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Woody Plant Species Diversity of Lay Agerit Giorgis Natural Forest, Merabeti District of North Shoa Zone in Amhara Region, Ethiopia

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Abstract: Ethiopia is one of the biodiversity reach areas in the world. This study was conducted in Lay Agerit Giorgis forest is located in Merabeti district of North Shoa zone in Amhara region. This inventory was done with the aimed of woody plant species diversity documentation; determine floristic composition and regeneration status of woody plant species in Lay Agerit Giorgis Natural Forest. Systematic sampling was employed for the purpose of woody plant inventory in this area. The total of 34 quadrates were established with 6 transects in each of them 100meter apart and also 100meter distance in between plots with the sample plot area enumerated as the 10X 50meter. The major forest disturbance factors were recorded 35.16% light and moderate Browsing, 36.26% light and moderate Grazing and 28.57% light and moderate disturbance levels shows by logging /cutting. A total of 48 woody plant species belong to 38 genera and 27 families were recorded. The most frequent genera in the woodland were (Fabaceae), (Capparidaceae), (Celastraceae) and (Tiliaceae), respectively. The species frequency ranges between 2.94 – 76.4% with *Dichrostachys cinerea* (74.4%), *Acacia tortilis* (67.6%), each *Dodonaea angustifolia* and *Euclea racemosa* (64.7%) are among the top and *Gardenia ternifolia, Ficus sur, Commiphora africana, Celtis africana* are among the lowest in frequency distribution (2.94%). Setting high priority is needed to conserve these endangered woody plant species following either the *ex-situ* or field Gene bank or both conservation systems.

Keywords: Lay Agerit Giorgis Forest, Disturbance, Inventory

1. Introduction

Ethiopia is one of the biodiversity reach areas in the world [9]. The country is extremely heterogeneous in ecology with diversity species [19]. It is estimated that between 6,500 and 7,000 species of higher plants occur in Ethiopia, of which about 15% are endemic [16]. The dry land area in Ethiopia covers a substantial region endowed with diverse plant resources. However, the landmass has received less attention even if it has high ecological, environmental and economic uses [10]. In the country forest play an indispensable role in the protection of regulating climate, controlling water runoff, maintaining ecological balance and producing valuable materials such as timber for construction and furniture, extraction of chemicals, paper and pulp. Furthermore, they have paramount role in purifying the air and serving as a habitat for wild animals [17, 11]. The community serves the forest as a source of food, household energy, construction and agricultural material, tourism, recreation and medicines [18].

In many parts of the world, particularly in developing countries natural forest vegetation cover is diminishing at an alarming rate. This is resulting in an exceptional loss of biological diversity. Undoubtedly; the situation in Ethiopia is even bleaker. In addition, basic information on the extent, distribution, species diversity and the rate of deforestation in Ethiopia is very limited. It is hardly known; as to what extent Ethiopia was covered by forest vegetation, earlier than mid-1950s. The widely held belief that approximately 35% of the country's total land area (110 mill. ha) was covered by montane forest vegetation by end of 19th century is attributable to the estimation made by [5]. According to [4], a wide spread deforestation had already overcome most of the montane forest areas, and consequently, the remaining total extent of the montane forest vegetation cover, in mid 1950s was not more than 16% (i.e. about 17 mill. ha) of the country's total land area. Such a devastating trend of deforestation continued unchallenged over the five decades that followed, and in the event, the remaining natural high forest vegetation suffered an ever more drastic loss. To this effect, [4]and several other relevant sources report that only 2.3–2.7% of the country's total land area (i.e. about 2.5mil. ha) remained at the beginning of 1990s. In Ethiopia forest distribution can be affected by different environmental factors such as altitude, slope, and aspect [2]. The plantation is deforested from time to time and accelerates loss of biodiversity [11]. Encroachment, over harvesting, agriculture, Browsing and grazing are factors towards the degradation of the vegetation burning and overgrazing have resulted in the clearing of woodlands. Soil erosion also affects floristic diversity [7, 15, 10]. The renewal of species through the regeneration is not adequate; the vulnerability of young plants to disturbance has caused slower replacement into tree size class [1]. The single most crucial reason underlying the speedy rate of deforestation in Ethiopia has been and still remains being the ever-elevating population growth. The same is continuing with about 3% annual increment, and highly limited alternatives of livelihood for the rural majority (representing 85% of the total population). Losses of forest with various threatened species have negative impact on the environment [6].

However, despite the designation and demarcation of its boundaries, the forest is still experiencing a persistent human pressure, mainly resulting from an ever-increasing expansion of agricultural cultivation [3]. A growing number of people, both from adjacent areas, and immigrants from other parts of the country began establishing new settlements, within the designated state forest territory. Sustainable farming practice conserves biodiversity, reducing negative impacts of agriculture on biodiversity and provides wood and energy to local community is a good solution to reduce deforestation and forest degradation [3]. Merabeti Lay Agerit Giorgis forest is one of the forests affected by the above listed problems. This forest is one of the Lowland forests, which occur in central parts of Ethiopia. This inventory was conducted with the aimed of Woody Plant Species Diversity documentation; determine the floristic composition of the natural forest in the area and regeneration status of the woody plant species.

2. Materials and Methods

2.1. Description of the Study Area

2.1.1. Location

Lay Agerit Giorgis forest is located in Merabeti woreda of North Shoa zone in Amhara region, 5km far from Alem ketema to Diga Meragna town direction in Lay Agerit kebele. Part of the Semien Shewa Zone, Merhabete is bordered on the south by Ensaro, on the west by the Oromia Region, on the north by Mida Woremo, on the east by Menz Keya Gebreal, and on the southeast by Moretna Jiru. The Jamma River defines these district southern and eastern boundaries, and its tributary the Qechene defines its western and northern. The administrative center is Alem Ketema; other towns in this district include Fetira. Based on the report [21], this district has a total population of 126,501, an increase of 27.87% over the 1994 census, of whom 63,997 are men and 62,504 women; 13,113 or 10.37% are urban inhabitants. Geographically Lay Agerit Giorgis forest is situated on the range of latitude 10°04' 25.0″ - 10°07' 53.6″ N and longitude 038°57' 19.9″ - 038°58' 22.1″ E covering a total area of 35ha.

2.1.2. Topography

The Topographic feature of Lay Agerit Giorgis forest is hilly undulating forest, which has lower area at eastern side. An altitude variation is low between 1484m to as high as 2059m.a.s.l. The slope range of the forest area was observed to be 15 - 45%.

2.1.3. Climate

Lay Agerit Giorgis forest area has single climatic rainfall patterns as the rest part of eastern plateau. This forest has maximum rainfall runs from June to October and the average annual rainfall ranges from 900 – 1500mm. High rainfalls were recorded in June, July and August. The mean monthly minimum and maximum temperature Varies from 14°C to 18°C and 27°C to 35°C, respectively. From the proceeding information it could be concluded that Lay Agerit Giorgis forest lies under the traditional agro-climatic zone classification of dry semi desert "Qolla and Weynadega".

