, which could initiate more attention for further enhancement of their conservation based on the socio-ecological values of the tree species. *Aloe megalacantha* subsp. *megalacantha* (86.93), *Lanthana camara* (28.23) and *Grewia erythraea* (23.88) were the three shrub species with average higher IVI in the study area (Table 2).

Table 2. Importance value index of some shrub species with average higher and lower IVI values in Harla-Ija Aneni Valley and Mountain complex landscape.

Scientific name	Local name/AO	BA (m²)	RD	F%	RF	D	RD	IVI
Aloe megalacantha subsp. *megalacantha*	HARGESA GURACHA	0.27	65.6	73.76	8.95	1,902.3	12.39	86.9
Lanthana camara	BAKA-ARKATE	0.028	7.9	71.98	8.67	1,748.0	11.59	28.2
Grewia erythraea	DHEEKAA	0.016	3.7	91.46	11.14	1,410.3	9.09	23.9
Cadia purpurea	CHEEKA	0.009	2.1	75.04	9.22	1,481.0	9.24	20.6
Croton dichogamum	DHARA	0.009	2.1	58.21	7.14	1761.6	10.87	20.1
Opuntia ficus-indica	TINI	0.006	0.6	49.67	6.11	945.3	5.99	12.7
Opuntia stricta	TINI JALDEYSAA	0.005	0.2	1.75	0.19	7.0	0.06	0.5
Teclea nobilis		0.003	0.1	1.75	0.19	7.0	0.06	0.4
Cadaba farinosa	KELKELCHA	0.002	0.1	1.75	0.19	7.0	0.06	0.4
Jasminum floribundum	BILUU	0.002	0.1	1.58	0.19	6.4	0.04	0.3
Secamone spp.		0.001	0.1	1.58	0.19	6.4	0.04	0.3
Thesium schweinfurthii	DHIRI	0.001	0.1	1.58	0.19	6.4	0.04	0.22

Note: *AO = Afan Oromo; BA = Basal Area; RD = Relative Density; F = frequency; RF = Relative Frequency; D = Density; RDo = Relative Dominance; and IVI = Importance Value Index.*

Therefore, these shrub species are ecologically important in the study sites, which could attract attention for their conservation except *Lanthana camara* and *Opuntia stricta* reported as invasive alien plant species. On the other hand, trees species such as, *Barbeya oleoides* (1.07), *Ficus vasta* and *Salvadora persica* (0.57 each) and shrub species like, *Cadaba farinosa* (0.33), *Jasminum floribundum* (0.27), and *Thesium schweinfurthii* (0.22) have lower average values of IVI (Tables 1 and 2). This might be due to an observed anthropogenic disturbance in the study sites or their least ecologically significant in this specific landscape. The lower IVI value might also be a sign of over utilized or poorly managed natural vegetation in areas where there are prevalent human impacts on the natural vegetation (Balemlay Sewale and Siraj Mammo, 2022). These could lead to total loss of these species from the vegetation community unless supported with conservation effort to enhance their population in their respective floristic community. Hence proper management and conservation are required for those species at the lower IVI since this is an indicate of threatened woody species and demand immediate conservation measure.

3.5. Population Structure of Woody Plant Species

The overall pattern of both diameter and height class distribution of woody species exhibited inverted J-shaped distribution (Figures 6 and 7). This could happen when most of the individuals of the species had high frequency in the lower diameter and height classes and a gradual decrease towards the higher classes. In this respect, 94.29% of the total DBH frequency lies between ≤2—15 cm diameter classes, whereas, about 5.71% of the frequency was lies between 15.1—30 and above cm diameter classes (Figure 6). This indicated that there might be selective removal of high diameter class by the local communities for various purposes like, house construction, fuel wood and charcoal production, which were reported as the major challenges in *Acacia* woodland (Anteneh Belayneh *et al.*, 2011).

