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Original Research

Species Diversity and Plant Community Analysis in Angar Forest, Horro Guduru Wollega Zone, Western Ethiopia

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Abstract

In Ethiopia, natural vegetation is facing serious peril. Areas that were covered by forest a few decades ago are now converted to farmland and settlement areas. However, a few remnant forest patches are still present in inaccessible remote areas such as the Angar Valley. This study investigated species diversity and community types in Angar Forest. Forty quadrats each with 400 m^2 were laid following altitudinal gradients. Smaller subquadrats of 1 m^2 were also established within each of the main quadrats to record herbaceous plants. All vascular plants were recorded and identified in each quadrat. Cluster analysis was used to divide the vegetation into plant community types, and species diversity was determined for each community. One hundred sixty-two species of plants that belong to 67 families were documented. Thirteen of these are endemic to Ethiopia. With 14 and 12 species, Asteraceae and Fabaceae, one after the other, were the richest plant families. Concerning habit, trees were more abundant. Three plant community types were identified. Rich floristic diversity with endemic taxa showed Angar Forest is a potential site for biodiversity conservation. Hence, restoration activities are vital to protect the forest and its plant species from further degradation.

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INTRODUCTION

Plant and animal diversity is not uniform throughout the world. Largely, the variation in latitude and altitude determines the compositions and distribution of all life forms. Ethiopia, although completely a tropical country, its a diverse topography (Friis et al., 2010) and has provided various habitats that support diverse flora and fauna. The country has a rich biodiversity. Hence, Friis et al. (2010) explained it as the centre of diversity and endemism for several plant species. The country also hosts significant portions of the Eastern Afromontane and Horn of Africa biodiversity hotspots. This indicates grave anthropogenic disturbance, with more than

70% of the natural habitat being highly threatened by human activity. Currently, the vegetation in Ethiopia consists of about 6000 species of higher plants with 10% endemics (Kelbessa & Demissew, 2014). Generally, the vegetation in Ethiopia is categorised into 12 vegetation types, each with distinct species composition (Friis et al., 2010).

In Ethiopia, natural vegetation provides food, fodder, and medicine, asserting its importance for the livelihood of the indigenous communities. Furthermore, natural vegetation provides enumerable ecosystem services, including water shade protection, carbon storage, and biodiversity conservation that indirectly benefit human society (Gurmessa et al., 2021; Amberber et al., 2020). However, the high socioeconomic potential and ecological role of forests are declining in Ethiopia due to land cover conversion and the alarming deforestation rate (Tamire et al., 2023). Deforestation significantly influences the diversity, physiognomy, and regeneration status of a forest and ultimately affects forest-dependent societies (Owiunji & Plumptre, 1998; Joshi & Kumar, 2008). The rapidly increasing human population needs additional farmland and settlement sites and an aggravated deforestation rate in Ethiopia (Amberber et al., 2020). This intensified the need for additional land for agriculture, settlement, etc. Land for farming and settlement is obtained by removing natural vegetation, including those in the conservation networks (IBC, 2009; Ango, 2018). So, assessing and documenting species richness and diversity of the remnant natural forests, such as Angar Forest, is becoming vital as it is the primary step towards sustainable forest conservation.

Angar Forest consists of a variety of flora and fauna, including medicinal and wild edible plants. The forest also provides wild honey, game for hunting, and wood for timber, construction, and fuel to the local people. The forest provides numerous ecosystem services, including carbon sequestration and watershed protection. Investigating plant species diversity and community distribution of remnant forest patches are among the key steps in prioritising conservation activities (Myers et al., 2000; Magurran, 2004). As Angar Forest received little/no conservation attention, it is facing threats from anthropogenic activities, mainly agricultural expansion, and cutting of trees for timber, fuel, and construction that ultimately affected the biodiversity of the forest. As no detailed scientific study has been made so far, information on species diversity and physiognomy of Angar Forest is scant despite its rich floristic diversity. Therefore, this study explored species richness, diversity, and plant community types in Angar Forest.

MATERIALS AND METHODS

Study area description

Angar Forest is found in Jardega Jarte district, western Ethiopia, at a distance of 374 km from Addis Ababa to the west and 5 km north of Alibo town (Jardega Jarte district capital). Geographically, the forest lies between 9° 55'0" to 10°0'15" N latitudes and 036°70'80" to 037°4'5" E longitudes (Figure 1). Angar Forest is bounded by Sombo Wato kebele in the east, Ejere Goromti kebele (from Amuru district) in the west and north, and Sago and Iro kebele in the south. Angar Forest has a total area of more than 1500 ha.

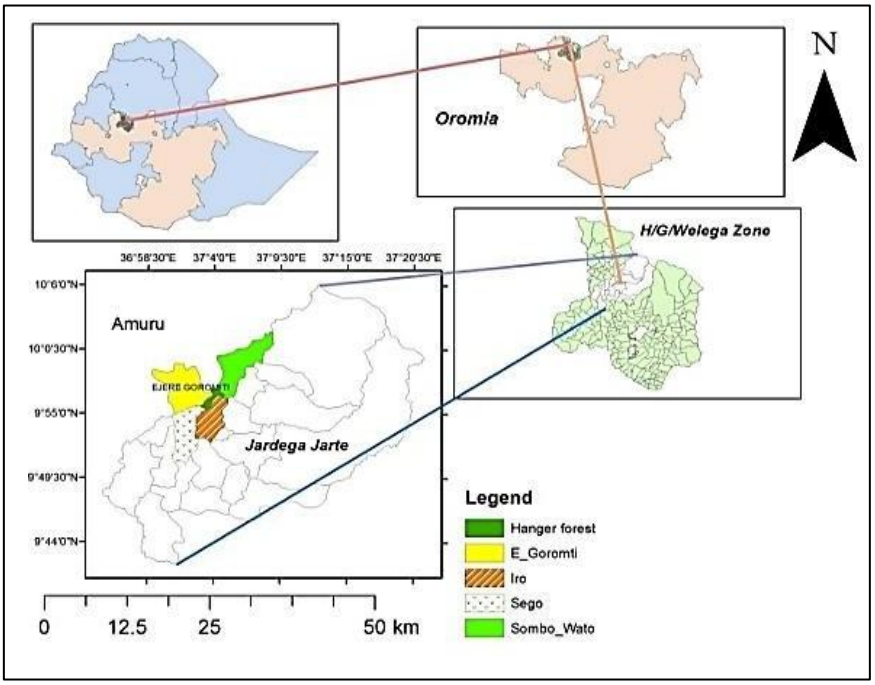

Figure 1. *Location map of Angar Forest*

Eleven years (2010 to 2020) of climate data obtained from the nearest meteorological station revealed humid and moderately hot climates (a mean of 17.6˚C) predominate in the area. Precipitation is maximum between May and October and gradually declines to very little or no rainfall in January and February. The area receives a mean annual precipitation of 1599 mm (Figure 2). The vegetation of Angar Natural Forest is diverse, including riverine and broad-leaved *Combretum-Terminalia* woodland types.

