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Research article

Analysis of plant species diversity and forest structure in Arero dry Afromontane forest of Borena zone, South Ethiopia

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Abstract: Accelerated human population growth mostly coupled with poverty has enhanced negative impacts on forest resources in Ethiopia. This study aims to assess the vegetation structure, composition, and plant species diversity and regeneration status of Arero dry Afromontane forest. Concentric circular plots of 1m, 3m and 10m radius were used for recording seedling, sapling and tree species respectively. As the result, 84 species that belong to 44 families were recorded in the forest. The Shannon-Wiener diversity indices and evenness of woody species were H'=2.67 and J'=0.79 respectively. The total density and abundance of woody species were 272 stems ha per hectare and 427 individuals per all of the sampled plots. The forest is floristically diverse and rich as compared to many similar forests in Ethiopia. The structural analyses of the population of some dominant species experience poor regeneration. This implies that current management practices are not satisfactory to sustain forest conditions.
Keywords: Arero - Afromontane forest - Plant diversity - Forest structural analyses.

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INTRODUCTION

Tropical forests are the habitat of numerous species of living things which constitute biodiversity through webs of life. Forests support various life forms including human beings who dwell in settlements in and around forests (Mukhopadhyay *et al*. 2007). According to FAO (2007), 11.9% of Ethiopia's land area is covered with forests including closed forest plus woodlands. The same report narrated that between 1990 and 2000, 141,000 ha forest of Ethiopia were lost every year, which equals an average annual deforestation rate of 0.93%. On the other hand, between 2000 and 2005, the rate of deforestation increased by 1.03% to 10.4% per year *i.e.* 2,114,000 ha of forest cover lost in 15 years between 1990 and 2005. Gatzweiller *et al.* (2007) estimates that the area of closed forest has declined to about 3–4% in the country.

Despite the declining of vegetation cover, Ethiopia hosts rich biological diversity. This can be attributed from its great geographical diversity with high and rugged mountains, flat-topped plateau and deep gorges, incised river valley and rolling plains (Teketay 1999, Kassa *et al.* 2016, Tadesse *et al.* 2017). The size of the Ethiopian higher plant flora is estimated to about 6000 species out of which about 12% are probably endemic to Ethiopia (G/Hiywot 2003). The total number of woody plants is estimated to be 1000 (Biru 2003). However, unsustainable utilization of these resources has resulted in the declining of the country's biodiversity at a much faster rate.

In Ethiopia, accelerated human population growth mostly coupled with poverty has enhanced the negative human impact on the forest resources. Among the tropical forests, dry forests have been preferred for human settlement than wetter forest zones, due to different biological and ecological reasons (W/Mariam 1998). In rural area in Ethiopia where the livelihood of 83% of the population resides and dependent on renewable natural resources, the pressure on forest resources is high. These causes depletion and deterioration of the forest resources which have resulted in reducing agricultural productivity and hence the quality of life (Merga 2006). To improve the conservation of the remaining natural forests in Ethiopia, the remnant forest resources have

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been portioned into 58 National Forest Priority Areas (NFPAs) covering an area of 3.6 million ha (FSCDD 1990). These areas comprise natural forests, plantations, and non-forested land. Arero forest is one of these delineated priority forest areas of Oromia National Regional State in South Ethiopia.

Like most forests of the country, Arero forest is experiencing deforestation and degradation. It is obvious that these changes cause dynamics in the composition and forest structures. Several studies covering wider disciplines have been conducted in the areas which have contributed to the improved understanding of the ecological and socio-economic conditions and for better management of the forest. For instance, among several studies (Haugen 1992, Coppock 1993, Coppock 1994, Mengistu 1998, Angassa 2002, Angassa & Beyene 2003, Dale *et al*. 2005, Adelio *et al*. 2005, Takele 2006, Worku 2006). However, informations are lacking regarding forest conditions in Arero forest. Therefore, this study aims to respond for research questions such as: 1) What are the overview of vegetation structure in the forest? 2) What are the statuses of composition and plant species diversity? and 3) What are the regeneration status of plant species in the forest?

MATERIALS AND METHODS

Description of the study area

This study was carried out in Oromiya Regional National State, Borena Zone in Arero dry afromontane forest (Fig. 1). The forest is located 670 km south of Addis Ababa on the left-hand side of the high way running to Moyale town, 96 km from Yabelo town capital of Borena Zone. The boundary of the forest is approximately 7 km from the district town of Meta Gefersa. The forest is located 38°48′ and 38°55′ East and 4°45′ and 4°48′ north and at an altitude ranging from 1,606 to 1,805 masl. Arero forest has a total area of 29,226.39 ha.

