

FLORISTIC COMPOSITION AND PLANT DIVERSITY ANALYSIS OF ANBESSA FOREST IN WESEREN ETHIOPIA AND ITS CONTRIBUTION TO BIODIVERSITY CONSERVATION

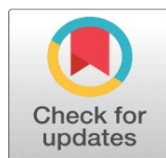
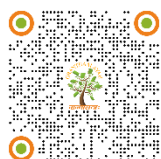
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ABSTRACT

The study was conducted at Anbessa forest in Western Ethiopia with the objectives to make an assessment of plant diversity and plant community. A systematic sampling technique was used and a total of 30 sample plots each with 20 x 20 m were laid along the altitudinal gradient. A total of 118 plant species were identified which belong to 93 genera in 46 families. Out of which 14.41 % were Fabaceae (17 species), followed by Asteraceae 11.86 % (14 species), Poaceae 8.47 % (10 species) and Lamiaceae 5.93 % (seven species). Out of the 118 identified plant species, 33.05 % were trees, 11.86 % shrubs, 11.86 % climbers and the rest 43.22 % were herbs. The present study reported nine endemic plant species are present in Anbessa forest. Moreover, 29 plant species were recorded as new records for Wellega floristic region from Anbessa forest. Four plant communities were identified. In Anbessa forest Combretum collinum - Dombeya quinqueseta - Securidaca longepedunculata community was the most diverse community, whereas Oxytenanthera abyssinica - Combretum molle - Syzygium guineense subsp. macrocarpum community was the least diverse with H' 0.16. The result showed that, Anbessa forest can play a significant role in biodiversity conservation.

Keywords: Plant Diversity, Floristic Composition, New Records, Endemic Species, Biodiversity Conservation



1. INTRODUCTION

With its geological history, broad latitudinal spread and immense altitudinal range, Ethiopia spans a remarkable number of the world's broad ecological regions. These range from the Dalol depressions in the Afar (120 meters below sea level (m.b.s.l)) to the spectacular mountaintops of Ras Dashen (4620 meters above sea level (m.a.s.l.)) in the north and the Bale Mountains such as Tullu Dimtu (4337 m and the second-highest peak in Ethiopia) and Batu (4307 m) in the southeast. These varieties of habitats also support rich variety of different species contributing to the biological diversity of the country [Institute of Biodiversity Conservation \(2005\)](#).

Biodiversity is a common factor that links agriculture, forestry, fisheries, and other sectors and provides the necessary materials for livelihood, sustenance, trade, medicines and industrial development. Ethiopia is endowed with plant diversity; the total number of vascular plants in Ethiopia is estimated to be about 6000 species [Hedberg et al. \(2009\)](#) out of which about 10% are endemic. The number of woody plants is said to be around 1000 and out of which about 300 are tree species [Berhan \(1991\)](#), [Ethiopian Forestry Action Program \(1994\)](#), [Environmental Protection Authority \(1997\)](#). According to Kent and Coker [Kent and Coker \(1992\)](#), over large parts of the globe, human populations have modified plant communities extensively. This is also true in Ethiopian condition. However, there is high deforestation and the annual rate of deforestation of the high forests in Ethiopia ranges from 150,000 to 200,000 ha [Ethiopian Forestry Action Program \(1994\)](#), [Environmental Protection Authority \(1997\)](#). The Ethiopian country report of the FAO, from the Global Forest Resources Assessment (GFRA), also shows similar results of deforestation rate which is 1.25% for forests (156,241.96 ha of forest per year) [Food and Agriculture Organization of the United Nations \(2015\)](#). From the same report the deforestation rate for woodlands is even more serious which amounts 1.8% per year which is 731,363.13 ha of woodlands per year.

Information on vegetation may be required to help to solve ecological problems such as biological degradation, as an input for environmental impact assessments, to monitor management practices or to provide the bases for prediction of possible future changes.

Eventhough some studies were conducted on Anbessa forest, it did not provide holistic information. Currently information on the status of plant diversity of Anbessa forest is not available. Factors such as landscape change (changing forest to other type of land use), deforestation, agricultural expansion, climate change and others are affecting the forest. Therefore, this study was initiated to conduct plant diversity study and vegetation structure, in order to support the knowledge-based plant diversity conservation planning effort of the country, to support the sustainable development of the forest, as well as to supply current information of the forest for the scientific community.

2. MATERIALS AND METHODS

2.1. DESCRIPTION OF THE STUDY AREA

- Geographical location

Anbessa forest is located in Bambacy district ("Wereda"), Assosa zone of the Benshangul Gumuz National Regional State (BGNRS) in Western Ethiopia. It is located at 9° 55' 40.8" N Latitude in the north to 9° 53' 24.3" N Latitude in the south and around 34° 50' 55.3" to 34° 39' 09.0" E Longitude in the east and west,

respectively. The forest is very narrow from north to south, while it is wide east - west ward, which reach near to Dabus River in the east. The main asphalt road from Addis Ababa (Bambacy) to Asossa crosses the forest around the western part. Anbessa forest is found surrounded by six Kebele administratives namely: Amba 16, Jematsa, Garabiche Welega, Sonka, Village 44, and Village 47 (Figure 1). According to the information from the local communities, the forest is said to be stretched from Dabus River in the east, to Ethio-Sudan border in the west. The eastern part, which goes to Dabus River, is called Sissa, the middle part is called Anbessa, and the western part, which extends to Ethio-Sudan border, is called Penshuba forest. The total area of the Anbessa forest is estimated to be 15,072 hectares.