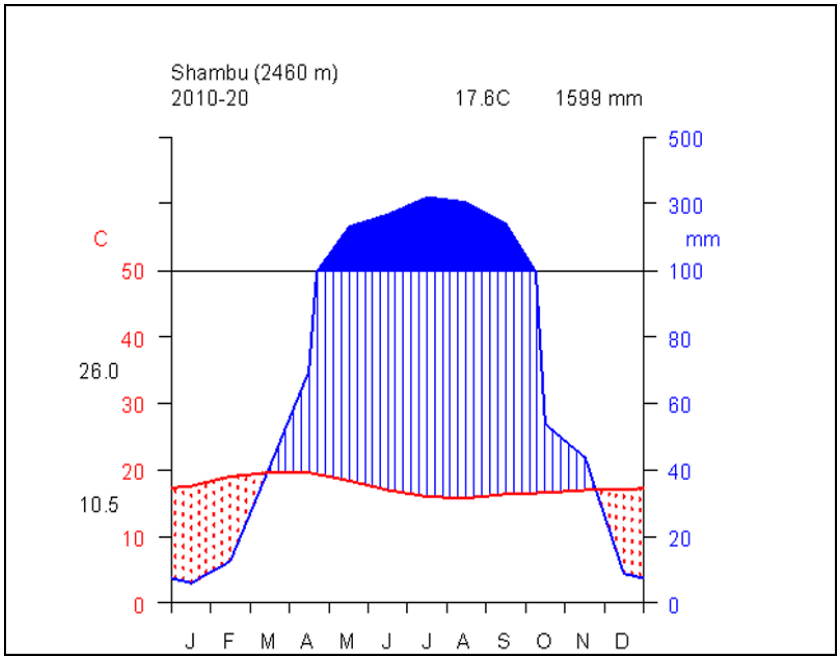

Figure 2. *Climadiagram of Study area (Shambu Station)*
Source: EMSA, 2022

Data Collection

Vegetation data was collected from 40 sample quadrats, each with a 20 m x 20 m area. The quadrats were systematically laid along 5 transect lines (Muller-Dombois & Ellenberg, 1974; Kent & Coker, 1992). The distances between transects and successive quadrats on each transect were 500 and 200 m, respectively. To record herbaceous plants, 5 nested quadrats of $1m^2$ (one at the center and one at each corner) were used (Figure 3).

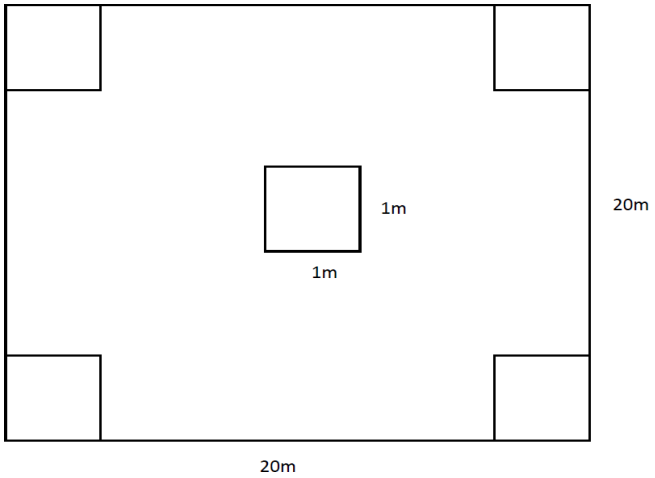

Figure 3. *Lay out of the study plot*

In all the quadrats, vascular plants were recorded. Those species that occurred in the forest but outside the quadrats were also registered as present for floristic richness. Taxonomic identification of specimens was made following Flora of Ethiopia and Eritrea Volumes 1-8. The abundance data of each species in each quadrat was converted to the modified 1-9 Braun-Blanquet scale by van der Maarel (1979) and was used in vegetation classification and further analysis.

Data Analysis

Species cover-abundance data was used to divide the natural vegetation of Angar Forest into plant community types using agglomerative hierarchical classification algorithms in the R-Statistical package version 3.4.2 (R Core Team, 2018). The number of vegetation units in the forest was decided after visual inspection of the dendrogram. Among the identified vegetation clusters, the hypothesis of no difference was tested using MRPP (McCune & Grace, 2002). The indicator value of each species was calculated (Dufrene & Legendre, 1997), and the statistical significance of indicator values was tested using the Monte Carlo technique (number of runs = 4999). PC-ORD version 5.0 was used to compute MRPP and indicator species analysis. Vegetation units were labelled as plant communities and were named using two species with higher indicator values. Richness, diversity, and evenness were calculated for each sample plot using;

$$H' = -\sum_{i}^{s} p_i (\ln p_i); J = \frac{H'}{\ln S}$$

Where: H' = Shannon-Weiner Diversity Index; P_i = proportion of the i^{th} species in the sample; $\ln p_i$ = logarithm of the i^{th} species; J = evenness; S = all species in the sample.

The variation between plant communities with respect to diversity indices was

statistically tested using ANOVA. The floristic resemblance between plant communities and the phytogeographical comparison between Angar natural forest and other natural vegetation in Ethiopia was made using Sorensen's Similarity coefficient (Sorensen, 1948).

$$Ss = \frac{2a}{(2a + b + c)}$$

Where:Ss=Sorensen's coefficient of similarity, a= common species; b= unique species to a given forest/community; c= unique species to the other forest/community.

RESULTS

Species composition

One hundred sixty-two species of plant belonging to 151 genera and 67 families were documented from Angar Forest (Appendix 1). The 4 species-rich plant families were Asteraceae, Fabaceae, Poaceae, and Euphorbiaceae, each with 14, 12, 9, and 7 species, respectively (Figure 4).

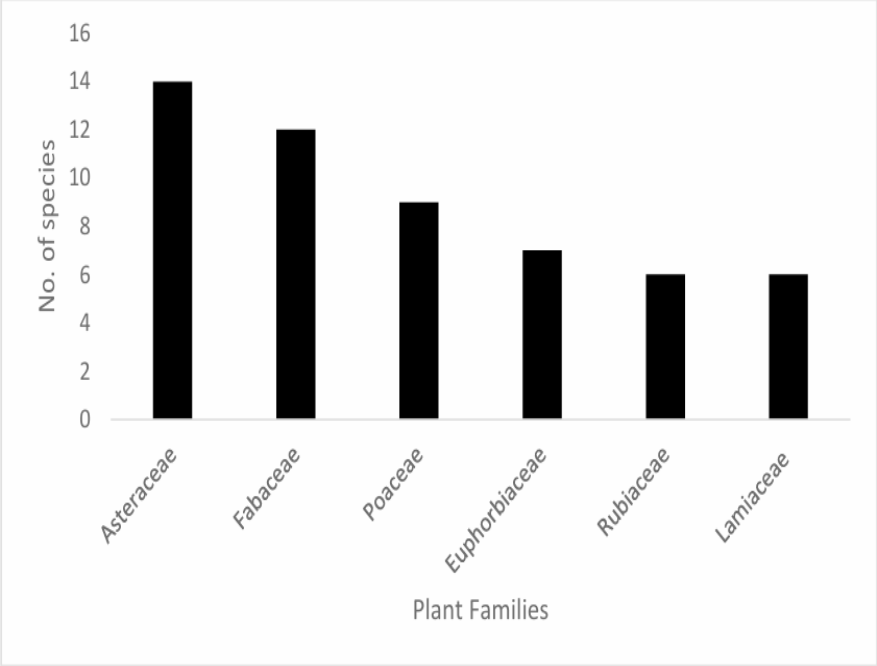

Figure 4. *Species-rich plant families in Angar Forest*

Rubiaceae and Lamiaceae, each with 6 species, are also among the well-represented plant families. The 6 families alone contributed 33.33% of the species in the forest. The remaining 61 families had 5 or fewer species each. In terms of habit, trees account for 36.42%, followed by herbs and shrubs, each with 28% and 26.54% of species, respectively. Lianas constitute the remaining 9.04% (Figure 5). Angar Forest consists of endemic plant species. Out of the 162 species recorded in the forest, 13 (8.18%) are endemic to Ethiopia (Table 1). Moreover, 30 of the species (28 genera and 23 families) were not known to occur in the Wollega Floristic Region on the FEE (Table 2).