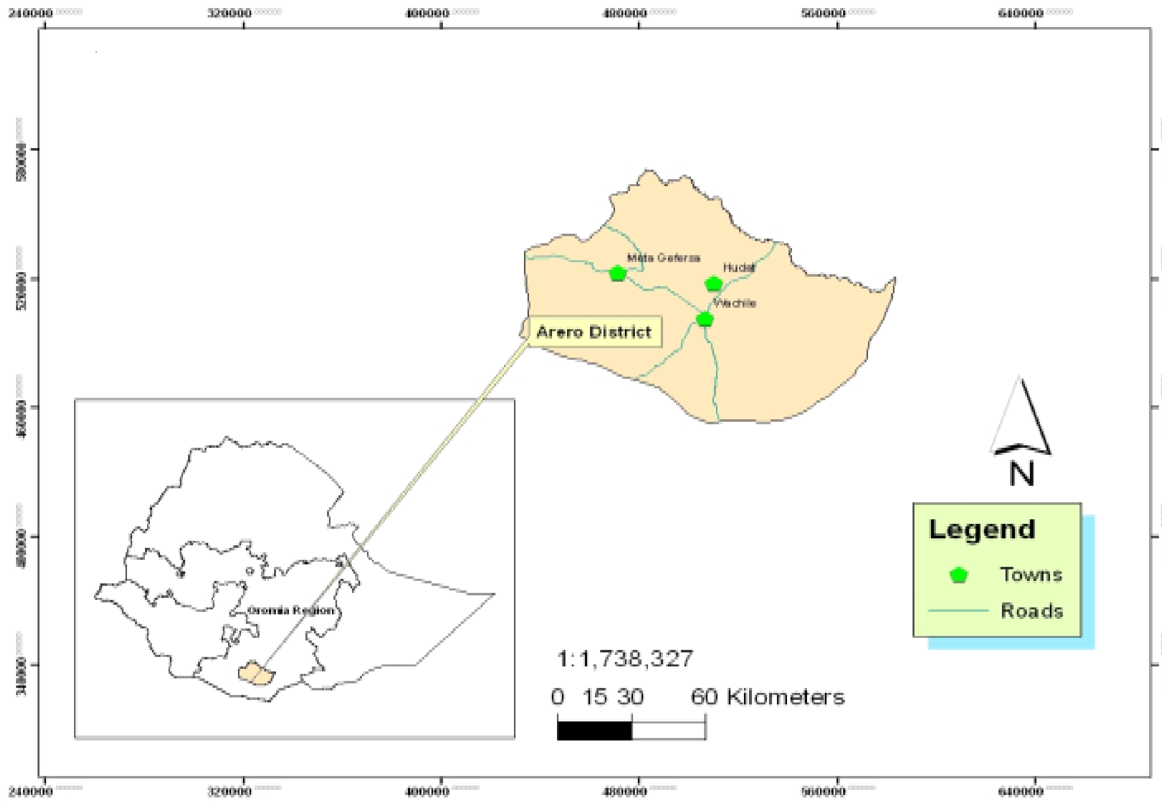

Figure 1. Map of the study area.

The population of Arero district were estimated to be 74,119 out which 11,859 or 16% are categorized as semi and sedentary farmers, while 62,260 (84%) are pastoralists and mixed farmers. There are about 12,595 households in the district, of which 3,108 households are members of different forest user groups. They are organized by SOS Sahel Ethiopia. The forest user groups are Borana and Guji people (FSCDD 1990).

Since there is no meteorology station at Arero district, data from the nearest Mega Meteorology Station was used. Hence, based on 20 (1984–2004) years meteorological data the mean monthly rainfall at the nearby station was 47.1mm. The mean annual rainfall of the district was 532.2 mm. The rain fall regime in Borena dry lands is bimodal with two rainy seasons (Fig. 2). The main rainy season, known as the long rainy season is between March and May with a peek in April, and a short rainy season is between September and November, with a peek in October. The mean monthly minimum and maximum temperature of Arero district was 16.2°C and 18.3°C, respectively. The mean annual temperature was 18.9°C. The dominant soil types found at Arero district are Chromic and Eutric Luvisol, Calcaric and Eutric Fluvisol and Chromic, Eutric and Calcari. Its bottom lands of the Borana rangeland are predominated by vertisols (OBPED 2000). Arero forest is upland dry evergreen forest dominated by *Juniperus procera* Hockst. ex Endl., but also consists of plant species such as *Olea europaea* L. subsp. *cuspidata* (Wall. ex G.Don) Clf., *Terminalia brownii Fresen.*, *Croton macrostachyus* Del., *Carissa edulis* Wahl., *Ehretia cymosa* Thonn., *Acokanthera schimperi* (A . DC.) Schweinf., *Dodonaea angustifolia* L. f., *Balanites eagyptica* (L.) Del., *Calpurina aurea* (Ait.) Benth., and *Acacia tortilis* (Frossk.) Hayne (Demesa 2002).

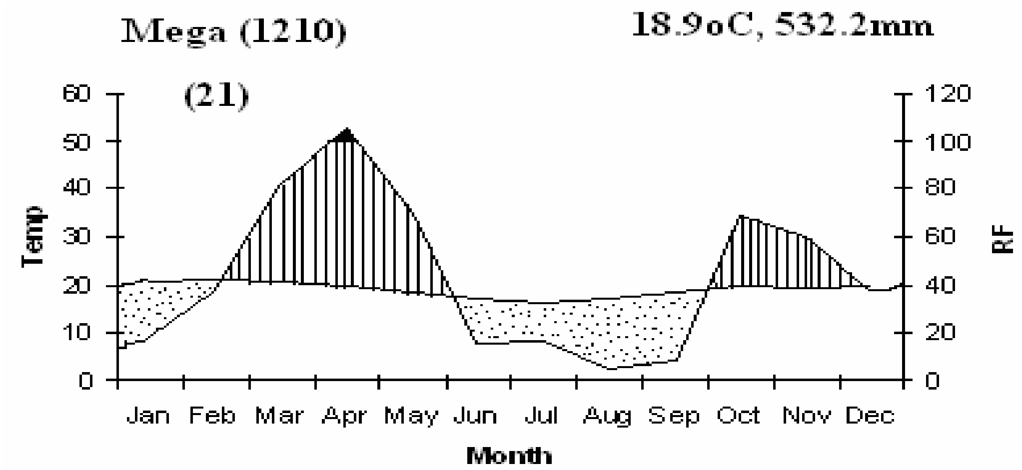

Figure 2. Climatic diagram of Mega, Borena zone, Ethiopia. (**Source:** Worku 2006)

Data collection

Line transects were laid on the basis of the differences in landscapes such as altitudinal ranges, drainage patterns, size and heterogeneity of the forest. Then, the distance between two consecutive parallel transect lines was 500 meters. Along the transect lines, sample plots were laid down at intervals of 300 meters. Concentric circular plots of 1m, 3m and 10m radius of were established along transect lines (Fig. 3). Then, 50 plots were distributed randomly on 19 transect lines.

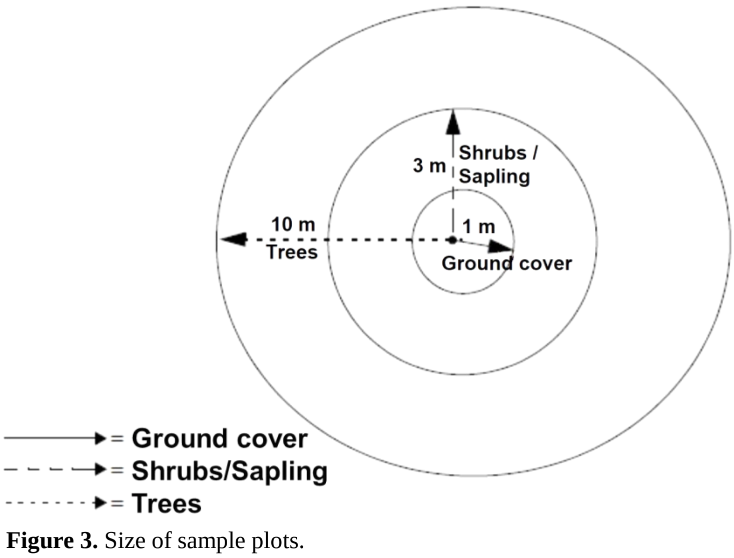

Figure 3. Size of sample plots.