2.2. Biotic Attribute

2.2.1. Vegetation

The central high land plateau and low land forest is composed of broad and deciduous species and taking the area as a whole the most frequent wood land and wooded grass land species. There are *Acacia tortilis, Albizia amara, Dichrostachys cinerea, Dodonaea angustifolia, Rhus glutinosa, Rhus retinorrhoea, Grewia ferruginea,* and *Ximenia americana*, The ground cover is dominated by short grasses.

2.2.2. Wildlife

There are a number of wild animals in or around forest. The following mammal species are found in or around Lay Agerit Giorgis forest: *Cercopithecus aethiops* ("Tota"), *Papio anubis doguera* ("Zinjero"), *Vivera civetta* ("Tirgn"), *Viverridae sanguineus* ("Shelemitmat"), *Ichneumia albicauda* ("Faro"), *Felis silvestris* ("Anner"), *Felis serval* ("Neberart"), *Felis pardus* ("Nebir"), and also so many birds and reptiles found in Lay Agerit Giorgis forest.

2.3. Materials

There are materials used during the inventory and study. Thus, are compass, measuring tap, digital camera, not book, data sheet, GPS (digital positioning system), DSH/DBH measurement (caliper) meter, laptop computer, pressing materials and plastics.

2.4. Methods

2.4.1. Sampling Design

Systematic sampling was employed for the purpose of woody plant inventory in this area. This sampling technique involves setting location of sampling quadrates at regular or systematic intervals along a predetermined transect line. The optimum number of the transect lines, their spatial distribution and the total coverage was determined on priory in main office based on the in-situ site map and satellite image in following a preliminary designed layout of the forest. The total of 34 quadrates were established with six transects in each of them 100meter apart and also 100meter distance in between plots. The sample plot area enumerated as the standard of EBI inventory manual recommended 10X 50meter.

Figure 1. *The transect layout of samples plots and quadrates geospatial data in Lay Agerit Giorgis forest.*

2.4.2. Data Collection

Data on the administrative location (Region, Zone and Woreda), geographical location (Latitude N, Longitude E and/or Altitude (m.a.s.l), vegetation type and physiognomy, agro-ecological zone, relief form, slope gradient, and geo-physical aspect, in which each sample quadrate occurred was measured using appropriate field equipment and/ or methodological guide-lines. The resulting information was duly recorded in a “Woody plant inventory data sheet”.

2.4.3. Vegetation Data

Each woody plant species was first identified and recorded, using vernacular names Amharic language. The specimen of every woody plant species, encountered was collected and duly pressed. Individual stems/ species were characterized on the basis of their growth habit and accordingly recorded either as a tree, shrub or woody liana. Only the stems of trees, with diameter, at breast height (DBH), and shrubs, at stump height (DSH), exceeding 2.5cm were treated in the data collection process. Three major structural parameters (including: Number of stems, DSH/DBH and Height) were measured and recorded in an appropriate data sheet. Both quantitative and qualitative data on the occurrence of seedlings and saplings was collected. Sub-quadrate, measuring 2m by 5m and laid, alternatively following the longitudinal/central axis at either end of the main quadrates were established and investigated in this respect. Individuals attaining maximum height less than 0.5m were counted and recorded as seedlings and those of which had heights >0.5m, but not exceeding 2m were recorded as saplings.

Vertical Structure

In the tropics the vertical structure of the vegetations was categorized according [8] as follows:

1) *Upper storey:* the layer comprising the tree species which attain a height greater than two-third of the top height of a given forest.
2) *Middle storey:* When the stratum is formed by individual tree/shrub species with a height greater than one-third of the top height in a given forest.
3) *Lower storey:* When the stratum is formed by individual tree/shrub species with a height less than one-third of the top height in a given forest.

2.4.4. Data Processing and Analysis

All raw data was entered into database for processing. Further more detailed analysis of the emerging information was done using various statistical tools, pertaining to the Excel program.

Accordingly the following parameters were calculated:

$$\text{Density of all tree/shrub species} = \frac{Total\ number\ of\ stems\ of\ all\ tree/shrub\ species/}{Sample\ size\ in\ ha}$$

$$\text{Density of each individual tree/shrub} = \frac{Total\ number\ of\ stems\ encountered\ for\ a\ given\ tree\ or\ shrub/}{Sample\ size\ in\ ha}$$

$$\text{Relative density of each individual tree/shrub} = \frac{Number\ of\ stems\ of\ each\ individual\ tree/shrub\ x1oo/}{Total\ number\ of\ stems\ of\ all}$$

The frequency, Relative frequency, Basal area (Ba), Dominance and Relative dominance were also calculated as follows for each tree/shrub species with DBH/DSH >2.5cm:

$$\text{Frequency} = \frac{Number\ of\ quadrates\ in\ which\ a\ species\ recorded\ x\ 100/}{Total\ number\ of\ quadrates}$$

$$\text{Relative frequency} = \frac{Frequency\ of\ a\ species\ x100/}{Sum\ frequency\ of\ all\ tree/shrub\ species}$$

Ba=22 x d2/28, Where Ba=basal area, d=diameter at breast height or stump height

Dominance=Mean Ba per tree/shrub species x Density of a tree/shrub species

Importance Value Index=Relative density + Relative frequency + Relative Dominance

Diameter and height class distribution and correlation of vegetation with physiographic feature analysis were also done by using Excel software.

3. Results and Discussions

3.1. Environmental Data

3.1.1. Land Use-Land Cover

The major land cover types of this forest are Dry afromontane Ecosystem vegetation type and also the existing forest categorized as low land forest. The forest land was nearly undulating terrain is covered by different small trees and short grass species. The forest disturbance suffered with Browsing and some extent of encroachment for fuel wood, house construction and domestic animals grazing inside the Lay Agerit Giorgis forest. All this forest disturbance types, other than the agricultural one, have been considered comparatively high damaging as compared those other forests. The types of crops cultivated are mainly SORGHUM, MAIZE, BARLEY and TEFF and CEREALS. Since the area is high rainfall receiving area in the country grass species is rapidly grows the forest area.

3.1.2. Forest Disturbance

The agriculture induced type of forest disturbance prevails, mainly in the form of newly began forest clearance at the village side with the purpose of expanding the existing adjacent farm lands, and also inside the forest southern boundary new house settlement exist in the natural forest. Selective logging, agriculture, honey production and pollarding were the most important forest disturbance types, recorded in Lay Agerit Giorgis forest. But the main recorded was cutting, grazing and followed by browsing was comparatively high influential in the context of Lay Agerit Giorgis forest. However, the level of impacts that these factors cause varies. About 35.16% of the negative impacts that encompasses light and moderate attributed by Browsing and 36.26% and negative impacts that encompasses light and moderate disturbance levels shows by Grazing, and also 28.57% light and moderate disturbance levels shows by logging /cutting /disturbance recorded respectively (See Table 1).