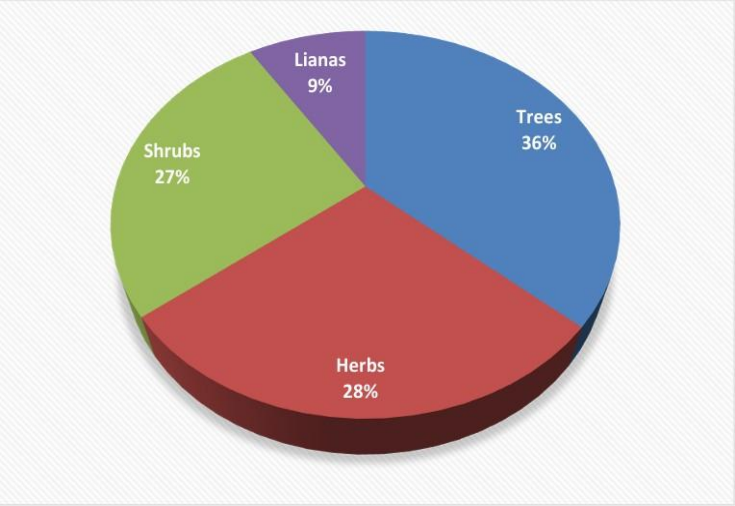

Figure 5. *Growth form/habit of plant species growing in Angar Forest*

Table 1

Plant species in Angar Forest that are endemic to Ethiopia.

S/N	Scientific Name	Families
1	*Echinops kebericho*	Astraceae
2	*Erythrina brucei*	Fabaceae
3	*Justicia diclipteroides* subsp. aethiopica	Acanthaceae
4	*Kalanchoe petitiana*	Crassulaceae
5	*Laggera tomentosa*	Astraceae
6	*Lippia adoensis*	Verbinaceae
7	*Mikaniopsis clematoides*	Asteraceae
8	*Millettia ferruginea*	Fabaceae
9	Phragmanthera *macrosolen*	Loranthaceae
10	*Phyllanthus dewildiorum*	Euphorbiaceae
11	*Pycnostachys abyssinica*	Lamiaceae
12	*Tiliacora troupinii*	Mersipermaceae
13	*Vepris dainelli*	Rutaceae

Table 2

New records for WG floristic region in the FEE.

S/N	Species Name	Family	Habit	Local name
1	*Vachellia gerrardii* Benth.	Fabaceae	T	Doddota
2	*Achyrospermum schimperi (*Hochst.exbriq.) Perkins	Lamiaceae	H	kusaayee
3	*Arisaema schimperianum Schott*	Araceae	H	Niitii Bofaa
4	*Asplenium aethiopicum* (Burm.f) Bech.	Aspleniaceae	F	Trimmii
5	*Bidens macroptera* (Sch. Bip. ex Chiov.) Mesfin	Asteraceae	H	Hadaa
6	*Bidens rueppellii* (Sch.Bip.) Sherff	Asteraceae	H	Hadaa

Table 2 **Continues.**

7	*Clutia abyssinica* Jub. & Spach	Euphorbiaceae	S	Ulee Foonii
8	*Cynodon dactylon (L.) Pers.*	Poaceae	H	Coqorsa
9	*Dipsacus pinnatifidus* Steud. ex A. Rich.	Dipsacaceae	H	
10	*Dovyalis abyssinica (*A. Rich.) Warb.	Flacourtaceae	S	Koshommii
11	*Eleusine floccifolia* (Forssk.) Spreng.	Poaceae	H	Daggoo
12	*Faurea speciosa* Welw.	Proteaceae	T	Gaarrii Kormaa
13	*Hyparrhenia anthistirioides* (Rochat. exA. RiCh.) Stapf	Poaceae	H	Daggala
14	*Laggenaria abyssinica (*Hook.f.) C. Jeffrey	Cuccurbitaceae	H	B/seexanaa
15	*Lantana trifolia* L.	Verbenacae	S	kusaayee
16	*Mikaniopsis clematoides (*A. Rich.) Miln-Redh	Asteraceae	H	H/Hantuutaa
17	*Myrsine africana L.*	Myrsinaceae	S	Qacamaa
18	*Ochna holistii* Engl.	Ochnaceae	T	Lookoo
19	*Olea europaea L.* sub sp cupidata (wall ex.G. Don) Cif	Oleaceae	T	Ejersa
20	*Olea capensis subsp. macrocarpa (*C. A. Wright) Verdc.	Oleaceae	T	Gagamaa
21	*Plumbago zeylanica* L.	Plumbaginaceae	H	Ameeraa
22	*Polyscias fulva (*Hiern) Harms	Araliaceae	T	Hombolxoqa
23	*Rosa abyssinica* Lindley	Rosaceae	S	Qagii
24	*Rubia cordifolia* L.	Rubiaceae	H	maxxannee
25	*Schrebera alata* (Hochst.) Welw.	Oleaceae	T	Qassee adii
26	*Sclerocarya birrea* (A. Rich.) Hochst.	Anacardaceae	T	
27	*Sporobolus pyramidalis* P. Beauv.	Poaceae	H	Murii
28	*Tiliacorpa troupinii* Cufod.	Menispermaceae	L	H/liqimmee
29	*Urtica simensis* Steudel	Urticaceae	H	Gurgubbee
30	*Warburgia ugandensis* Sprague	Canellaceae	T	Beftii

Key: Habit (T=Tree; S=Shrub; H=Herb; L=Liana and F=Ferns

Plant community types

Three plant communities, namely *Prunus africana-Cordia africana*, *Teclea nobilis-Nuxia congesta,* and *Vachellia lahai-Acanthus eminens* were identified by agglomerative hierarchical cluster analysis (Figure 6). Analysis of MRPP showed a test statistic (T) of -17.63 ($p < 0.001$) and an agreement statistic (A) of 0.24 for the three groups. Plant communities are explained as follows:

Community 1: *Prunus africana - Cordia africana*

This community occupied the higher altitude with a mean elevation of 1751.23 m a.s.l. The community includes 11 sample plots and 53 species of which 20 are with significantly higher indicator values ($p < 0.05$) (Table 3). Species such as *Prunus africana, Cordia africana, Millettia ferruginea, Bersama abyssinica, Tiliacorpa troupinii, Pittosporum viridiflorum., Clausena anistata, Croton macrostachyus,* and *Dovyalis abyssinica* had higher indicator value in this community. *Dombeya torrida, Pycnostachys abyssinica, Erythrina brucei, Carduus schimperi, Euphorbia ampliphylla, Landolphia*

buchanani, Olea capensis, Mimusops kummel, Vachellia abyssinica, and herbaceous plants namely *Achyranthes aspera* and *Hyparrhenia anthistirioides* were also abundant and more frequent in this community type.