In each plot, the percentage of ground cover was estimated as the percentage in 1m radius circle under the shade or canopy of trees. Then, local names for the woody seedlings and herbaceous plants and the number of seedling species were recorded in the field. All of the shrubs, saplings and woody climbers (vines, liana) in 3m radius circle were also recorded and identified. Trees and climbers were collected in the largest circle, with a radius of 10 m (Ostrom 2007). The DBH of saplings and trees were measured using caliper. Diameter tape was used for tree diameters beyond caliper size which measures circumference, then later converted to diameter.

For regenerated seedlings (height less than 1.0 m), only their number were recorded. Individual woody categorization was made at height less than 1.0 m and DBH less than 2.5 cm for seedlings. The height 1.0–3.0 m and DBH 2.5–10 cm for saplings, and height greater than 3.0 m and DBH greater than or equals to 10.0cm for tree species were measured (Ostrom 2007). Height was measured using the hypsometer. Where slope, topography and/or crown structure made it difficult to use hypsometer, height was estimated visually. For plot location, compass was used to direct the straight line between transect lines and successive plots. For species that were difficult to identify in the field, herbarium specimens were collected, pressed, dried and transported to the national herbarium in the Department of Biology in Addis Ababa University for proper identification.

Data processing and analyses

Species diversity in the forest was estimated using Shannon Wiener Diversity Index and species richness (Kent & Coker 1992):

$$H' = -\sum pi \ln pi$$

Where, H'= Shannon diversity index,
Pi = Proportion of individual found in the i^{th} species.

The Ratio of observed Shannon index to maximum diversity ($H_{max\ =}$ lns) can be taken as a measure of evenness (J') (Kent & Coker 1992).

$$\text{Equitability (evenness) } J = \frac{H}{H'max}$$

$$J = \frac{-\sum pi \ln pi}{\ln x}$$

Where, X= the Shannon diversity index number
H'= Shannon diversity index,
P_i = Proportion of individual found in the i^{th} species.

The basal area per tree is calculated using the formula (Lamprecht 1989):

$$\text{Basal Area (BA)} = \frac{\pi d^2}{4}$$

Where, d= DBH and Π= 3.14

The Importance Value Index (IVI) indicates the importance of species in the system and calculated with three components as follows (Kent and Coker 1992),

$$\text{Relative Density (RD)} = \frac{\text{Number of individuals of species}}{\text{Total number of individuals}} \times 100$$

$$\text{Relative Dominance (RDo)} = \frac{\text{Dominance of species}}{\text{Total dominance of all the soecies}} \times 100$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of species}}{\text{Total frequency of all the soecies}} \times 100$$

The Importance Value Index (IVI) of each woody species is:

$$IVI = RD + RDo + RF$$

To analyse the population structure of woody species, all individuals of each species encountered in the plots were grouped into arbitrary diameter classes and histograms were developed using the diameter classes versus the number of individuals categorized in each of the classes using Microsoft Excel.

RESULTS

Floristic composition and diversity of plant species

Table 1. Number, percentage and life form of collected species in Arero forest.

S.No.	Life form	Number	Percentage
1	Trees	30	34.48
2	Shrubs	9	10.35
3	Climbers	3	3.45
4	Herbs	45	51.72

In this study, 84 plant species representing 44 families were recorded in the forest including trees, shrubs and herbaceous plants (Appendix A). From all the species collected 51.72% were herbs, 34.48% trees, 10.35% shrubs and 3.45% were climbers (Table 1). Of all families, Poaceae constitutes the highest number of species (11.5%) followed by Fabaceae (10.3%), Acanthaceae (5.8%) and Euphorbiaceae (4.6%). The results showed that species diversity (H') and evenness (J') in the forest were 2.67 and 0.79 respectively (Table 2).

Table 2. Summary of the diversity parameters for woody forest species in Arero forest.

Characteristics	**Plant species**	
	Woody	**Herbaceous**
Evenness (J')	0.79	0.64
Diversity (H')	2.67	2.44

Importance value of woody species

The results showed that 4777 seedlings, 78 saplings and 194 trees stems per ha were recorded in the forest. The total density of all woody species was found to be 272 stems per ha in the forest excluding seedlings (Table 3). The density of few woody species, for instance *Olea europaea* L., subsp. *cuspidata* (Wall. ex G.Don) Clf., *Juniperus procera* Hockst. ex Endl., *Scolopia theifolia* Gilg and *Acokanthera schimperi* (A.DC.) Schweinf were higher in the forest (Table 3). The results also revealed that *Olea europaea* L. subsp. *cuspidata* (Wall. ex G.Don) Clf., *Juniperus procera* Hockst. ex Endl., *Acokanthera schimperi* (A.DC.) Schweinf, *Scolopia theifolia* Gilg, *Teclea simplicifolia* (Engl.) verdoorn, *Psydrax schimperiana* A. Rich Bridson and *Nuxia congesta* R.Br. ex Fresen were the most frequent species in the forest. The dominance of the species also showed that *Juniperus procera* Hockst. ex Endl., *Olea europaea* L. subsp. *cuspidata* (Wall. ex G.Don) Clf., *Psydrax schimperiana* A. Rich Bridson, *Acokanthera schimperi* (A.DC.) Schweinf. and *Scolopia theifolia* Gilg species were the five top dominant species in the forest (Table 3). Considering the individual species, *Olea europaea* L., subsp. *cuspidata* (Wall. ex G.Don) Clf., *Juniperus procera* Hockst. ex Endl., *Scolopia theifolia* Gilg, *Teclea simplicifolia* (Engl.) verdoorn, and *Acokanthera schimperi* (A.DC.) Schweinf were the five top abundant species in the forest (Table 3). Like *Juniperus procera* Hockst. ex Endl., *Olea europaea* L. subsp. *cuspidata* (Wall. ex G.Don) Clf., *Scolopia theifolia* Gilg, *Acokanthera schimperi* (A.DC.) Schweinf and *Teclea simplicifolia* (Engl.) verdoorn species had the highest IVI of the total woody species in the forest (Table 3).

Table 3. List of woody species in Arero forest.