Table 1. *Influence of forest disturbance in Lay Agerit Giorgis forest.*

Factors of forest disturbance	Disturbance Scale				
	1 (Negligible)	2 (Light)	3 (Moderate)	4&5 (Intensive/Heavy)	Total (%)
Browsing	4.40	21.98	8.79	0	35.16
Grazing	2.20	20.88	13.19	0	36.26
Logging (cutting)	2.20	19.78	6.59	0	28.57
Total	8.80	62.64	28.57	0	100

The data were taken from four topographic aspects and slope positions (1521 – 2060m.a.s.l.) and within the 8- 45% slope gradients.

Table 2. *Topographic features and level of forest disturbance.*

Slope position	Altitude (m.a.s.l.)	Slope gradient (%)	Aspect	Number of quadrates	Forest disturbance types	Forest disturbance intensity	Proportion of sample plots (%)
Lower	1521 - 1565	3 -10	N & NE	8	Cutting	Moderate	17.8
Middle	1940- 1985	10 - 30	ALL	20	Grazing	light	44.4
Upper	1986 -2060	31- 45	E, W, & NW	17	Browsing	light	37.8
Total				45			100

3.2. Floristic

From the inventoried Lay Agerit Giorgis forest a total of 48 woody plant specimens were collected; all specimens were identified. The identified specimens belong to 38 genera and 27 families. The most frequent genera in the woodland were (Fabaceae), (Capparidaceae), (Celastraceae) and (Tiliaceae), respectively. On the other hand the family of these genera is also the most frequent and diverse in the inventoried wood land. From each respective genera, *Dichrostachys cinerea, Acacia tortilis, Dodonaea angustifolia*, *Maytenus undata*, *Albizia amara,* and *Senna singueana,* were found to be the most diverse woody plant species. On the contrary *Securidaca longepedunculata, Pterolobium stellatum, Halleria lucida*, *Gardenia ternifolia, Ficus sur, Commiphora africana Celtis africana*, *Bersama abyssinica* and *Balanites egyptiaca* were the least frequent and least diverse in the woodland.

3.3. Structure

3.3.1. Species Dimensions

The maximum height attained in the forest was 12 m while the maximum DBH/DSH was 54cm represented by the *Acacia tortilis* tree species. This tree species is also the highest in terms of mean height (5.5 m) and mean DBH/DSH (14.8 cm). The maximum number of stems sampled and measured was for those tree species that are the most diverse or frequently appearing in the inventoried woodland. On the other hand, the least size of DSH/DBH and total height recorded was 2.5 cm and 2.5 m respectively

Vertical Structure

The tree species whose height exceeds 10m belonged to the *upper story* comprising about 9.5% of the floristic composition; those tree species whose height ranges between 8.7 - 10 m were categorized to the *middle stratum* consisting of about 26.2% species composition and those tree species whose height is less than 8.7m were classified to the *lower layer***,** about 64.3% in proportion from the woody plant species inventoried in Lay Agerit Giorgis forest. In general, the analysis of the vertical structure of the Lay Agerit Giorgis forest reveals that the majority of the floristic composition is found in the Middle strata of the vegetation.

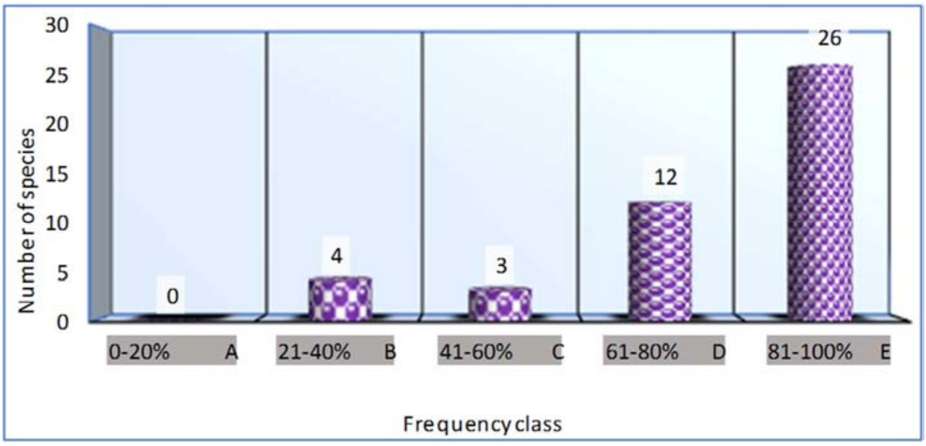


Figure 2. *The number of species by frequency class.*

3.3.2. Species Frequency

The result of the study showed that the variation of the species frequency ranges between 2.94 – 76.4%. This implies that there is heterogeneity in species distribution in the Lay Agerit Giorgis forest. Among these, *Dichrostachys cinerea* (74.4%), *Acacia tortilis* (67.6%), each *Dodonaea angustifolia* and *Euclea racemosa* (64.7%) and *Rhus retinorrhoea* (52.9%) are respectively the most frequently appearing or are the most widely distributed woody plant species. Moreover, *Maytenus undata* (44.1%) *Carissa spinarum* (41.2%), each *Albizia amara*, *Osyris quadripartite*, *Rhus glutinosa* and *Senna singueana* (38.2%), are the woody species possessing the higher frequency next to the aforementioned species which attained the highest frequency. On the other hand, *Securidacalonge pedunculata, Pterolobium stellatum, Halleria lucida*, *Gardenia ternifolia, Ficus sur, Commiphora africana, Celtis africana*, *Bersama abyssinica* and *Balanites aegyptiaca* are the species which are uniformly the lowest in frequency distribution (2.94%). Hence, there is a high variation in species distribution between the above-mentioned groups of species that showed the highest and the lowest frequency. In other words, when the distribution of species was interpreted in terms of frequency classes, four species, *Dichrostachys cinerea, Acacia tortilis*, *Dodonaea angustifolia* and *Euclea racemosa* was B (61-80%) and also three species belonged to fallen frequency class C (41-60%). Further, as illustrated in Figure 2, about 26.66% the species was included under frequency class D (21-40%) while 57.77% of the species were categorized under frequency class E (1-20%). Therefore, the falling of highest percentage (or number of species) under low value frequency class implies as the distribution of the species is in the woodland is not generally high.

3.3.3. Species Density

The species density of the woodland ranges between 0.59 – 190.6 per ha. The variation of the relative density of the species is also between 0.04 – 12.6%. The least species density was for *Securidaca longepedunculata, Celtis africana, Balanites aegyptiaca, Ficus sur*, *Commiphora africana* and *Bersama abyssinica*, while the highest species density (>100 per ha) was for *Dichrostachys cinerea* (190.6), *Dodonaea angustifolia* (167.1), *Carissa spinarum* (122.9), and *Acacia tortilis* (103.5). This result Pointed out that there is a significant variation among the individual tree/shrub species in density per ha. In the inventoried woodland, the total species density per ha was 1512.9. To summarize, the species density was organized by density classes as shown in Table 4. Here, the majority of the species (26.7% and 48.9%) was belonged to density class C and D respectively.