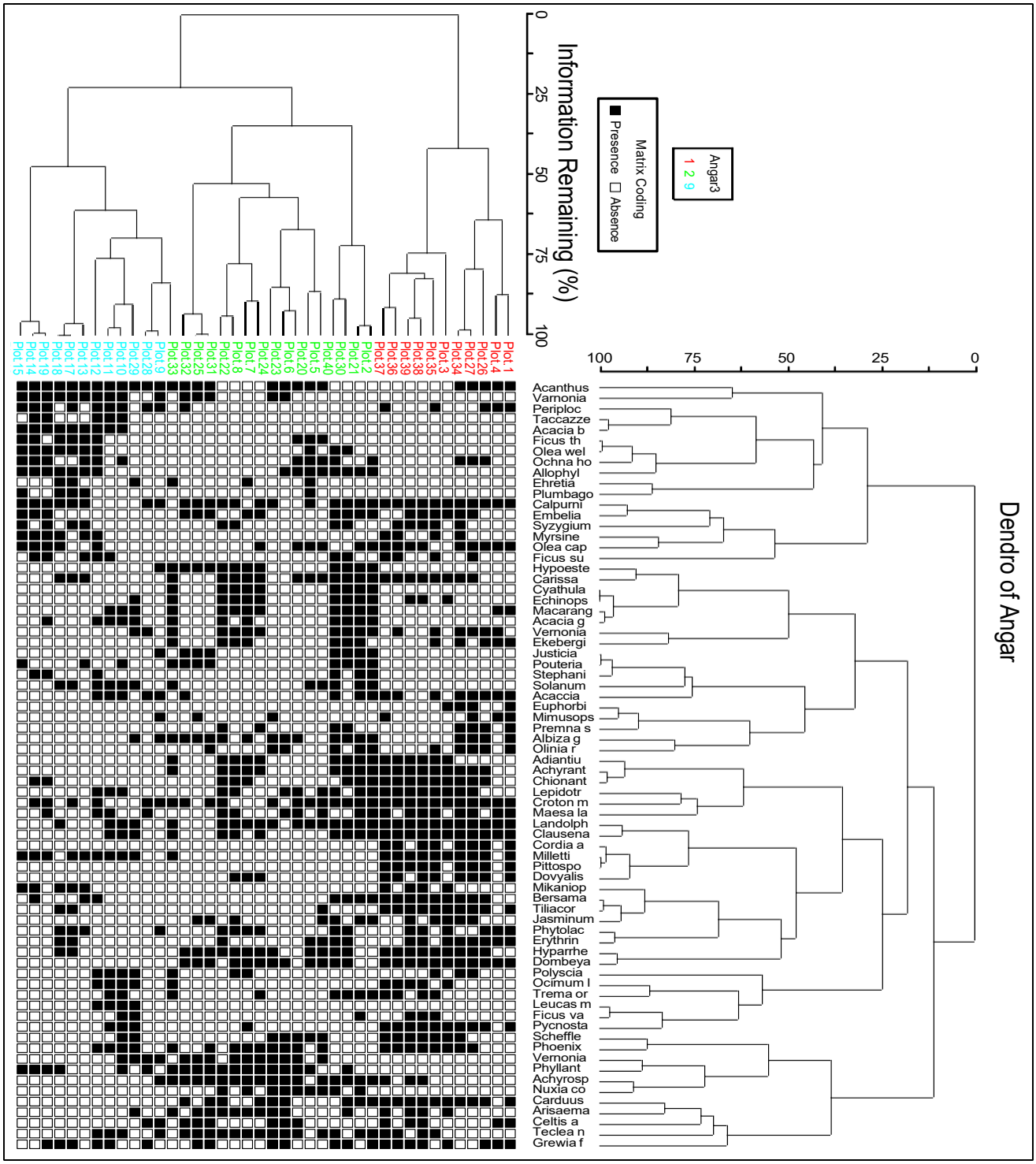

Figure 6. *Two-way cluster dendrogram exhibiting the distribution of sample plots and species. The 3 different colours represent the different plant communities.*

Table 3

Plant species with significantly higher indicator values in each community ($p < 0.05$).

Community type	1	2	3	*p-value*
Number of quadrats	11	16	13	
Prunus africana	81	10	2	0.0002
Cordia africana	73	0	0	0.0002
Millettia ferruginea	76	0	13	0.0002
Bersama abyssinica	68	2	2	0.0002
Tiliacorpa troupinii	80	0	1	0.0002
Pittosporum viridiflorum	82	0	0	0.0002
Clausena anistata	65	9	4	0.0002
Dombeya torrida	59	31	0	0.0004
Dovyalis abyssinica	55	5	0	0.0006
Croton macrostachyus	53	20	10	0.0008
Pycnostachys abyssinica	52	1	8	0.001
Erythrina brucei	54	5	1	0.0012
Carduus schimperi	53	24	0	0.0016
Euphorbia ampliphylla	36	0	0	0.0038
Landolphia buchanani	48	13	1	0.0054
Achyranthes aspera	42	22	0	0.0158
Olea capensis	43	6	12	0.016
Hyparrhenia anthistirioides	42	31	1	0.0218
Mimusops kummel	28	2	1	0.04
Vachellia abyssinica	36	6	10	0.0478
Teclea nobilis	4	74	1	0.0002
Nuxia congesta	0	56	0	0.0002
Schrebera alata	0	55	3	0.0004
Cyathula cylindrica	0	44	1	0.0016
Vernonia auriculifera	0	49	6	0.0022
Justicia schimperiana	0	41	1	0.0034
Albizia grandibracteata	9	49	2	0.0034
Achyrospermum schimperi	11	46	5	0.009
Phyllanthus dewildiorum	0	44	22	0.0154
Echinops amplexicaulis	5	34	2	0.0334
Arisaema schimperiana	11	35	1	0.0442
Carissa spinarum	17	40	6	0.0448
Vachellia lahai	0	0	69	0.0002
Acanthus eminens	13	8	55	0.0006
Vernonia amygdalina	0	10	53	0.001
Taccazzea apiculata	0	0	38	0.0024
Olea welwitschii	0	4	42	0.0034
Ficus thonningii	0	2	40	0.0076
Periploca linearifolia	17	0	42	0.009
Leucas martinicensis	0	0	31	0.0118
Urtica simensis	0	1	26	0.0422

Community 2: *Teclea nobilis - Nuxia congesta*

This community consists of 16 sample plots and 60 species. Twelve species had significantly higher indicator values ($p < 0.05$) (Table 3). The community is found from 1428 to 1645 m a.s.l. with an average elevation of 1506.63 m. Its indicator species are *Teclea nobilis, Nuxia congesta, Schrebera alata, Cyathula cylindrica, Vernonia auriculifera, Justicia schimperiana, Albizia grandibracteata, Achyrospermum schimperi, Phyllanthus dewildiorum, Echinops amplexicaulis, Arisaema schimperiana, Carissa spinarum,* etc. Species such as *Allophylus abyssinicus, Celtis africana, and Grewia ferruginea* were also common in this community. *Arisaema schimperiana, Kalanchoe petitiana, Kalanchoe lanceolata, Medicago sativa,* and grasses such as *Setaria megaphylla, Sporobolus pyramidalis,* and *Hyparrhenia* sp dominated the herb layer.