Species	**Ab**	**D/ha**	**F**	**RF**	**BA/ha**	**RDo**	**RD**	**IVI**
Acokanthera schimperi (A.DC.) Schweinf	34	22	38	8.60	0.56	2.66	7.96	19.23
Euclea divinorum Hiern	6	4	4	1.08	0.01	0.06	1.41	2.54
Ruttya fruticosa Lindau	26	17	4	1.08	0.40	0.01	6.09	7.17
Olea europaea L., subsp. *cuspidata* (Wall. ex G.Don) Clf.	79	50	76	19.35	2.80	19.39	18.50	57.25
Commiphora campestris Engl.	2	1	2	0.54	0.01	0.10	0.47	1.11
Pavetta abbyssinica Fresen	3	2	6	1.61	0.03	0.24	0.70	2.55
Nuxia congesta R.Br. ex Fresen	28	18	28	7.53	0.22	1.64	6.56	15.72
Psydrax schimperiana A. Rich Bridson	25	16	32	8.60	0.46	3.42	5.85	17.88
Boscia punctulata Decne.	18	11	2	0.54	0.02	0.12	4.22	4.87
Dodonaea angustifolia L. f.	20	13	6	1.61	0.03	0.23	4.68	6.52
Scolopia theifolia Gilg	38	24	36	9.68	0.22	1.66	8.90	20.24
Papea Cappensis Eckl & Zeyh	2	1	4	1.08	0.05	0.39	0.47	1.93
Juniperus procera Hockst. ex Endl.	61	39	52	13.98	8.75	65.26	14.28	93.52
Haplocoelum foliolosum (Hiern) Bullock	15	10	8	2.15	0.12	0.91	3.51	6.58
Acacia tortolis (Forssk)	3	2	2	0.54	0.03	0.24	0.70	1.48
Acacia seyal DC.	1	1	2	0.54	0.01	0.05	0.23	0.82
Zanthoxylum usambarense (Engl.) Kokwaro	1	1	2	0.54	0.01	0.04	0.23	0.82
Waagaa (OL)	1	1	2	0.54	0.01	0.05	0.23	0.82
Diospyros abyssinica (Hiern) F.white	4	3	6	1.61	0.06	0.43	0.94	2.98
Teclea simplicifolia (Engl.) verdoorn	36	23	36	9.68	0.20	1.49	8.43	19.60
Cissus petiolata Hook.f.	1	1	2	0.54	0.01	0.08	0.23	0.86
Baddaa (OL)	1	1	2	0.54	0.01	0.04	0.23	0.81
Secamone punctulata Decne.	2	1	4	1.08	0.40	0.00	0.47	1.55
Cissampelos pareira L.	4	3	8	2.15	0.80	0.02	0.94	3.10
Combretum collinum Fresen	5	3	6	1.61	0.10	0.76	1.17	3.54
Ormocarpum muricatum Chiov.	3	2	4	1.08	0.05	0.39	0.70	2.17
Ficus vasta Forsek	1	1	2	0.54	0.01	0.11	0.23	0.88
Fonqolcha (OL)	5	3	4	1.08	0.03	0.20	1.17	2.45
Gaaddallaa (OL)	2	1	2	0.54	0.01	0.04	0.47	1.05
Total	**427**	**272**	**372**	**100**	**15.65**	**100**	**100**	**300**

Note: Ab= Abundance/50 plots (seedlings +saplings +trees), D/ha= Density per hectare, F= Frequency, RF= Relative Frequency, BA/ha= Basal Area per hectare (saplings + trees), RDo= Relative Dominance, RD= Relative Density, IVI= Importance Value Index, OL= Oromo Language.

Population structure of whole woody species

The DBH was classified into ten DBH classes and tree height was also classified into nine classes (Fig. 4). The results showed the existence of variations in diameter and height classes of the vegetation of species in the forest. The abundance of stems in general was very high at medium diameter classes. Good abundance of diameter class was found in 3rd diameter class (Fig. 4).

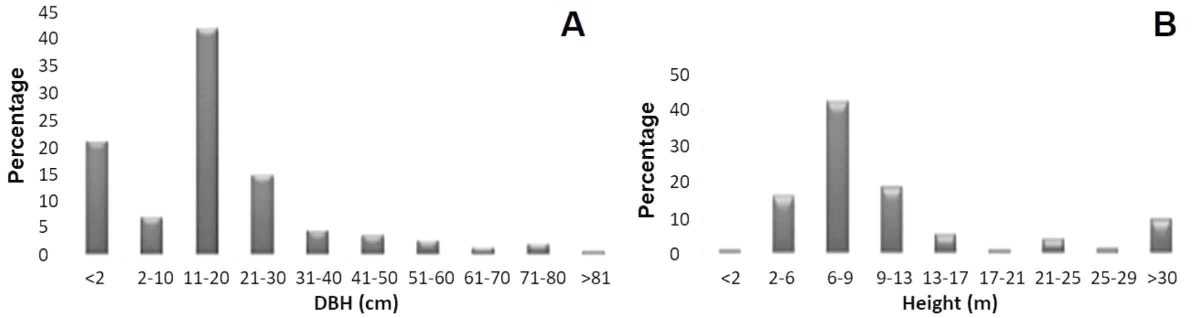

Figure 4. Percentage distribution of the whole woody species in Arero forest: **A**, DBH classes; **B**, height classes.

Diameter and height distribution of woody species

The population structure of six top most abundant species in the forest were separetely presented in (Fig. 5A–F). Based on the analyses of population structures, the study species encountered at the study area were grouped in to three categories: type I, II ,and III. The results for both diameter class showed that *Juniperus procera* Hockst. ex Endl., and *Psydrax schimperiana* (A. Rich) Bridson were grouped as type II in the forest, while, *Acokanthera schimperi* (A.DC.) Schweinf, *Olea europaea* L., *Scolopia theifolia* Gilg., subsp. *cuspidata* (Wall. ex G.Don) Clf. and *Teclea simplicifolia* (Engl.) verdoorn were grouped as type III. However there were no species grouped as type I distribution pattern for diameter.