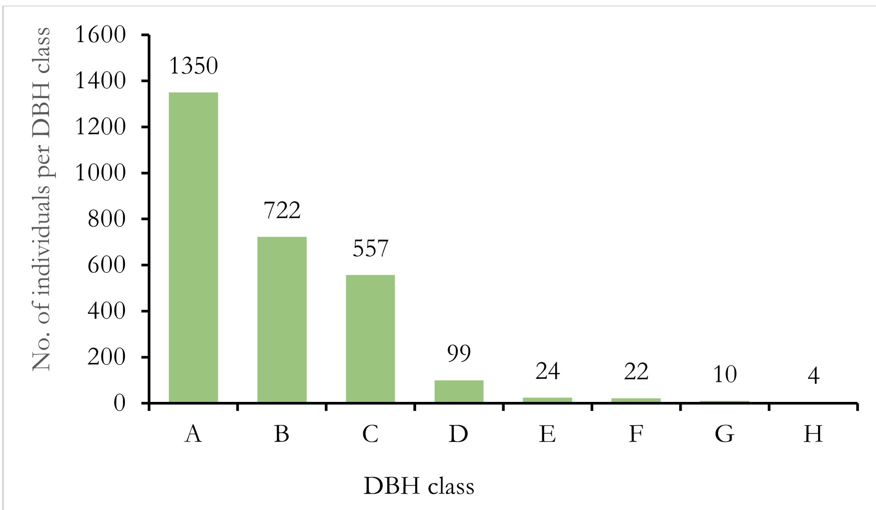

Figure 6. The total number of woody species distribution in each diameter class (in cm) in the HIVMC landscape (A = < 2; B = 2.1—5; C = 5.1—10; D = 10.1—15; E = 15.1—20; F = 20.1—25; G = 25.1—30; H = A = >30.1).

The density of woody individuals in different height classes showed a similar pattern inverted J-shape distribution. Most of the individuals are in the lower height classes and the number is subsequently decreasing so that the higher classes are having very few individuals (Figure 7). Such inverted J-shape distribution of height and diameter classes indicated a continuous and good regeneration and/or a stable population of woody species in the different types of natural vegetation (Motuma Didita *et al.*, 2010; Tesfay Atsbeha *et al.*, 2019). Such pattern of distribution encourages an enclosure as a landscape restoration strategy in conservation planning.

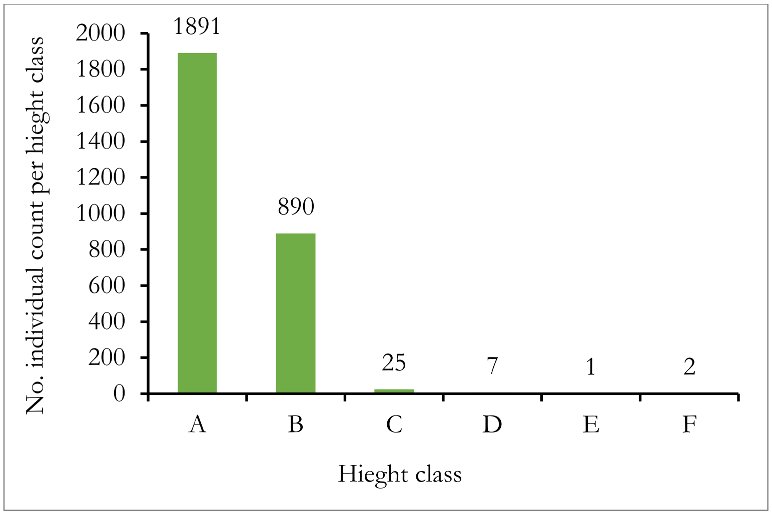

Figure 7. Height class (in meter) distribution of woody species in the HIVMC landscape (A = ≤ 1; B = 1.1—5; C = 5.1—10; D = 10.1—15; E = 15.1—20; F = ≥ 20).

3.6. Species Diversity, Richness, and Evenness

The overall pooled mean of species diversity, evenness and richness were 3.12 and 0.38 and 121, respectively. These could indicate the species diversity of the study area was relatively better whereas the lower evenness value indicates the dominance of some species in the floristic composition. Shannon diversity index considered as high when the calculated value is ≥ 3.0, medium when it is between 2.0 and 3.0, low between 1.0 and 2.0, and very low when it is ≤ 1.0 (Girmay Darcha *et al*., 2015). According to Kent (2011), Shannon-Wiener index value varies between 1.5 and 3.5 and rarely exceeds 4. Accordingly, HIVMC landscape had better Shannon diversity index. In general, the result for Shannon diversity index of this ecosystem was relatively higher as compared to other findings (Wakshum G. Shiferaw *et al*., 2018). However, it was lower compared the findings of Sudi (2018) and (Gadisa Demie, 2019). On the other hand, species evenness of HIVMC landscape was less (0.35), which was relatively lower compared with Wakshum G. Shiferaw *et al.* (2018), Sudi Dawud (2018), and Gadisa Demie (2019). Lower evenness indicated the dominance of few species in the plant communities (Anteneh Belayneh *et al*., 2011), which is one of the indicators for potential invasive species in the vegetation under study.

The number of species richness (121) recorded in the study area was higher than Dengego mountain natural vegetation in Eastern Ethiopia (n = 49) (Tessema Toru *et al*., 2023), and equal to the arid and semi-arid regions elsewhere (He *et al*., 2023). In contrast, the total number of species recorded in this study were found to be lower than reported from Hirmi woodland vegetation (n = 171) (Mehari Girmay *et al*., 2020) and woodland vegetation in Dello Mena (n = 171) (Motuma Didita *et al*., 2010). Though all are the tropical semi-arid vegetation types, the different environmental and climatic factors might lead to such deviations in those studies. These include rainfall patterns, resource availability, overlap of habitats, land use of an area, and human activities (Mengesha Asefa *et al*., 2020).