Community 3: *Vachellia lahai - Acanthus eminens*

This community has 13 quadrats and 61 species, out of which 9 are with significant indicator value ($p < 0.05$). The community occupied lower altitudes with a mean elevation of 1479.92 m and experienced more anthropogenic impact. *Vachellia lahai, Acanthus eminens, Vernonia amygdalina, Taccazzea apiculate, Olea welwitschii, Ficus thonningii, Periploca linearifolia, Leucas martinicensis,* and *Urtica simensis* were the characteristic species of this community (Table 3). *Jusminum abyssinicum, Ochna holistii, Syzygium guineense, Ficus sur, Mikaniopsis clematoides,* and *Myrsine africana* were also observed in this community type. *Leucas martinicensis, Oplismeunus hirtellus, Plumbago zeylanica,* and *Rubia cordifolia* were abundant in the ground layer.

Species diversity and floristic similarity

Overall mean diversity and richness of Angar Forest were 3.05 ± 0.29 (a value ranging from 2.26 to 3.54) and 25.83 ± 7.24 (a value ranging from 11 to 40), respectively. Plant communities were significantly different concerning the Shannon diversity index ($F_{1,38} = 15.14$; $p < 0.001$) and species richness ($F_{1,38} = 20.90$; $p < 0.001$) but not in evenness index ($F_{1,38} = 1.89$; $p > 0.05$). Hence, the 3 plant communities in Angar Forest were floristically less similar to each other. As it is obvious to observe species overlap among vegetation units, *Teclea nobilis - Nuxia congesta* and *Vachellia lahai - Acanthus eminens* communities were floristically more similar (Table 4).

Table 4

Comparison of Floristic similarity among the 3 plant community types

Communities	1	2	3
1	1		
2	0.72	1	
3	0.72	0.80	1

DISCUSSION

Species Diversity and Floristic Composition

The presence of 162 species of vascular plants (151 genera and 67 families) asserts that Angar Forest plays a critical role in preserving biodiversity in the era of grave anthropogenic disturbance. This amounts to ca. 2.8% of the total higher plant species in the country. Even if the comparison of different studies is not reasonable due to the difference in study objectives and physiographic and anthropogenic factors, the number of species in a forest may show how diverse a given ecosystem is (Gole, 2003). Accordingly, Angar Forest consists of much fewer vascular plant species than Berhane-Kontir (374) and Harenna forests (289) (Senbeta et al., 2014), and Tulu Lafto (230) Gurmessa et al., 2022), but equivalent to Maji (146), Dense (158) and Agama (162) (Senbeta et al., 2014; Molla, 2014; Addi et al., 2016). The reason for the differences in floristic richness between Angar Forest and the other forests could be due to the dissimilarity in topography, climate, soil, and degree of anthropogenic disturbance (Dobrowski, 2011).

In Angar Forest, 7 plant families contributed 36.42% of the total and the order of species-rich families is similar to the findings of previous studies in the country. Similar to several other forest patches in Ethiopia (Gurmessa et al., 2013; Molla, 2014; Addi et al., 2016), Asteraceae had more species in Angar Forest. Asteraceae is known to have many species both in Ethiopia (Hedberg et al., 2009; Kelbessa & Demissew, 2014) and the world (Funk et al., 2005). Efficient seed dispersal strategies and easy adaptation to varied ecological conditions are among the reasons for the success of the Asteraceae family. Fabaceae, the 2nd richest family in Angar Forest, is also the top species-rich family in the flora area (Kelbessa & Demissew, 2014). Unlike other montane forests in the region that had more herbaceous plant species (Gurmessa et al., 2013), the dominant growth form in Angar Forest was trees, suggesting herbaceous plants have been suppressed by some anthropogenic activities such as frequent forest fires.

Western Ethiopia was reported to have fewer endemic plant species than southeastern, central, and northern Ethiopia (Friis, 2009), asserting that endemic plant species are not evenly distributed in Ethiopia (Vivero et al., 2006; Friis, 2009). This study investigated 13 endemic plant species. Out of these, four of them, namely *Laggera tomentosa (NT), Millettia ferruginea (NT), Phyllanthus dewildiorum (NT), and Tiliacora troupinii (VU)* were reported in the IUCN red data list qualifying for the near threatened and vulnerable category. Asteraceae and *Fabaceae* had 38.46% of the total endemic plant species in Angar Forest. The proportion of endemic species in Angar Forest (8%), although lower (Friis et al., 2001), is equivalent to that of Gerba Dima (Dibaba et al., 2022), Tulu Lafto (Gurmessa et al., 2022) and Guard Forests (Dagne & Birhanu, 2023) and may be due to geographical proximity and similar environmental factors. On the other hand, Angar Forest has more endemic species than Garjeda, Anbessa, Dense and Yayu Forests (Yohannes, 2016; Molla, 2014; Gole, 2003) may be due to habitat heterogeneity and sampling intensity. The occurrence of endemic species entitles Angar Forest as an important refuge of biodiversity.

Moreover, previous studies by Gurmessa et al. (2022) and Yohannes et al. (2022) stated that several plant species in the Wollega floristic region (WG) were not known to exist

in the region in the different volumes of FEE. This study also identified 30 plant species as new records for the Wollega (WG) floristic region. This signifies how much floristic studies in the region were incomplete. Even though altitudinal gradient usually is positively correlated to the number of taxa (Friis et al., 2005), this is not the case in WG floristic regions that have wide altitudinal gradients but lower species richness than other areas in the FEE. Hence, the few species reported on FEE could be attributed to limited floristic studies in the region (Friis, 2009; Gurmessa et al., 2022). Hence, based on the justification given in this paper and other related studies in the region (Gurmessa et al., 2022; Yohannes et al., 2022), urgent and comprehensive botanical expeditions are vital in the region.

Plant community analysis and phytogeographical comparison

The distribution of plant communities across a landscape is largely determined by environmental heterogeneity (Munishi et al., 2007). Similar requirements to one or more ecological factors assemble species and form discrete vegetation units. Based on the degree of floristic association and MRPP test, 3 plant communities were identified in Angar Forest. MRPP generated a more negative test statistics T value. More negative value shows stronger separation (McCune & Grace, 2002).