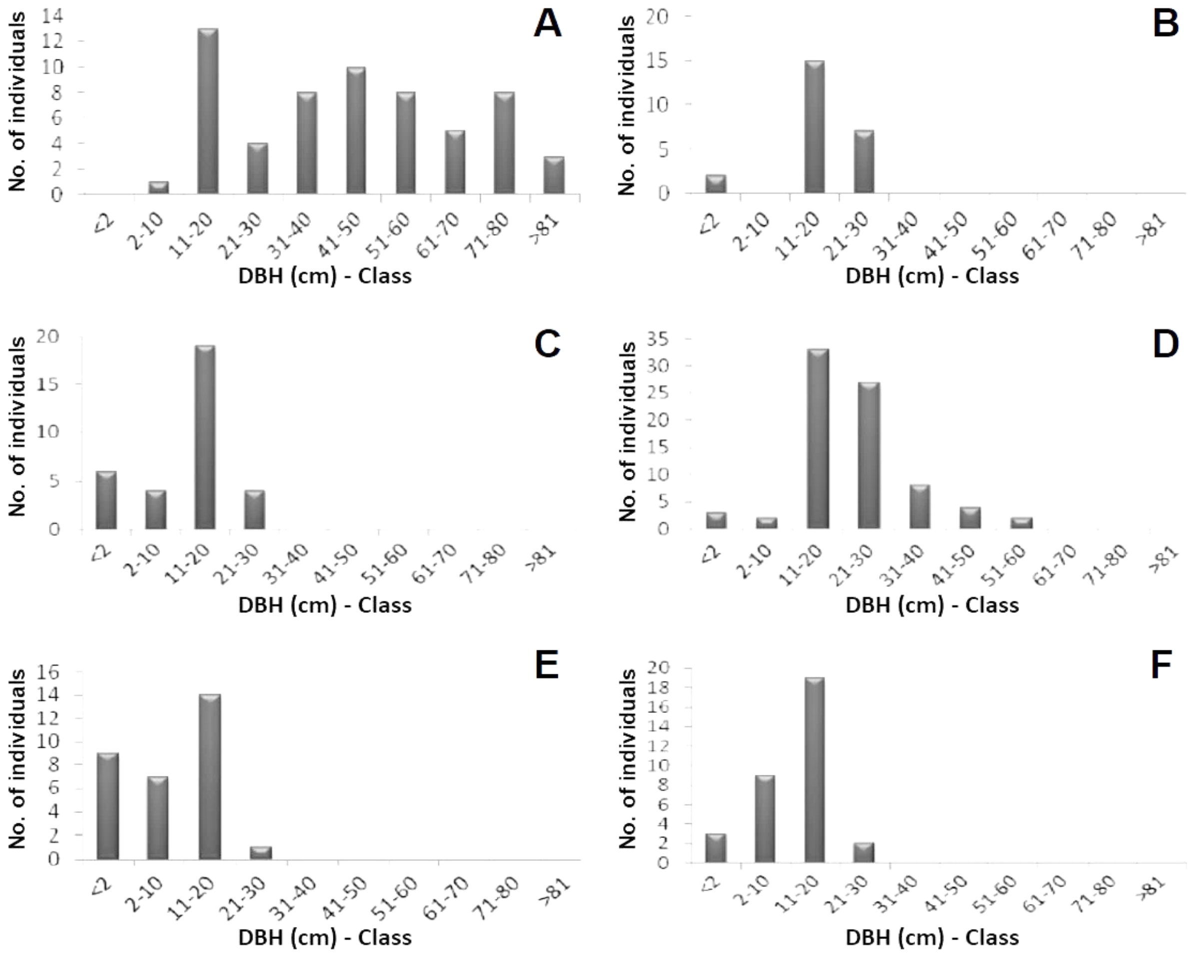

Figure 5. Distributions of individual structure in different DBH class for six most abundant tree species in Arero forest: **A**, *Juniperus procera* Hockst. ex Endl.; **B**, *Psydrax schimperiana* (A. Rich) Bridson; **C**, *Acokanthera schimperi* (A.DC.) Schweinf; **D**, *Olea europaea* L.; **E**, *Teclea simplicifolia* (Engl.) verdoorn; **F**, *Scolopia theifolia* Gilg.

Regeneration status of woody species

Regeneration status of the forest as a whole was examined using the result of diameter and height class distributions of the vegetation as a whole (Fig. 4). Therefore, the frequency histograms of these species as an individual vegetation of the forest were none of an inverted "J'' shape. In comparison to trees, the abundance of seedlings and saplings of the study species were found to be 110 and 9 respectively per total sampled plots in the forest.

DISCUSSIONS

The forest is richer in species compared to Menagesha Suba forest which had 82 species (Zewdie 2007) and Harena forest with 85 plant species (Nigatu 1987). In present study, the number of woody species including trees, shrubs and climbers were 42, which were comparable with findings made by Mekonnen (2006) which had 39 woody species for Dilfaqar National Park.

Patterns of plant species diversity are used to be noted for ranking conservation activities because they show the underlying ecological processes that are important for management and conservation (Senbeta 2006). In this particular study, the result showed the existence of high diversity in the case of whole woody species encountered in the forest. However, as it was the case in species diversity in the forest for instance had relatively less value of Shannon diversity index (H'=2.67) as compared to Chilimo forest (H'=2.77) (W/Mariam 1998), on Peninsula of Zegie (H'=3.72) (Alelign *et al*. 2007) and (H'=2.87) (Mekonnen 2006) in Dilfaqar Regional Park. The reason might be due to the dominance of few species, which could be caused by selective logging of some species (Senbeta 2006). According to Kent & Coker (1992), low Shannon evenness is an indication the existence of unbalance distribution of the individuals of species encountered in this study area and this probably due to impact of livestock grazing, human influence, and drought in this forest area. On the other hand, the Shannon diversity index of the forest was comparable with Shi & Zhu (2009) in southwestern China (H'= 1.82–3.29) and Sudhakar *et al.* (2008) in Chandoli National Park, northern Western Ghats, India (H'= 2.0–3.2). Lower evenness indicates the dominance of a few species. Therefore, the implications of evenness values is that, when there is a high evenness value in a given forest, the location of conservation sites might not be of such importance compared to when the evenness value of the forest is low (Senbeta 2006). The evenness index of this particular forest was relatively less than other findings by (Adekunle 2006) for instance in southwest Nigeria (J=0.91). However, it was comparable with findings by Shi and Zhu (2009) (J=0.58–0.90) in Southwestern China. In this particular forest the density of woody species was also comparable with reports made by Sudhakar *et al.* (2008) in India which ranged from 112 to 406.8 stems per ha.

Few species like *Acokanthera schimperi* (A.DC.) Schweinf, *Dodonaea angustifolia* L.f. and *Ruttya fruticosa* Lindau were overtaking in the forest. Most of the seedlings and saplings were frequent in sampled plots which constituted to these species. The dominance and /or abundance of the species contributed a number of factors such as disturbance factors, successional stage of the forest or survival strategies of the species. On the other hand, some plant species may have a wide range of dispersal mechanisms and/or rapid reproduction strategies. Some studies for instance Senbeta (2006) in the Afromontane rainforests of Southwest and Southeast Ethiopia and report made by Bekele (2000) in dry Afromontane of Southern Wollo in Ethiopia indicated that in early successional development many pioneer species may establish and grow together in high density until they reach the climax stage where many individuals were eliminated due to competition. This might also be due to the species are able to survive and flourish after disturbance tend to be those that reproduce rapidly and abundantly and dispersed widely.