Table 3. *Species density class and distribution*

Species density class	Total density	Relative density	Number of species	Proportion (%)
A (>95)	728.2	48.13	5	11.1
B (50.1–95)	239.4	15.82	3	6.7
C (20.1–50)	363.5	24.03	12	26.7
D (1–20)	179.9	11.89	22	48.9
E (<1)	1.77	0.12	3	6.7
Total	1512.9	100	45	100

The species densities per ha with the diameter size greater than 10 cm DSH/DBH and greater than 20 cm DSH/DBH are 100.02 and 37.07 respectively and their ratio is 29.35. This implies that the number of stems per hectare was much higher for species of smaller diameter size than for species of greater diameter size.

3.3.4. Stand Diameter and Height Profile

(i) Stand Diameter Profile

For ease of the comparison and interpretation, the diameter class was formed in to ten groups as: A (2.5–7.5 cm); B (7.6–12.5cm); C (12.6– 17.5cm); D (17.6–22.5 cm); E (22.6–27.5); F (27.6–32.5 cm); G (32.5–37.5 cm); H (37.6–42.5cm) andI (>42.6cm). The result of the analysis of the diameter profile data indicated that about 78.9% (N=35) of the tree/shrub species are those species which have fallen in diameter class A; 14.3% (N=28) in diameter class B; 2.5% (N=15) in diameter class C; 2.0% (N=11) in diameter class D; 1.2% (N=8) in E; 0.9% (N=5) in diameter class F0.4% (N=4) in G 0.1% (N=2) in diameter class H. (See Figure 2).

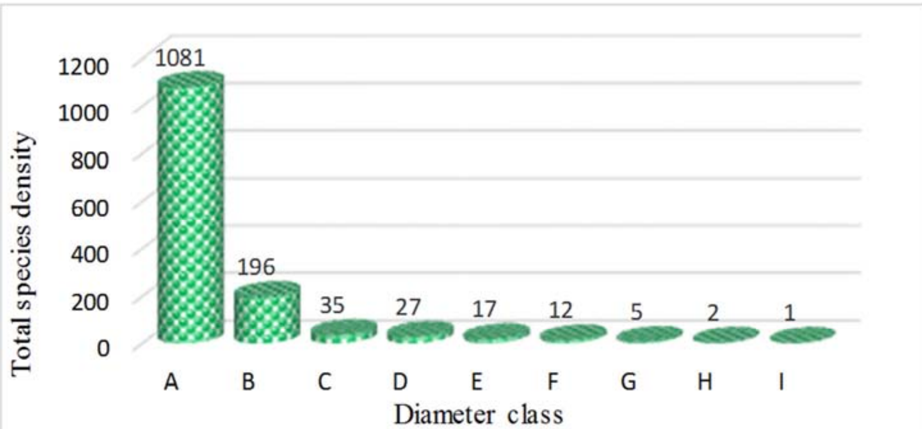


Figure 3. *Number and total species density by diameter class.*

(ii) Stand Height Profile

In determining the stand height profile, the height class was formed in to four groups as: A (≤ 5 m); B (5.1–10 m); C (10.1–15cm) and D (>15m). The result of the analysis of the height profile data indicated that about 93.8% (N=41) of the tree/shrub species are those species which have fallen in height class A; 6.1% (N=17) in height class B0.2% (N=3) in height class C and no species recorded in D diameter class (See Figure 3). This depicts that the majority of the species belongs to the lower height class in similar trend as diameter distribution. The possible reason could be that selective matured tree cutting, intensive browsing and moisture deficit or recurrent droughts were the determinants for the appearing of the majority of the tree/shrub species in the lower height class.

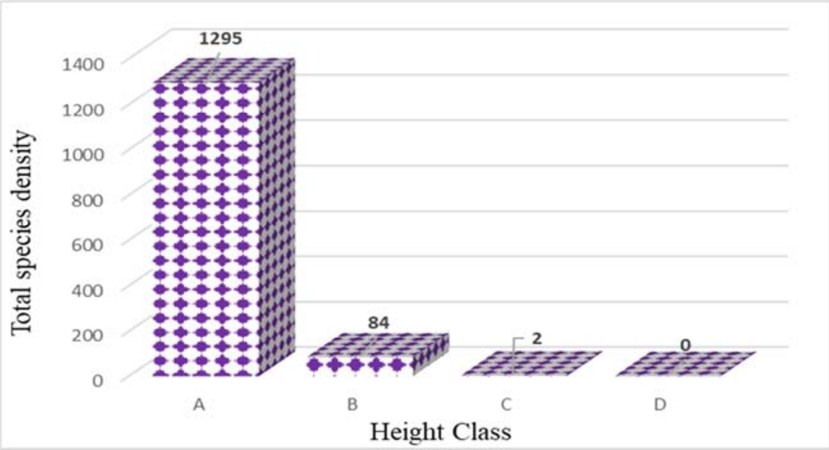


Figure 4. *Number and total species density by height class.*

3.3.5. Basal Area and Dominance of Woody Plant Species

The total basal area for the inventoried woodland is 0.35 m^2 per ha. The biggest basal area recorded was for *Ficus sur*0.063 m^2 ha^{-1}. The following species were also found with little mean basal area *Grewia villosa*, *Otostegia integrifolia*, *Securidaca longepedunculata,* and *Halleria lucida* (with mean basal area less than 0.001 m^2). While the largest dominance and relative dominance was for *Acacia tortilis* (2.45 and 34.6% respectively). The top five dominant woody plant species were *Acacia tortilis, Albizia amara, Euclea racemosa*, *Maytenus undata* and *Acacia seyal* respectively within the range of 2.45 – 0.27. Here the number of stems of a species plays a crucial role for a certain species is dominant or not besides the mean basal area of the species. About 72.98% of the dominance was accounted by 10 species of the forest. These include, *Acacia tortilis, Albizia amara, Euclea racemosa*, *Maytenus undata, Acacia seyal, Dichrostachys cinerea, Stereospermum kunthianum*, *Acacia senegal, Acacia abyssinica* and *Rhus retinorrhoea*. There are nine species with least dominance value in this forest (with dominance value less than 0.001 Rs).

Table 4. *IVI class and proportion of the woody plant species.*

Species IVI class	Number of species	Total IVI	Proportion (%)
A (<1)	8	4.48	1.52
B (1.1– 3)	5	7.74	2.62
C (3.1–8)	19	91.41	30.99
D (8.1–40)	9	143.04	48.49
E (> 40.1)	1	48.32	16.38
Total	42	300	100

3.3.6. Important Value Index (IVI)

The important value index of the species indicates how dominant is the species in a certain area and hence helps to compare ecological importance of the species in vegetation's [20]. Here in the inventoried Lay Agerit Giorgis forest, the species IVI varies between 0.35 – 48.32. It is lowest for *Securidaca longepedunculata*, *Celtis africana*, *Commiphora africana* and *Bersama abyssinica,* while it is highest for *Acacia tortilis* and *Euclea racemosa*. This reveals that in this woodland the species relative frequency, density and dominance differ accordingly. This in turn implies the importance of developing the conservation priority for the existing species in the woodland.