Prunus africana - *Cordia africana* community occupied a relatively higher altitude with an average elevation of 1649.04 m a.s.l. It includes 11 sample plots and 53 species. Twenty of them had a higher indicator ($p < 0.05$). Species such as *Prunus africana, Cordia africana, Millettia ferruginea, Bersama abyssinica, Tiliacorpa troupinii, Pittosporum viridiflorum., Clausena anistata, Croton macrostachyus,* and *Dovyalis abyssinica were* those with higher indicator value in this community. *Dombeya torrida, Pycnostachys abyssinica, Erythrina brucei, Carduus schimperi, Euphorbia ampliphylla, Landolphia buchanani, Olea capensis, Mimusops kummel, Vachellia abyssinica* and herbaceous plants, namely *Achyranthes aspera* and *Hyparrhenia anthistirioides* are also abundant and frequently observed in this community type. The presence of tree species namely *Cordia africana*, *Croton macrostachyus*, *Prunus africana*, *Vachellia abyssinica*, *Celtis africana*, *Ekebergia capensis*, *Albizia gummifera, Pouteria adolfi-friederici*, *Olea welwitschii*, and shrubs such as *Rytigynia neglecta*, *Clausena anisate,* and lianas *Combretum paniculatum* and *Urera hypselodendron* indicated its strong floristic affinity to secondary MAF of Friis et al. (2010). A similar vegetation unit was reported from Tulu Lafto Forest (Gurmessa et al., 2022).

Teclea nobilis - *Nuxia congesta* community occupied a mean elevation of 1496.48 (altitude range 1431 to 1632 m a.s.l.). The community consists of 16 sample plots and 60 plant species with 12 of them having significantly higher indicator value. *Teclea nobilis, Nuxia congesta, Schrebera alata, Cyathula cylindrica, Vernonia auriculifera, Justicia schimperiana, Albizia grandibracteata, Achyrospermum schimperi, Phyllanthus dewildiorum, Echinops amplexicaulis, Arisaema schimperiana, Carissa spinarum,* etc. are indicator species to this community. Species such as *Allophylus abyssinicus, Celtis africana, and Grewia ferruginea* were also observed here. *Arisaema schimperiana, Kalanchoe petitiana, Kalanchoe lanceolata, Medicago sativa,* and grasses such as *Setaria megaphylla,*

Sporobolus pyramidalis, and *Hyparrhenia* sp. were abundant herbs.

Vachellia lahai - *Acanthus eminens* community consists of 13 sample plots and 61 species. Nine of them were significantly restricted to this community ($p < 0.05$). The characteristic species include *Vachellia lahai, Acanthus eminens, Vernonia amygdalina, Taccazzea apiculate, Olea welwitschii, Ficus thonningii, Periploca linearifolia,* and *Leucas martinicensis*. In addition, Jusminum *abyssinicum, Ochna holistii, Syzygium guineense, Ficus sur, Mikaniopsis clematoides,* and *Myrsine africana* were observed. *Urtica simensis, Leucas martinicensis, Oplismeunus hirtellus, Plumbago zeylanica* and *Rubia cordifolia* covered the ground layer. This community is more or less floristically similar to riverine vegetation (RV) and shared some of its characteristic tree species, namely *Phoenix reclinata, Syzygium guineense* ssp. *guineense, Mimusops kummel, F. vasta, Albizia grandibracteata, Trema orientalis, Manilkara butugi,* etc. (Friis, 1986; Friis et al., 2010).

Comparison of Angar Forest with other 5 forest paths in the region showed more floristic affinity to Tulu Lafto Forest (Gurmessa et al., 2022) than Guard Forest (33%) (Dagne & Birhanu, 2023), Dirki and Jato Forest patches (38%) (Tadesse et al., 2017) and Gerba Dima and Agama Forests (both 39%) (Addi et al., 2016; Dibaba et al., 2022). Angar Forest is floristically more similar to Tulu Lafto Forest because of its geographical proximity (found in the neighbouring districts of the Horo Guduru Wallaga zone). It is a little similar to the Agama and Gerba Dima Forests that are located in the Ilu Aba Bor zone and typically Moist Forest type (MAF) while Guard Forest and Dirki and Jato Forest patches are representatives of the Dry Afromontane Forest type (DAF). Angar Forest shared some important plant species from both MAF (*Pouteria adolfi-friederici* and *Olea welwitschii*) and DAF (*Olea europaea* subsp. *cuspidata*) signifying its floristic affinity to both MAF and DAF. It was indicated that moist forests stretch to the north (Friis, 1992) and the Shewa plateau (Bekele, 1994), while dry forests are extended to the west and are observed in the WG floristic region (Friis et al., 2010). Similar to the study conducted in the WG floristic region by Gurmessa et al. (2022), this study also suggests further investigation of species distribution to map and recognise the vegetation types in the Eastern edge of WG floristic regions including areas of this study area.

Species diversity and floristic similarity

Angar Forest had a diversity and richness index of 3.054 ± 0.29 (value ranges from 2.26 to 3.54) and 25.83 ± 7.24 (value ranges from 11 to 40), respectively, and plant communities in the forest were significantly different in both richness and diversity of species. Species diversity reflects the dynamics in plant species composition of a community (Yan et al., 2023). It is used to assess changes in biological diversity across space and/or time due to either anthropogenic impacts or natural disturbance factors (Gurmessa et al., 2022). Considerable differences between plant communities with respect to species richness and diversity in Angar Forest suggest a heterogeneous environment and/or differences in disturbance factors.

CONCLUSIONS

Angar Forest is the headwater source for the Angar River, a tributary to the Blue Nile River. This study contributed to the species richness and diversity of Angar

Forest. One hundred sixty-two species constituting 2.81% of all higher plant species in Ethiopia are found in the forest. Asteraceae, Fabaceae, Poaceae, and Euphorbiaceae were more represented in the forest. The abundance of these families could be because of their well-developed seed dispersal strategies that helped them to successfully arrive in suitable habitats. Angar Forest harbours 13 endemic plant species to the flora area. The study forest was floristically more similar to TLF than other forests may be due to similar environmental factors as a result of geographical proximity. Although Angar Forest provides enumerable ecological and economic importance to the local people, some important species such as *Albizia malacophylla* and *A. schimperiana* that were reported to exist in the forest are currently missing and were observed as dead stump alone. This could be because of the excessive exploitation of trees in Angar Forest for timber, construction, and fuel that ultimately hampered the natural regeneration. Angar Forest shared species from both DAF and MAF but little similar to either of them asserting that the present vegetation map needs further revision. Moreover, forest conservation actions should be started as soon as possible before the endemic species and those that are locally threatened are irreversibly lost from the area.

Credit authorship contribution statement:

Shiferaw Geleta: Investigation, Writing – original draft, Writing –review. **Fekadu Gurmessa:** Conceptualization, Data curation, methodology, Visualization, **Moa Megersa:** Supervision, Validation, & editing.

Declaration of Competing Interest

The authors declare that they have no conflicts of interest.

Ethics statement

The authors explained the objectives of the study obtained a support letter from Wollega University and were granted permission from a government institution in the Abe Dongoro district and the local community.

Data availability statement

All data are available from the corresponding author upon request.