3.7. Vegetation Structure

3.7.1 Plant Community types

Three plant community types were distinguished from the data matrix of 121 species and 58 sample plots using hierarchical cluster analysis. The name for each community type was given based on high synoptic values of the vegetation of cover estimate. The first was *Acacia tortilis-Rhus natalensis* community type (CI) at altitudinal range between 1444–1536 m a.s.l. The common shrubs with in the community were *A. harlana, Aloe mcloughlinii, Aloe trichosantha, Croton dichogamum, Kleinia odora, Lanthana camara,* and *Lepidagathis calycina* with climber species like, C*issampelas mucronata.* The common herbs in this community include *Helichrysum glumaceum, Ocimum lamiifolium* and *Parthenium hysterophorus,* and grasses like, *Chloris radiota, Oplismenus compositus, Panicum coloratum* and *Sporobolus stapfianus.* The second was *Ficus vasta-Acacia brevispica* Community type (CII) found at altitudinal range between 1672–1890 m a.s.l. This community type has *Acacia tortilis,* and shrubs like *Acacia senegal, Commicarpus plumbagineus, Croton dichogamum, Heliotropium cinerascen, Lanthana camara, Myrsina Africana, Opuntia ficus-indica* and *Sarcostemma viminale. Echinops echinatus, Eulophia petersii, Gomphocarpus purpurascens* and *Helichrysum glumaceum* were among the dominant herbs while *Chloris radiota* and *Panicum coloratum* are common grasses.

The third was *Canthium pseudosetiflorum-Psychotria orophila* Community type (CIII) found at altitudinal range is between 1538-1882 m a.s.l. The dominant shrubs are *A.*

bussei, Acacia etbaica, A. senegal, Aloe harlana, Croton dichogamum, Dracaena ombet, Euphorbia tirucalli, Lanthana camara and *Opuntia ficus-indica*. *Asparagus racemosus, Commicarpus plumbagineus* and *Sarcostemma viminale* were the common climbers in this community type. The herbs were *Echinops echinatus, Helichrysum glumaceum, Eulophia petersii* and *Parthenium hysterophorus*. Dominant grass species were *Chloris radiota, Cynodon dactylon, Digitaria velutina, Oplismenus compositus, Panicum coloratum* and *Sporobolus stapfianus*. There is a tendency of spread of invasive alien plant species like, *Lantana camara* and herbaceous species *Parthenium hysterophorus* in all community types, which urges conservation and management concern.

3.7.2 Coefficient of similarity

The Jaccard's coefficient of similarity was computed to compare the similarity in species composition of the three vegetation community types (CI, CII, and CIII). The overall similarity coefficient ranges from 64-84% among the community types. The Jaccard's similarities of species for CII and CIII were 84% followed by CI and CII with 74% similarly and less similarity level for observed between CI and CIII with 64% similarity level (Table 3). This difference in similarity between the three community types might be due to topographic variation, extent of anthropogenic disturbance, and differences in altitudinal range as well as some variations in bio-physical environments (Anteneh Belayneh *et al*., 2011; Bert and Jan, 2023).

Table 3. The coefficient of similarity level of plant species between the three plant community types.

Community	CI	CII	CIII
CI	–	–	–
CII	0.74	–	–
CIII	0.64	0.84	–

4. Conclusion

The floristic composition, vegetation structure and diversity of the HIVMC landscape were analysed to support and enhance the dryland restoration efforts in this complex landscape. The vegetation of the study area harbours ecologically important plant species with promising composition, diversity with endemism and population structure, which can be considered as one of the semi-arid natural vegetation genetic resources provenance in eastern Ethiopia. The floristic composition that accounted about 62% of woody plant species is a feature of woodland vegetation, which deserves for dryland restoration in this semi-arid ecosystem. Moreover, among the ten endemic plant species in the area, *Aloe harlana* (the specific epithet "*harlana*" indicate one site of the study area called "Harla") is endemic (rare endemic since restricted only in this locality in the world) required much attention since its population seems highly declining. This study signifies a number of endemic plant species, which encourage for further investigation for endemic plant species to be recognized as one of an important centre of endemism. An inverted J-shape distribution of height and diameter classes indicated a continuous and good regeneration and/or a stable population of woody species encouraged for enclosure-based landscape restoration. However, selective exploitation of matured woody plant species for firewood selling should be controlled since could aggravate the risk of high flood to the nearby port city, Dire Dawa. In addition, there is high risk of invasive species like *Lanthana camara,* which urges immediate attention for control and management. In general, such natural vegetation, which is disturbed by anthropogenic factors at the higher diameter and height classes, could be planned for conservation through enclosure as a degraded landscape restoration tool. Therefore, the maintenance of floristic diversity should be emphasized to promote sustainable use of the natural vegetation through dryland restoration and conservation practices. Moreover, there should be further taxonomic expeditions in the study area for more number of endemic plant species and threatened multipurpose woody plant species of conservation attention.

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