The majority of the species (*ca* 66.67%) are appearing in the IVI class C and D contributing around 79.48% to the total IVI. The one dominant species which is *Acacia tortilis* that categorized to the IVI class E consisting about 16.38% from the whole IVI. *Acacia tortilis*, *Euclea racemosa*, *Dichrostachys cinerea, Dodonaea angustifolia* and *Albizia amara* by its own contributed 44.22% to the total IVI, and hence this is the most frequent and dominant species in the woodland. On the contrary *Solanum incanum*, *Halleria lucida, Gardenia ternifolia, Balanites aegyptiaca*, *Bersama abyssinica*, *Commiphora africana*, *Celtis africana*, and *Securida calongepedunculata* possess the lowest IVI, they do not frequently exist and are the most minor or rare species in the woodland. In principle, when a certain species receives the lowest IVI, it entails as it demands high priority for conservation while those species with the highest IVI require only monitoring and management in lieu of setting priority for conservation. In accordance with this, the above eight species demand high priority for conservation. The remaining 34 species needs monitoring and management efforts.

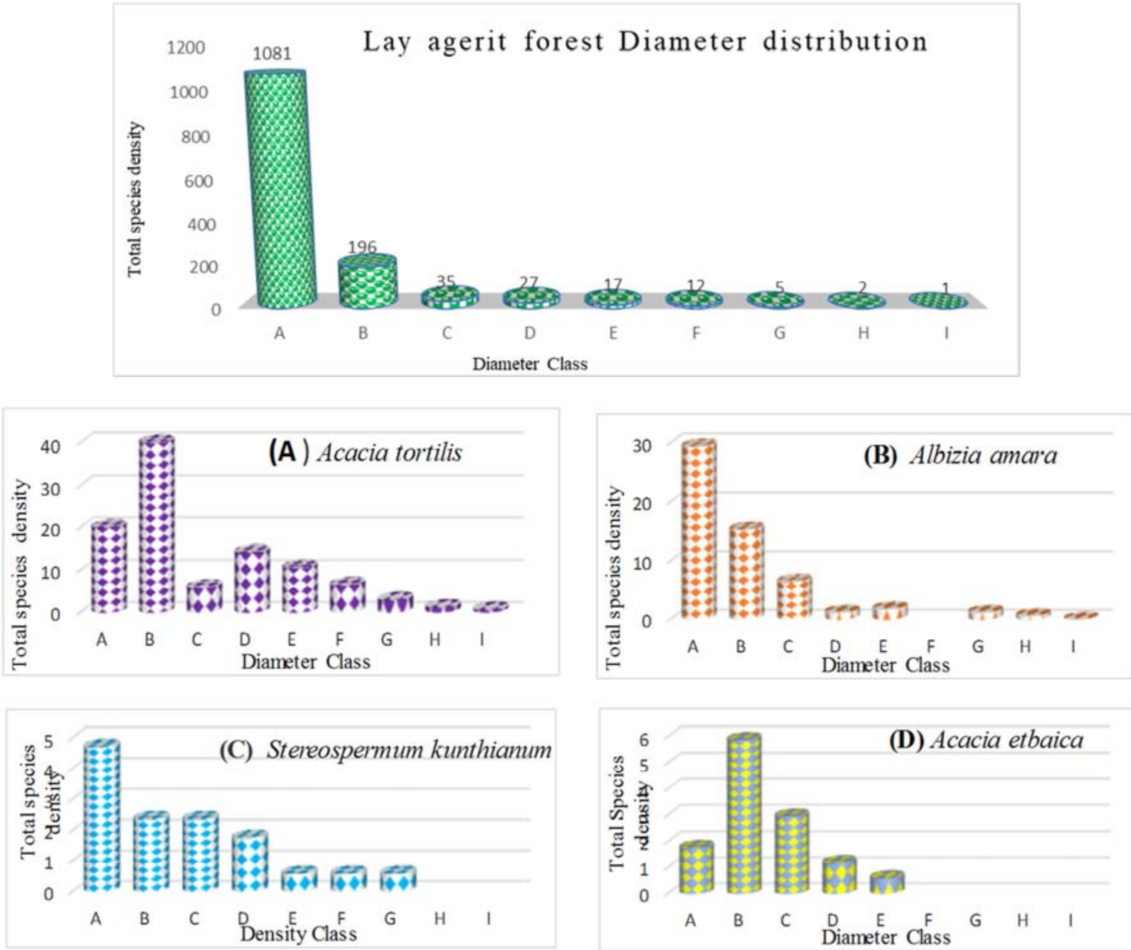
Table 5. *Woody plant species under IVI classes.*

No	A (<1)	No	
1	*Solanum incanum*	9	*Acacia abyssinica*
2	*Halleria lucida*	10	*Boscia salicifolia*
3	*Gardenia ternifolia*	11	*Acacia senegal*
4	*Balanites aegyptiaca*	12	*Acacia brevispica*
5	*Bersama abyssinica*	13	*Erythrina abyssinica*
6	*Commiphora africana*	14	*Acacia etbaica*
7	*Celtis africana*	15	*Grewia villosa*
8	*Securidaca longepedunculata*	16	*Premna schimperi*
	B (1.1– 3)	17	*Cadaba farinosa*
1	*Otostegia integrifolia*	18	*Acokanthera schimperi*
2	*Sterculia africana*	19	*Croton macrostachyus*

No	A (<1)	No	
3	*Opuntia ficus-indica*		D (8.1 – 40)
4	*Ficus sur*	1	*Euclea racemosa*
5	*Maytenus arbutifolia*	2	*Dichrostachys cinerea*
	C (3.1–8)	3	*Dodonaea angustifolia*
1	*Grewia bicolor*	4	*Albizia amara*
2	*Sennasingueana*	5	*Maytenus undata*
3	*Osyris quadripartita*	6	*Carissa spinarum*
4	*Grewiaf erruginea*	7	*Rhus retinorrhoea*
5	*Ximenia americana*	8	*Rhus glutinosa*
6	*Ziziphus spina-christi*	9	*Acacia seyal*
7	*Stereospermum kunthianum*		E (>40.1)
8	*Maytenus obscura*	1	*Acacia tortilis*

3.3.7. Species Population Structure

The pattern of diameter size-class distribution has often been used to represent the population structure of a forest [19]. This is because the pattern of diameter class distribution connotes the general trends of population dynamics and recruitment process of a given species. This was depicted by the evaluation of the diameter class total species density distribution as an inverted J-shape curve (Figure 5), which shows a pattern where a total species density distribution has the highest density in the lower diameter class and a gradual decrease towards the higher classes. The evaluation of selected individual species also revealed two main patterns of population distribution. These are 1) inverted J-shape curve for *Acacia tortilis*, *Albizia amara* and *Stereospermum kunthianum*in similar to the general trend of the diameter class total density distribution, this shows the pattern which has the highest species density distribution in the lower diameter class and a gradual decrease towards the higher classes; 2) bell-shaped curve for *Acacia etbaica* which is a type of density distribution in which it is high in the middle diameter classes and lower in the lower and higher diameter classes (Figure 5 D).