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APPENDICES

Appendix 1

List of vascular plant species collected from Angar Forest

S/N	Species Name	Family	Habit	Local name
1	*Acanthus eminens* C.B. Clark		S	Kosorruu
2	*Justicia diclipteroides* Lindau subsp. aethiopica Hedren	Acanthaceae	H	Darguu
3	*Justicia schimperiana* (Hochst. ex Nees) T		S	Hummuugaa
4	*Adiantum poiretti* Wikstr.	Adiantaceae	F	Fernii
5	*Achyranthes aspera* L.	Amaranthaceae	H	Maxxannee
6	*Cyathula cylindrica* Moq		H	Kobboo
7	*Rhus ruspolii Engl*	Anacardaceae	T	Xaaxessaa
8	*Sclerocarya birrea* (A. Rich.) Hochst.		T	
9	*Carissa spinarum* L	Apocyanceae	S	Hagamsa
10	*Landolphia buchanani* (Hall.f.) Stapf.		L	Hidda Geeboo
11	*Arisaema schimperiana* Schot	Araceae	H	Niitii Bofaa
12	*Polyscias fulva (*Hiern) Harms	Araliaceae	T	Hombolxoqa
13	*Schefflera abyssinica (*Hochst.ex.A. Rich.) Harms		T	Gatamaa
14	*Phoenix reclinata* Jacq.	Arecaceae	T	Meexxii
15	*Periploca linearifolia* Quart. -Dill. & A. Rich.	Asclepiadaceae	L	Aannannoo
16	*Taccazzea apiculata* Oliv		L	Gurra Hantuutaa
17	*Asparagus afracanus* Lem.	Asparagaceae	S	Sariitii
18	*Asplenium aethiopicum* (Burm.f) Bech.	Aspleniaceae	F	Trimmii
19	*Bidens macroptera* (Sch. Bip. ex Chiov.) Mesfin		H	Hadaa
20	*Bidens rueppellii* (Sch.Bip.) Sherff		H	Hadaa
21	*Carduus leptacanthus Fresen.*		H	Qoraattii harree
22	*Carduus schimperi* Sch. Bip. ex Rich.		H	Qoraattii Harree
23	*Crepis rueppellii* Sch.Bip.		H	Aannannoo
24	*Echinops amplexicaulis* Oliv.		S	Kosorruu dhaltuu
25	*Echinops longifolius* A. Rich.	Asteraceae	S	Qoraattii harree
26	*Laggera tomentosa* Sch. Bip. ex Oliv. et Hiern		S	Ajaayee
27	*Mikaniopsis clematoides (*A. Rich.) Miln-Redh		H	H/Hantuutaa
28	*Vernonia amygdalina* Del.		T	Eebicha
29	*Vernonia auriculifera* Hiern		S	Reejjii
30	*Vernonia purpurea* Sch. Bip.ex Walp		S	Sooyyoma
31	*Vernonia wollastonii* S. Moore		S	Gosa Reejjii
32	*Echinops kebericho* Mesfin		H	Qarabichoo
33	*Basella alba L.*	Basellaceae	H	
34	*Cordia africana* Lam.	Boraginaceae	T	Waddeessa
35	*Ehretia cymosa* Thonn.		T	Ulaagaa
36	*Warburgia ugandensis* Sprague	Canellaceae	T	Beftii
37	*Cadaba farinosa* Forssk.	Capparidaceae	S	
38	*Hippocratea goetezi* Looes.Celastraceae	Celastraceae	L	H/qolalaafessa

S/N	Species Name	Family	Habit	Local name
39	*Matyenus gracilipes (*Welw.ex Oliv.) Excell		S	Hicaacii
40	*Maytenus undata (*Thumb.) Blakelock		S	Muka ilkaa
41	*Maytenus senegalensis* (Lam.) & Exell		T	Muka re'ee
42	*Combretum paniculatum* Vent.	Combretaceae	L	Hidda Baggii
43	*Terminalia schimperiana* Hochst.		T	Dabaqqaa
44	*Kalanchoe petitiana* A. Rich.	Crassulaceae	H	Busuqqee
45	*Kalanchoe lanceolata* (Forssk.) Pers.		H	Busuqqee
46	*Laggenaria abyssinica (*Hook.f.) C. Jeffrey	Cuccurbitaceae	H	B/seexanaa
47	*Zehneria scabra (*linn.f.) sond		H	Gosa Hidda
48	*Dipsacus pinnatifidus* Steud. ex A. Rich.	Dipsacaceae	H	
49	*Dracaena afromontana* Mildbr.	Dracaenaceae	S	Qooccoo Qamalee
50	*Dryopteris anthamantica* (Kunze)Kuntze.	Dryopteridaceae	F	Trimmii
51	*Diospyros abyssinica (*Hiern.) F. White	Ebenaceae	T	Hilkee/Lookoo
52	*Euclea divinorum* Hiern.		S	Mi'eessaa
53	*Argomuelera macrophylla* Pax.		S	Hanbuubbuu
54	*Clutia abyssinica* Jub. & Spach		S	Ulee Foonii
55	*Croton macrostachyus* Del.		T	Makkanniisa
56	*Erythrococca trichogyne* (Muell.Arg.) Prain	Euphorbiaceae	T	Caakkoo
57	*Euphorbia ampliphylla* Pax.		T	Hadaamii
58	*Macaranga capensi* (Bail.) Sim.		T	Ho'aa
59	*Phyllanthus dewildiorum M.* Gilbert.		S	
60	*Vachellia abyssinica* Hochst.ex Benth		T	Laaftoo
61	*Vachellia gerrardii* Benth.		T	Doddota
62	*Vachellia lahai* Steud. & Hochst. er Benth.		S	Garbii
63	*Albizia gummifera* (J.F. Gmel.) C.A.S.M.		T	Muka arbaa
64	*Albizia grandibracteata* Taub.		T	Birbirii
65	*Caesalpinia decapetala* (Roth.) Alston	Fabaceae	L	Harangamaa
66	*Calpurnia aurea* (Ait.) Benth		S	Ceekaa
67	*Dalbergia lactea* Vatke		S	waraa billee
68	*Erythrina brucei* Schweint.		T	Waleensuu
69	*Lonchocarpus laxiflorus* Guill. & Petr.		T	Qanqalsha
70	*Medicago sativa L.*		H	Siddisa
71	*Millettia ferruginea* (Hochst.) Bak.		T	Sotalloo
72	*Dovyalis abyssinica (*A. Rich.)Warb.	Flacourtaceae	S	Koshommii
73	*Flacourtia indica Burm.f.* Merr.		T	Akuukkuu
74	*Drimia* altissima (L.f) Ker-Gawl.	Hyacinthaceae	H	Qullubbii jaldessaa
75	*Achyrospermum schimperi (*Hochst.exbriq.) Perkins		H	kusaayee
76	*Leucas martinicensis* (Jacq.) R.BR.		H	Dalee
77	*Ocimum lamiifolium* Hochst.ex Benth.	Lamiaceae	S	Wancabbii
78	*Oiumium Urticifolium* Roth		S	Gosa Wancabbii
79	*Premna schimperi* Engl.		T	Urgeessaa
80	*Pycnostachys abyssinica* Fresen		S	Doroomii