The species with high IVI were the most dominant while the lower ones were less in the forest. This might be due to fire damage, natural selection and livestock grazing or trampling of other species. These showed also that the species were among the best adapted, dominant and with more or less good population status in the forest. Woody species with high resistance to anthropogenic disturbance and those with efficient regeneration capacity have relatively high chance of remaining dominant in the forest. Important value indices in the species showed similar trends with findings made by Worku (2006) and Addo-Fordjour *et al.* (2009). Woody species that constitute the lowest IVI depicted that the species could be prioritized for conservation. Therefore, those species with least IVI should need conservation measure, as they are important in terms of ecological, social and economic services they provide.

Some classes in lower and higher diameter classes were represented with few individuals and species. Species richness decreased at lower and higher diameter classes. In other words, the vegetation structure of the forest was a disturbed shape distribution of type II category. Population structures of woody plant species in arbitrarily diameter-height size classes were determined to provide the overall regeneration profile of the vegetation and species (Worku 2006, Lalfakawma *et al*. 2009). Information on the population structure of a tree species indicates the history of the past disturbance to that species and the environment and hence used to forecast the future trend of the population of that particular species. Population structure is also an extremely useful tool for indicating management activities and may be the most important for assessing both the potential of a given resource and the impact of resource extraction (Peters 1996). The pattern of the height class distributions was also varied from species to species (Fig. 4B). The height class distribution shows the representation of relatively high individuals in 3rd class, but low individuals in lower and higher classes. In other words, there were the declines of species abundance in lower and higher diameter classes.

The results for both diameter classes showed that *Acokanthera schimperi* (A.DC.) Schweinf, *Teclea simplicifolia* (Engl.) verdoorn, *Scolopia theifolia* Gilg, and *Psydrax schimperiana A. Rich Bridson*were grouped as type II in the forest, while , *Juniperus procera* Hockst. ex Endl., and *Olea europaea* L., subsp. *cuspidata* (Wall. ex G.Don) Clf. were grouped as type III. However, there were no species grouped as type I distribution pattern for diameter class and these could also be poor regeneration status of the forest probably due to high impact of livestock grazing, house construction, fuel wood and moisture stress in the forest. This argument agrees with findings made by Senbeta *et al*. (2007) in Afromotane forests of Ethiopia. As numbers of seedlings are greater than saplings which showed that the woody species had healthy regeneration profiles. However, as regeneration profiles of most top six woody species were seen their diameter and height classes were not healthy. The low in number of seedlings and saplings of woody species in the forest might be due to impact of livestock grazing; selected cutting for house construction particularly true for saplings in the study area (Lalfakawma *et al*. 2009). According to G/Hiywot (2003), composition and density of seedlings and saplings would indicate the status of the regeneration of a given tree species. Accordingly, the regeneration of woody species was poor in the forest. These could be due to afro mentioned reasons.

CONCLUSIONS

Arero forest is floristically diverse and rich as compared to many similar forests in Ethiopia. However, the structural analyses of the population of some dominant species experience poor regeneration. This study also showed that *Juniperus procera* Hockst. ex Endl., *Olea europaea* L. subsp. *cuspidata* (Wall. ex G.Don) Clf., *Psydrax schimperiana* A. Rich Bridson, *Acokanthera schimperi* (A.DC.) Schweinf, *Scolopia theifolia* Gilg, *Teclea simplicifolia* (Engl.) verdoorn and *Nuxia congesta* R.Br. ex Fresen species were found to be the dominant and frequent species in the forest.

This also implies that current management practices are not satisfactory to sustain the forest conditions. Indeed, it deserves concerted effort by local traditional Gadaa System of Oromo People and SOS Sahel Ethiopia and other institutions to improve its conservation and sustainable use of forests.

Unless improved management interventions are made the sustainability of contribution to livelihoods from the forest will be at stake in the future. Furthermore, detail study in the forest such as soil seed banks and carbon potential of the forest will be conducted to show complete diversity and biomass of the forest for carbon sequestration for biodiversity conservation and climate change mitigation in the region.

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REFERENCES

Addo-Fordjour P, Obeng S, Anning AK & Addo MG (2009) Floristic composition, structure and natural regeneration in a moist semi-deciduous forest following anthropogenic disturbances and plant invasion. *International Journal of Biodiversity and Conservation* 1: 21–37.

Adekunle VAJ (2006) Conservation of tree species diversity in tropical rainforest ecosystem of south-west Nigeria. *Journal of Tropical Forest Science* 18: 91–101.

Adelio M, Yadessa A, Jiru D, Tadesse S, Legesse A & Alemayehu L (2005) *Invasive Trees and Shrubs in Borana Rangeland: Challenges and Opportunities for Pastoralists and Agro-pastoralists.* In: 58 Proceedings of the 12th Annual Conference of Ethiopian Society of Animal Production (ESAP) held from 12-14 August 2004, Addis Ababa, Ethiopia.

Alelign A, Teketay D, Yemshaw Y & Sue Edwards (2007) Diversity and status of regeneration of woody plants on the peninsula of Zegie, Northwestern Ethiopia. *Tropical Ecology* 48: 37–49.

Angassa A & Beyene F (2003). Current range condition in southern Ethiopia relation to traditional management strategies: The perception of Borana pastoralists. *Tropical Grasslands* 37: 53–59.

Angassa A (2002) The effect of clearing bushes and shrubs on range condition in Borana, Ethiopia. *Tropical Grasslands* 36: 69–76.

Bekele T (2000) Plant population dynamics of *Dodonaea angustifolia* and *Olea europaea* spp. *cuspidata* in dry Afromontane Forests of Ethiopia, (Ph.D. Thesis). Acta Universitatis Upsaliensis, Uppsala, 559.

Biru M (2003) An ecological study of Biteyu forest, Gurage Zone, Southern Nations, Nationalities Peoples Regions, (M.Sc. Thesis). Addis Ababa University, Ethiopia.

Coppock DL (1993) *The Borana Plateau of Southern Ethiopia: Synthesis of Pastoral Research, Development and Change, 1980-1999, ILCA System Study*, Addis Ababa, Ethiopia.

Coppock DL (1994) *The Borana plateau of Southern Ethiopia: Synthesis of pastoral research, development and changes 1980–1990*. International Livestock Center for Africa, Addis Ababa, Ethiopia.

Dale G, Brigittie L, Maass & Isselstein J (2005). Plant Biodiversity and Ethnobotany of Borana pastoralists in southern Oromia, Ethiopia. *Economic Botany* 59: 43–65.