DBH class: 1=2.5 -5 cm; 2=5.1-10.5cm; 3=10.1-15.0cm; 4=15.1-20.0cm; 5=20.1-25.0cm; 6=25.1-30.0cm; 7=30.1-35.0cm; 8=35.1-40cm; 9=>40.1cm

Figure 5. *Diameter class density distribution of selected tree species.*

The population structure of the species was grouped as follows for the sake of establishing the conservation priority for each species. To group these woody plant species the criteria used were reproduction and recruitment status of the species in the vegetation. Reproduction refers generally to the regeneration status while the recruitment is to mean the appearing of the species in different diameter classes or in the next growth stage. Hence, based on these; the species were categorized as group 1 if both reproduction and recruitment is bad, as group 2 if reproduction is good but recruitment is bad and group 3 if reproduction as well as recruitment is good. Accordingly, the species were listed in Table 6.

Table 6. *List of woody plant species by population structure.*

No.	Group 1both BD	Group 2G&BD	Group 3 GG
1	*Acacia abyssinica*	*Acacia seyal*	*Acacia tortilis*
2	*Acacia brevispica*	*Boscia salicifolia*	*Albizia amara*
3	*Acacia etbaica*	*Cadaba farinosa*	*Carissa spinarum*
4	*Acacia senegal*	*Celtis africana*	*Dichrostachys cinerea*
5	*Acokanthera schimperi*	*Grewia villosa*	*Dodonaea angustifolia*
6	*Balanites aegyptiaca*	*Halleria lucida*	*Euclea racemosa*
7	*Bersama abyssinica*	*Maytenus obscura*	*Grewia bicolor*
8	*Commiphora africana*	*Osyris quadripartita*	*Grewia ferruginea*
9	*Croton macrostachyus*	*Otostegia integrifolia*	*Maytenus undata*
10	*Erythrina abyssinica*	*Senna singueana*	*Rhus glutinosa*
11	*Ficus sur*	*Solanum incanum*	*Rhus retinorrhoea*
12	*Gardenia ternifolia*	*Ximenia americana*	*Ziziphus spina-christi*
13	*Maytenus arbutifolia*		
14	*Opuntiaficus-indica*		
15	*Premna schimperi*		
16	*Securidaca longepedunculata*		
17	*Sterculia africana*		
18	*Stereospermum kunthianum*		

Table 7. *List of woody plant species grouped by regeneration status (RS).*

No	Group 1	Group 2	Group 3
1	*Acacia brevispica*	*Acacia abyssinica*	*Dodonaea angustifolia*
2	*Acacia senegal*	*Acacia etbaica*	*Dichrostachys cinerea*
3	*Acokanthera schimperi*	*Croton macrostachyus*	*Euclea racemosa*
4	*Balanites aegyptiaca*	*Premna schimperi*	*Jasminum abyssinicum*
5	*Bersama abyssinica*	*Clutia abyssinica*	*Otostegia integrifolia*
6	*Commiphora africana*		*Grewia bicolor*
7	*Erythrina abyssinica*		*Cadab afarinosa*
8	*Ficus sur*		*Carissa spinarum*
9	*Gardenia ternifolia*		*Acacia tortilis*
10	*Maytenus arbutifolia*		*Senna singueana*
11	*Opuntia ficus-indica*		*Grewia ferruginea*
12	*Securidaca longepedunculata*		*Grewia villosa*
13	*Sterculia africana*		*Maytenus obscura*
14	*Stereospermum kunthianum*		*Maytenus undata*
15			*Rumex nervosus*
16			*Albizia amara*
17			*Osyris quadripartita*
18			*Rhus glutinosa*
19			*Acacia seyal*
20			*Pterolobium stellatum*
21			*Ziziphus spina-christi*
22			*Solanum incanum*
23			*Halleria lucida*
24			*Boscia salicifolia*
25			*Celtis africana*
26			*Rhus retinorrhoea*
27			*Capparistomentosa*
28			*Ximeniaamericana*

3.3.8. Regeneration Status

The seedling and sapling status was recorded for 31 and 26 woody plant species respectively. This becomes about 68.8% when compared to the total matured woody plant species richness inventoried. Moreover, the total seedling and saplings density per ha was 9897. *Dodonaea angustifolia, Dichrostachys cinerea, Euclea racemosa, Jasminum abyssinicum, Otostegia integrifolia* and *Grewia bicolor* respectively share the highest saplings density in the woodland. While *Acacia etbaica, Acacia abyssinica, Clutiaa byssinica,* and *Ximenia mericana* woody plant species is the least. In general, this implies that the regeneration status was low and the profound reason could be the intensive annual trampling by livestock while browsing and grazing in the woodland that compact the soil and thereby reduces the germination of the seeds from the soil seed bank. On top of this, they will cause the physical damage on the seedlings by peeling during grazing and browsing. Therefore, it demands high priority to ensure the regeneration of these species and thereby conserve in a sustainable way. Similarly, monitoring and conservation is also needed for those species which have had low regeneration status. Similar study conducted by [12, 14], the management of regeneration plays a vital role in sustainable forest practice and serving as an indicator of the forest condition of an area. The general grouping of the woody plant species was undertaken based on the criteria that if the species are totally absent in seedlings and saplings or in the regeneration list at all they were categorized as group 1; as group 2 if density is between 0.1-50 and group 3 if > 50 according to the list put in Table 7.

3.4. Vegetation-Environment Relationship

3.4.1. Floristic Richness by Altitude

The altitudinal range of Lay Agerit Giorgis forest is between 1500-2099m.a.s.l. and thus belongs to the Dry weynadega agro-ecological zone as defined between 1500-2300m above sea level consequently; the area has no wide altitudinal variation that affects low of the distribution and species richness of woody plant species. As of this, the result of the analysis of the floristic richness in relation to the altitudinal variation indicated little or some effect on the extent of species richness. Accordingly, about 13.7% of the total species richness was recorded from within the whole altitudinal range of 1500-2099m.a.s.l. while 55.6% was appeared at the middle and upper part of the altitude (1950–2099m.a.s.l.). However, some species (30.7%); were appeared only at one altitude drop which is the lower part of the altitude within the range of between 1500 - 1599m.a.s.l. Even though this altitudinal gradient is narrow, it could be concluded from this finding that the woody plant species composition changes or varies with the change in altitudinal gradients (along the altitudinal increase or decrease) in a non-linear relationship type of distribution and this was explained strongly by 100% (R^2=0.098; See Figure 6). As a result, the relationship between the distribution of the number of species and altitudinal gradient took a slight bell-shaped curve which means floristic richness and distribution is low at the lower altitude and increases to the mid altitudinal gradient and towards peak altitude.