S/N	Species Name	Family	Habit	Local name
81	*Buddleja polystachya Fresen*	Loganiaceae	T	Anfaaree
82	*Nuxia congesta* R.Br. ex Frese		T	Naffiroo
83	*Phragmanthera macrosolen* (Steud. ex A. Rich.) M.G. Gilbert	Loranthaceae	E	Eertoo
84	*Hibiscus macranthus* Hchst.ex A. Rich.	Malvaceae	S	Quncee
85	*Pavonia urens Cav.*		H	
86	*Dissotis canescens* (Graham) Hook.f.	Melastomataceae	H	
87	*Ekebergia capensis* Sparrm	Meliaceae	T	Somboo
88	*Lepidotrichilia volkensii* Gurke.) Leory		T	Bosoqa
89	*Bersama abyssinica* Fresen	Melianthaceae	S	Araarsaa
90	*Tiliacora troupinii* Cufod.	Mensipermaceae	L	H/liqimmee
91	*Stephania abyssinica Dillon* &A. Rich Walp.		L	Hidda kalaalaa
92	*Ficus sur Forssk.*	Moraceae	T	Harbuu
93	*Ficus thonningii* Blume		T	Dambii
94	*Embelia schimperi* Vatke		L	Haanquu
95	*Maesa lanceolata* Forssk	Myrsinaceae	T	abbayyii
96	*Myrsine africana* L.		S	Qacamaa
97	*Syzygium guineense* subsp. *macrocarpum* (Engl.) F. White	Myrtaceae	T	Goosuu
98	*Syzygium guineense* ssp. *guineense* (Engl.) F. White		T	Baddeessaa
99	*Ochna holistii* Engl.	Ochnaceae	T	Lookoo
100	*Ximenia americana* L.	Olacaceae	T	Hudhaa
101	*Jusminum abyssinicum* Hochst.ex DC.		L	Ichilmee
102	*Olea europaea* L. sub sp cupidata (wall ex.G. Don) Cif		T	Ejersa
103	*Olea capensis subsp. macrocarpa (*C. A. Wright) Verdc.	Oleaceae	T	Gagamaa
104	*Olea welwitschii (*Knobl.*)* Gilg & Schelleb.		T	Bahaa
105	*Schrebera alata* (Hochst.) Welw.		T	Qassee adii
106	*Olinia rochetiana* A. Juss.	Oliniaceae	T	Noolee
107	*Phytolacca dodecandra* L'Herit	Phytolaccaceae	L	Handoodee
108	*Pittosporum viridiflorum* Sims	Pittosporaceae	T	Qasammee
109	*Plumbago zeylanica* L.	Plumbaginaceae	H	Ameeraa
110	*Andropogon abyssinicus*Fresen		H	M/baallamii
111	*Cynodon dactylon (L.) Pers.*		H	Coqorsa
112	*Eleusine floccifolia* (Forssk.) Spreng.		H	Daggoo
113	*Hyparrhenia anthistirioides* (Rochat. exA. RiCh.) Stapf		H	Daggala
114	*Olyra latifolia* L.	Poaceae	H	
115	*Oplismeunus hirtellus* (L.) P. Beauv.		H	Marga Booyyee
116	*Pennisetum sphacelatum* (Nees) Th. Dur. & Schinz		H	Diffii
117	*Setaria megaphylla (*Steud.) Th. Dur.		H	Jajjabaa
118	*Sporobolus pyramidalis* P. Beauv.		H	Murii
119	*Podocarpus falcatus* (Thunb.) R. B. ex Mirb.	Podocarpaceae	T	Birbirsa
120	*Drynaria volkensii* J. Sim.	Polypodiaceae	F	Sokokkee
121	*Faurea speciosa* Welw.	Proteaceae	T	Gaarrii
122	*Protea gaguedi* J.F. Gamel.		T	Yubdoo
123	*Pteris catoptera* Kunze.	Pteridaceae	F	Trimmii

S/N	Species Name	Family	Habit	Local name
124	*Clematis simensis* Fresen	Ranunculaceae	L	Hidda feetii
125	*Clematis longicauda* Steud. ex A. Rich.		L	Hidda Feetii
126	*Helinus mystacinus* (Ait)E. MNey.ex Steud.	Rhamnaceae	L	
127	*Rhamnus prinoides* L.'Herit.		S	Geeshoo
128	*Ficus vasta* Forssk.	Rhizophoraceae	T	Qilxuu
129	*Hagenia abyssinica* (Bruce)J.F. Gmel	Rosaceae	T	Heexoo
130	*Prunus africana (*Hook.fkalkm*)*		T	Hoomii
131	*Rosa abyssinica* Lindley		S	Qagii
132	*Rubus steudneri* Schweinf		L	Goraa
133	*Galiniera saxifraga (*Hochst.) Bridson	Rubiaceae	S	Mixoo
134	*Gardenia ternifolia* Schumach. &Thonn.		T	Gambeelloo
135	*Pavetta abyssinica* Fresen.		S	mixoo
136	*Rothmannia urcelliformis* (Hiern.) Robyns.		T	Buruurii
137	*Rubia cordifolia* L.		H	maxxannee
138	*Rytigynia neglecta* (Hiern.) Robyns.		S	Mixoo dhalaa
139	*Clausena anistata* (Willd.) Bent	Rutaceae	S	Ulumaayyii
140	*Teclea nobilis* Del.		T	Gosa Hadheessaa
141	*Vepris dainelli* (Pichi-serm.) Kokwaro		T	Hadheessa
142	*Osyris quadripartita* Decn	Santalaceae	S	Waatoo
143	*Allophylus abyssinicus* (Hochst.) Radkofe	Sapindaceae	T	Malqaqqoo
144	*Dodonaea angustifolia* L. f.		S	Ittacha
145	*Manilkara butugi* Chiov.	Sapotaceae	T	Buttujjii
146	*Mimusops kummel* A.DC.		T	Qolaadii
147	*Pouteria adolfi-friederici (*Engl.) Baehni	Simaroubaceae	T	Sooqee
148	*Brucea antidysenterica* J.F. Mill.		S	Qomonyoo
149	*Solanum anguivi* Lam.	Solanaceae	H	hiddii saree
150	*Solanum giganteum* Jacq		S	Gosa hiddii
151	*Dombeya torrida (*J.F. Gamel.) P. Bamps	Sterculiaceae	T	Daannisoo
152	*Grewia ferruginea* Hochst.ex.A. Rich.	Tiliaceae	S	Dhoqonuu
153	*Sparmannia ricinocarpa (*Eckl. & Zehy.) O. Ktze.		S	burkutuu
154	*Celtis africana* Burma.f.	Ulmaceae	T	Cayii
155	*Trema orientalis* (L.) BL.		T	Fofoo
156	*Giradinia bullosa (*Steud.) Wedd.	Urticaceae	H	Doobbii
157	*Girardinia diversifolia* (Link) Friis		H	Gurgubbee
158	*Urera hypselodedron* (A. Rich.) Wedd.		L	Laanqessaa
159	*Urtica simensis* Steudel		H	Gurgubbee
160	*Lantana trifolia* L.	Verbenaceae	S	kusaayee
161	*Duranta erecta* L.		S	
162	*Lippia adoensis* Hochst.ex Walp.		S	Kusaayee