Demesa G (2002) Forest utilization and comparison between traditional lumber conversion methods and a portable sawmills in Arero, (M.Sc. Thesis), Swedish Agricultural University of Agricultural Sciences, Uppsala, Sweden, report no 52.

FAO (2007) *State of the World's Forests*. Food and Agriculture Organisation of the United Nations, Rome.

FSCDD (1990) *Ethiopian forest Resource base identification, Conservation and Rational use in Ethiopia*. Food Security, Disaster Prevention and Preparedness Office, State Forestry Conservation and Development Department, Addis Ababa, Ethiopia.

G/Hiywot K (2003) Ecology and Regeneration of *Boswellia papyrifera*, dry forest of Tigray, North Ethiopia, (Ph.D. Thesis). George-August University of Gottingen, Germany

Gatzweiller F, Reclluber A & Hein L (2007) *Why financial incentives can destroy economically valuable biodiversity in Ethiopia*. Development policy, no 115, Bonn, Germany.

Haugen T (1992) Woody Vegetation of Borana, south Ethiopia, a study on the main community types of the area. *SINET: Ethiopian Journal of Science* 15: 17–130.

Kassa Z, Asfaw Z & Demissew S (2016) Plant diversity and community analysis of the vegetation around Tulu Korma project centre, Ethiopia. *Tropical Plant Research* 3(2): 292–319.

Kent M & Coker P (1992) *Vegetation descrption and analysis: A practical approach.* England, pp. 97.

Lalfakawma UK, Sahoo S, Roy K, Vanlalhriatpuia PC & Vanalalhluna (2009) Community composition and tree population structure in undisturbed and disturbed tropical semi-evergreen forest stands of north-east India. *Applied Ecology and Environmental Research* **7**: 303–318.

Lamprecht H (1989) *Tropical forest ecosystems and their tree species. In: Siliviculture in Tropics, possibilities and methods for their long-term utilization*. Institute of for siliviculture of the University of Gottingen, Technical Cooperation of Federal, Republic of Germany, Berlin, pp. 296.

Mekonnen D (2006) *Woody species composition of Dilfaqar Regional Park and its socioeconomic importance*, (M.Sc. Thesis). Addis Ababa University, Ethiopia.

Mengistu A (1998) *The Borana and the 1991-1992 Drought: A Rangeland and Livestock Resource Study*. Institute for Sustainable Development, French Catholic Committee against Hunger and for Development, Addis Ababa, Ethiopia.

Merga M (2006) *Socio-economic and Demographic correlates of participatory forest management and local people's perception towards the approach*. Oromiya Region: the case of Chilimo forest, Addis Ababa, Ethiopia.

Mukhopadhyay D, Tewari HR & Roy SB (2007) Role of Community Institutions in Joint Forest Management. *Journal Human Ecology* 21: 37–42.

Nigatu L (1987) An ecological study of the vegetation of the Harenna forest, (M.Sc. Thesis). Addis Abeba University, Addis Abeba, Ethiopia.

OBPED (2000) *Physical and socioeconomic profiles of 180 districts of Oromia Region*. Oromia Bureau of Planning & Economic Development, Addis Ababa, Ethiopia.

Ostrom E (2007) *Field manual, International Forestry Resources and Institutions (IFRI) Research Program*. Centre for the Study of Institutions, Populations, and Environmental change, Indiana University, Version 13. Available from: http// www.indiana.edu/~ifri (accessed: 15 Oct. 2017).

Peters CM (1996) *The ecology and management of Non-Timber Forest Resources*. World Bank technical paper 322, ICBN 0/8213/3619/3, Washington.

Senbeta F (2006) Biodiversity and Ecology of Afromontane rainforests with wild *Coffee arabica* L. populations in Ethiopia, (Ph.D. Thesis). Ecology and Development Series, 38, University of Bonn, ZEF Bonn.

Senbeta F, Manfred Denich, Hans Juergen Boehmer, W/Mariam T, Teketay D & Demissew S (2007) Wild *Coffee Arabica* L. in the Afromontane rain forests of Ethiopia: distribution, ecology and conservation. *SINET: Ethiopian Journal Science* 30: 13–24.

Shi JP & Zhu H (2009) Tree species composition and diversity of Tropical Mountain cloud forest in the Yunnan, Southwestern China. *Ecological Research* 24: 83–92.

Sudhakar RC, Ugle P, Murthy MSR & Sudhakar S (2008) Quantitative Structure and Composition of Tropical Forests of Mudumalai Wildlife Sanctuary, Western Ghats, India. *Taiwania* 53: 150–156.

Tadesse Z, Kelbessa E & Bekele T (2017) Floristic composition and plant community analysis of vegetation in Ilu Gelan district, West Shewa Zone of Oromia region, Central Ethiopia. *Tropical Plant Research* 4(2): 335–350.

Takele T (2006) Study of woody species diversity and socio-economic importance of Boke salt resources, a volcanic crater lake, in semi-arid dry lands of Borana, southern Ethiopia, (M.Sc. Thesis). Addis Ababa University, Ethiopia.

Teketay D (1999) Past and present activities, achievement and Constraints in forest genetic resources conservation in Ethiopia.

W/Mariam T (1998) Diversity of woody plants and avifauna in dry Afromontane forests on the central plateau of Ethiopia, (M.Sc. Thesis). Swedish University of Agricultural Sciences, Uppsala, Sweden, and report no. 37.

Worku A (2006) Population Status and Socio-economic Importance of Gum and Resin Bearing Species in Borana Lowlands, southern Ethiopia, (M.Sc. Thesis). Addis Ababa University, Ethiopia.

Zewdie A (2007) Comparative Floristic study on Menagesha Suba State Forest on Years 1980 and 2006, (M.Sc. Thesis), Addis Ababa University, Ethiopia.

Supporting information

Appendix 1: List of plant species in Arero forest per all sampled plots.

Appendix 1: List of plant species in Arero forest per all sampled plots.