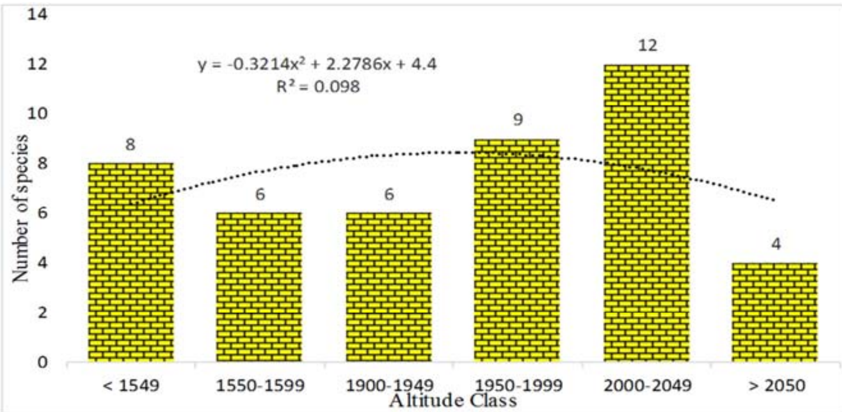


Figure 6. *Woody plant species composition or distribution by altitudinal gradient.*

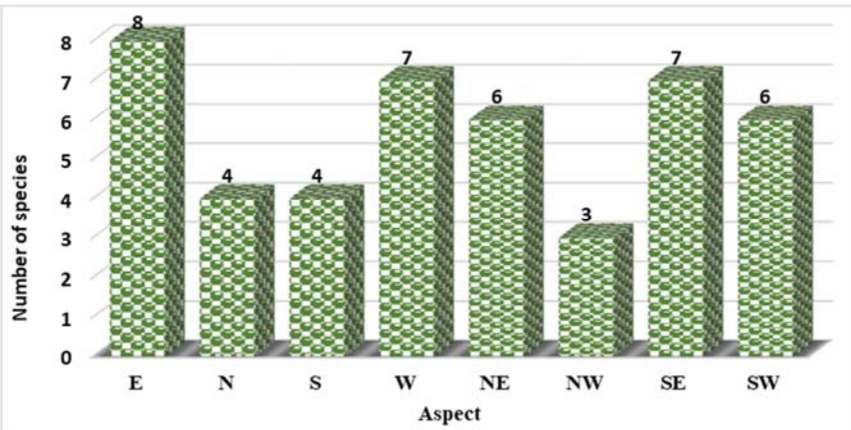


Figure 7. *Number of species recorded as per the topographic aspects.*

3.4.2. Floristic Richness by Aspect

The result of the study pointed out that the species distribution varies with aspects. In accord with this, about 9.0% of the species were recorded from the North and South respectively and similarly 14.6% from west and Southeast direction, and 14.0%from northeast and south west respectively. In addition to this 17.1% from East and 9.5%from northwest direction of the woodland topographic feature were recorded. In terms of the individual species, maximum number of woody plant species (8) was inventoried on the East, followed by (7) species West and southeast aspects respectively. This entails that the floristic composition of plant species is little affected by aspects and vary accordingly. Similar study conducted [13], diversity of plant species affected by aspect and slop position of the area.

3.4.3. Floristic Richness by Slope Gradients

The species occurrence analysis by slope gradient revealed that 23.5% of the total woody plant species inventoried was recorded from slope gradient class B; 30.6% from class C and finally 45.9% the total species was recorded from slope gradient class from D. As illustrated in Figure 8, the number of woody plant species composition or distribution was higher at slope gradient class C (11-30%). This slope gradient class is a landscape characterized by gentle to moderate slope where usually the soil nutrient movement is slow, while aeration and infiltration is high. This has created the optimum land suitability for plant growth. On the contrary, the species richness is highest at slope gradient class D (31-50%). This is because such type of topography is characterized by steep slope and the gravitational movement of soil nutrient is high besides the high impact of run off on soil and as a result, soil moisture content is low particularly in low land areas. This worsens the growth and regeneration of the plant species.

The relationship between the species richness and slope gradient was non-linear and this is strongly explained by 87% (R^2=0.8795). At the lower slope gradient class, the number of species is few and it increases towards the moderate slope class and then increases as slope gradient rises to steep slope.

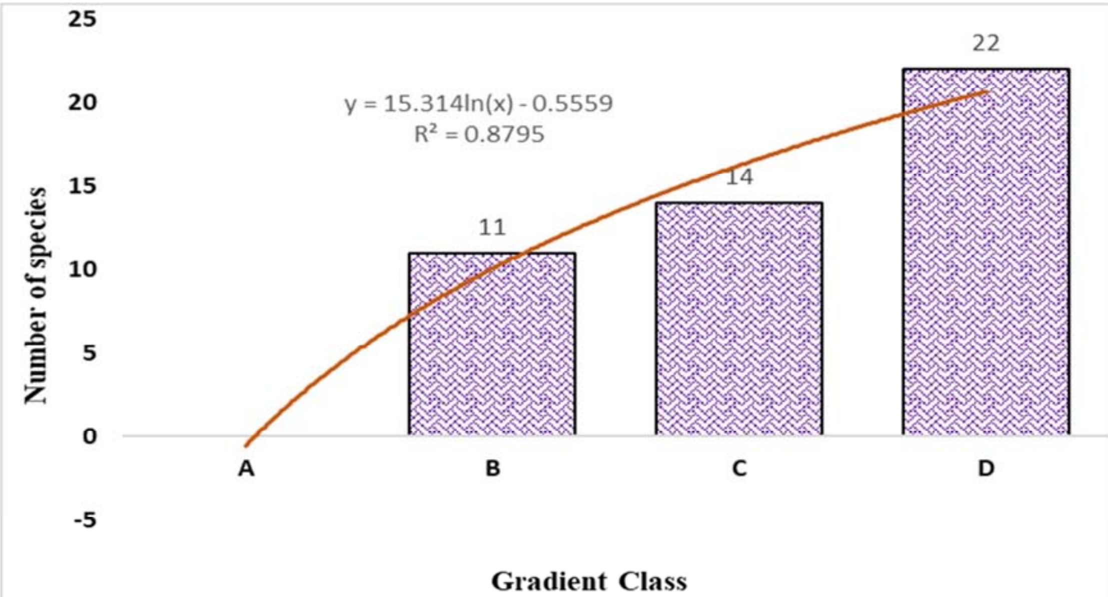


Figure 8. *Woody plant species distribution by slope gradient classes.*

4. Measures Proposed for the Genetic Conservation of Woody Plant Species

Based on the population structure (PS), regeneration status (RS) and IVI of the woody plant species, the conservation priority was proposed as summarized in Table 8.