Scientific name	Vernacular name	Family name	Growth habit
Acokanthera schimperi (A.DC.) Schweinf	Qaraaruu	Apocynaceae	S
Euclea divinorum Hiern	Mi'eessa	Ebenaceae	S
Olea europaea L., subsp. *cuspidata (*Wall. ex G.Don) Clf	Ejersa	Oleaceae	T
Chionothrix latifolia Rendle	Garbicha	Amaranthaceae	T
Commiphora terebinthina Vollesen	Sangaa igguu	Burseraceae	S
Calpurnia aurea (Ait.) Benth.	Ceekata	Fabaceae	T
Dichrostachys cinerea (L.) weight & Arn	Jirmee	Mimosaceae	T
Acacia brevispica Harms	Hamarressa	Mimosaceae	T
Rhus nathlensis Krauss	Daboobessa	Anacardiaceae	T
Dodonaea angustifolia L. f.	Ittacha	Sapindaceae	T
Jasminum grandiflorum L subsp. floribundum (R. Br. ex Fresen.) P.S.Green	Dogimaasa	Oleaceae	H
Haplocoelum foliolosum (Hiern) Bullock	Cannaa	Sapindaceae	T
Olea capensis (L) Subsp. marocarpa (C.A. wright verde)	Gagamaa	Oleaceae	T
Unknown	Dambisuu	Unknown	H
Pavetta abbyssinica Fresen	Korkorree	Rubiaceae	T
Cissampelos pareira L. Var. hirsuth (Buck. ex DC) Forman	Gaalee	Menispermaceae	C
Chrysopogon aucheri (Boiss.)	Alaloo	Orobanchaceae	H
Leptothrium senegalense (Kunth) Clayton	Ilmogoor	Poaceae	H
Unknown	Laabbessa	Unknown	H
Pavonia urens Var glabrescens	Icinnii	Gramineae	H
Fuerstia africana T.C.E.Fr.	Hancabbii	Lamiaceae	H
Ruttya fruticosa Lindau	Xuuxoo	Acanthaceae	S
Stylosanthes fruticosa (Retz.) Alston	Egajii	Fabaceae	H
Aspilia mossambicensis (Oliv.) Wild	Hadaa	Asteraceae	H
Dyschoriste radicans Nees	Qilxiphee	Acanthaceae	H
Solanum spp	Hiddii loonii	Solanaceae	H
Phyllanthus sepialis Muell. Arg.	Dhirrii warseesoo	Euphorbiaceae	H
Hibiscus micranthus L. f.	Bungaala	Malvaceae	H
Scolopia theifolia Gilg	Muka diimaa	Germniaceae	T
Nuxia congesta R.Br. ex Fresen	Muka daalacha	Logniaceae	T
Trianthema salsoloides Oliv.	Qanxallaa	Aizoaceae	H
Acanthus sennii Chiov.	Sookoruu	Acanthaceae	H
Eragrostis cilianensis (All.) Vign. Ex Janchen	Saagetuu	Poaceae	H
Digitaria velutina (Forssk.) P. Beauv	Raaphuphaa	Poaceae	H
Unknown	Fonqolcha	Unknown	T
Caralluma speciosa (N.E. Br.) N.E. Br.	Mata buttoo	Asclepiadaceae	H
Tagetes minuta L.	Sunkii	Asteraceae	H
Teclea simplicifolia (Engl.) verdoorn	Hadheessa	Rutaceae	T
Pavetta gardenifolia A.Rich	Gaadallaa	Rutaceae	T
Boscia punctulata Decne.	Dhumaayo	Capperidaceae	T
Cynodon dactylon (L.) Pers.	Sardoo	Poaceae	H
Papea Cappensis Eckl & Zeyh	Biiqqaa	Sapindaceae	T
Achyranthes aspera L.	Darguu hoolaa	Amaranthaceae	H
Ormocarpum muricatum Chiov.	Karraa	Fabaceae	T
Dombeya aethiopica Gilli	Sililaalcha	Sterculiaceae	H
Juniperus procera Hockst. ex Endl.,	Hindheessa	Cupressaceae	T
Cenchrus ciliaris L.	Mata guddisa	Poaceae	H
Heteropogon contortus (L.) Roem. & Schult.	Seericha	Poaceae	H
Acacia tortolis (Forssk)	Xaddacha	Fabaceae	T
Ormocarpum trichocarpum (Taub.) Engl	Buttiyyee	Fabaceae	S
Acacia seyal DC.	Waacuu	Fabaceae	T
Panicum maximum Jacq.	Lolloqaa	Poaceae	H
Chlorophytum spp	Miirtuu	Unknown	H
Indigofera spp	Agagaroo harree	Fabaceae	H
Asparagus aethiopicus L.	Sarittii	Asparagaceae	H
Sida ovata Forsk	Qarxaxummee	Malvaceae	S
Blepharis maderaspatensis (L.) Roth.	Darguu	Acanthaceae	H
Psydrax schimperiana A. Rich Bridson	Gaallee	Rubiaceae	T

Pellaea calomelanos (Sw.) Link.	Filaa tarrii	Sinopteridaceae	H
*Zanthoxylum usambarense (*Engl.) Kokwaro	Gadaa	Rutaceae	T
Acalypha fruticosa Forssk.	Dhirrii	Euphorbiaceae	S
Crotalaria distantiflora Bak.f.	Dacisaa	Fabaceae	H
Diospyros abbyssinica (Hiern) F.white	Lookoo	Ebenaceae	T
Oldenlandia corymbosa L.	Bilixuu	Portulacaceae	H
Microchloa kunthii Desv.	Areeddoo	Poaceae	H
Gnidia stenophylla Gilg.	Aarsaa	Thymelaeaceae	H
Combretum collinum Fresen	Lu'oo	Combretaceae	T
Ficus vasta Forsek	Qilxaa	Moraceae	T
Steganotaenia araliacea acea Hochst Ex A.Rich	Luqaanluqqee	Apiaceae	H
Eleusine jaegeri Pilg.	Coqqorsa	Poaceae	H
Vigna membranacea A.Rich.	Cimphaa	Fabaceae	H
Erica arborea L.	Saatoo	Ericaceae	S
Commelina diffusa Burm.f.	Qaayyoo	Commeliaceae	H
Ormocarpum mimosoides	Butiyyee	Loasaceae	H
Triumfetta pentandra A.Rich	Gurbii	Tiliaceae	H
Alectra sessiliflora (Vahl) Kuntze	Gurroo	Scrophulariaceae	H
Biophytum spp	Handaada	Oxalidaceae	H
Cissus petiolata Hook.f.	Arayyee	Vitaceae	H
Secamone punctulata Decne.	Dikicha	Asclepiadaceae	C
Tephrosia hildebrandtii Vatke	Jiraa gubataa	Fabaceae	H
Tetradenia riparia (Hochst.In C.Krauss)	Midhaan dubraa	Lamiaceae	H
Clutia lanceolata Forssk.	Darguu	Euphorbiaceae	S
Crabbea velutina S. Moore	Baballaa	Acanthaceae	H
Acacia oerfota (Forssk.) Schweinf.	waangaa	Fabaceae	T

Note: H= Herbs, T= Trees, S= Shrubs, C= Climber.