Table 8. *Woody plant species prioritized according to IVI, PS and RS groups at Lay Ageritforest.*

No	Species name	Selection criteria			Over all priority	*Conservation measures*	
		IVI	PS	RS		*In-situ*	*Ex-situ*
1.	*Balanitesaegyptiaca*	1	1	1	1	Seeding & planting in-situ; conservation of stands	Seeding & planting in-situ; seed storage
2.	*Bersamaabyssinica*	1	1	1	1	Seeding & planting in-situ; conservation of stands	Seeding & planting in-situ; seed storage
3.	*Commiphoraafricana*	1	1	1	1	Seeding & planting in-situ; conservation of stands	Seeding & planting in-situ; seed storage
4.	*Ficus sur*	1	1	1	1	Seeding & planting in-situ; conservation of stands	Seeding & planting in-situ; seed storage

No	Species name	Selection criteria			Over all priority	Conservation measures	
		IVI	PS	RS		*In-situ*	*Ex-situ*
5.	*Gardenia ternifolia*	1	1	1	1	Seeding & planting in-situ; conservation of stands	Seeding & planting in-situ; seed storage
6.	*Maytenusarbutifolia*	1	1	1	1	Seeding & planting in-situ; conservation of stands	Seeding & planting in-situ; seed storage
7.	*Opuntiaficus-indica*	1	1	1	1	Seeding & planting in-situ; conservation of stands	Seeding & planting in-situ; seed storage
8.	*Securidacalongepedunculata*	1	1	1	1	Seeding & planting in-situ; conservation of stands	Seeding & planting in-situ; seed storage
9.	*Acacia brevispica*	2	1	1	1	Seeding & planting in-situ; conservation of stands	Seeding & planting in-situ; seed storage
10.	*Acacia Senegal*	2	1	1	1	Seeding & planting in-situ; conservation of stands	Seeding & planting in-situ; seed storage
11.	*Acokantheraschimperi*	2	1	1	1	Seeding & planting in-situ; conservation of stands	Seeding & planting in-situ; seed storage
12.	*Erythrinaabyssinica*	2	1	1	1	Seeding & planting in-situ; conservation of stands	Seeding & planting in-situ; seed storage
13.	*SterculiaAfricana*	2	1	1	1	Seeding & planting in-situ; conservation of stands	Seeding & planting in-situ; seed storage
14.	*Stereospermumkunthianum*	2	1	1	1	Seeding & planting in-situ; conservation of stands	Seeding & planting in-situ; seed storage
15.	*Acacia abyssinica*	2	1	2	2	conservation of stands	seed storage
16.	*Acacia etbaica*	2	1	2	2	conservation of stands	seed storage
17.	*Crotonmacrostachyus*	2	1	2	2	conservation of stands	seed storage
18.	*Premnaschimperi*	2	1	2	2	conservation of stands	seed storage
19.	*Jasminumabyssinicum*	1	2	2	2	conservation of stands	seed storage
20.	*Pterolobiumstellatum*	1	2	2	2	conservation of stands	seed storage
21.	*Capparis tomentosa*	2	2	2	2	conservation of stands	seed storage
22.	*Celtisafricana*	1	2	3	2	conservation of stands	seed storage
23.	*Hallerialucida*	1	2	3	2	conservation of stands	seed storage
24.	*Solanumincanum*	1	2	3	2	conservation of stands	seed storage
25.	*Otostegiaintegrifolia*	2	2	3	2	conservation of stands	seed storage
26.	*Bosciasalicifolia*	2	2	3	3	conservation of stands	seed storage
27.	*Cadabafarinosa*	2	2	3	3	conservation of stands	seed storage
28.	*Grewiavillosa*	2	2	3	3	conservation of stands	seed storage
29.	*Maytenusobscura*	2	2	3	3	conservation of stands	seed storage
30.	*Acacia seyal*	3	2	3	3	conservation of stands	seed storage
31.	*Osyrisquadripartite*	3	2	3	3	conservation of stands	seed storage
32.	*Sennasingueana*	3	2	3	3	conservation of stands	seed storage
33.	*XimeniaAmericana*	3	2	3	3	conservation of stands	seed storage
34.	*Acacia tortilis*	3	3	3	3	conservation of stands	seed storage
35.	*Albiziaamara*	3	3	3	3	conservation of stands	seed storage
36.	*Carissa spinarum*	3	3	3	3	conservation of stands	seed storage
37.	*Dichrostachyscinerea*	3	3	3	3	conservation of stands	seed storage
38.	*Dodonaeaangustifolia*	3	3	3	3	conservation of stands	seed storage
39.	*Euclearacemosa*	3	3	3	3	conservation of stands	seed storage
40.	*Grewia bicolor*	3	3	3	3	conservation of stands	seed storage
41.	*Grewiaferruginea*	3	3	3	3	conservation of stands	seed storage
42.	*Maytenusundata*	3	3	3	3	conservation of stands	seed storage
43.	*Rhusglutinosa*	3	3	3	3	conservation of stands	seed storage
44.	*Rhusretinorrhoea*	3	3	3	3	conservation of stands	seed storage
45.	*Ziziphusspina-christi*	3	3	3	3	conservation of stands	seed storage

5. Conclusion

The Lay Agerit Giorgis forest belongs to the *Acacia – Commiphora* type of woodland ecosystem. The inventoried Lay Agerit Giorgis forest (within the altitudinal gradient of 1500-2099m.a.s.l.) consists of 34 woody plant species that belongs to 38 genera and 27 families. This implies that the vegetation is comprised of high species richness and diversity. However, similar to the other areas of the forest ecosystem of Ethiopia, this woodland is also under population pressure largely because of the Agrarian system and semi pastoral of browsing animals (goats) is exercised in the area. The main attributing factors towards the disturbance of the forest are browsing and grazing for browsing domestic animals, selective cutting or exploitation of mature trees for house construction and firewood and charcoal production. These factors have caused the stunted growth and thereby the absence of the floristic composition at the higher diameter and height classes. Furthermore, due to these factors and probably due to the environmental adversity (e.g. recurrent drought), the regeneration status of most economically important woody plant species is low. This raises the question of ‘Could this vegetation continue in a perpetual way keeping its optimal productivity without losing its floristic richness?' To answer this, it needs further investigation on the vegetation ecosystem functioning (that includes soil and soil seed bank), the impacts of climate change and human impacts. For the time being, however; the result of the IVI analysis showed *Securidaca longepedunculata, Celtis africana, Commiphora africana*, *Bersama abyssinica*, *Balanites aegyptiaca, Gardenia ternifolia, Halleria lucida, Solanum incanum, Maytenus arbutifolia, Ficus sur, Opuntia ficus-indica* and *Sterculia africana* deserved the lowest IVI value and were categorized in IVI class 1. Therefore, setting high priority is needed to conserve these endangered woody plant species. The conservation strategy could follow either the *ex-situ* or field Gene bank or both conservation systems. The other remaining species require monitoring and management efforts in a suitable way.

6. Recommendations

From the present study, for the sustainable genetic conservation of the woody flora of the area, the following recommendations were put forward:

1) Genetic conservation with high focus is required for those species identified and priority is set by IVI analysis, while regular monitoring and management is also needed for the remaining woody plant species,
2) Performing awareness creation for the local community on the socio-economic and ecological importance of the vegetation and on the flora genetic conservation,
3) Enhancing the value of the forest for the local people by devising mechanisms on how to generate cash income, for example from beekeeping; since traditional beekeeping is practiced in the area on one hand and,
4) Finally, further investigation is envisaged that focuses on reproductive phenology, seed physiology, soil seed bank, soil and plant relations, the impact of climate change and human on vegetation productivity.

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