Figure 1

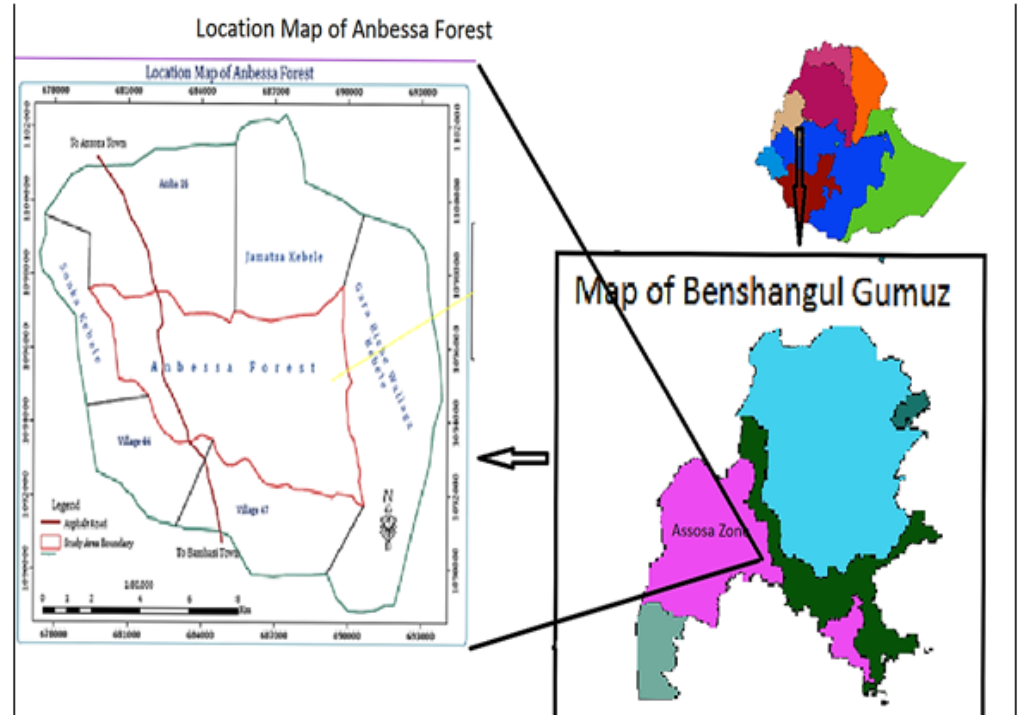


Figure 1 Map of Anbessa Forest with Bordering Kebeles

- Topography

The topography of Anbessa forest is very flat. Except for a few hills in the western part of the forest, near the main Addis Ababa-Asossa Road, the rest of the forest is flat wooded grass land with very small slope variation. The elevation ranges from 1292 to 1563 m.a.s.l. with the highest peak being to the western side, while the lowest area is to the eastern side around Selga River with a total elevation variation of only 271 meters.

- Hydrology

Anbessa forest is found in the Blue Nile River basin. There are a number of big and small rives which are tributaries of Blue Nile, such as Dabus, Afa, Selga, Shosha, Mutsa, Nifiro, Abakidi, Eshama, Chilonya and many small streams which pass through or near by the forest. As described by [Herrmann et al. \(2007\)](#), the Assosa-Bambasi area has many small creeks and rivers forming an extensive network of permanent water courses. Lakes do not exist only in and around Anbessa forest, but also in the whole of BGNRS. However, there are wetlands in some parts and during

the rainy season some depressions fill with precipitation water, forming temporary or even permanent pools [Herrmann et al. \(2007\)](#).

- Climate

Anbessa forest is found in the western lowlands of the country. Climate data from the nearest meteorological stations Amba 16 (only rainfall, from 1988-2013) and Assosa (from 1981-2013), were extracted and presented in [Figure 2](#) and [Figure 3](#). Amba 16 is located at 9° 57' 12.4" N Latitude and 34° 39' 21.7" E Longitude, with an altitude of 1401 m.a.s.l. and is found around three kms Northwest of Anbessa forest. Assosa is located at 10° 03' 56.7" N Latitude and 34° 32' 34.5" E Longitude, with an altitude of 1554 m.a.s.l. and is found around 20 km Northwest of Anbessa forest.

The average annual rainfall is 1381.42 mm and 1128.59 mm for Amba 16 and Assosa, respectively, while the mean annual maximum temperature is 28.37 °C for Assosa. The area is characterized by unimodal rainfall distribution with the rainy season extends from March to November and one distinct short dry season extending from December to February ([Figure 2](#) and [Figure 3](#)). Typically, during the onset of the main rainy season, the first two months receive small amount and gradually reach to its peak in August. More than 55% of the mean annual rainfall falls from June to August.

The mean maximum monthly temperature is about 28.37 °C. Mean maximum monthly temperature reaches to its peak during March followed by April and February, with a temperature of 32.69°C, 32.05 °C and 31.96 °C, respectively, whereas the lowest mean minimum monthly temperature occurs during December with a temperature of 13.28 °C.

Figure 2

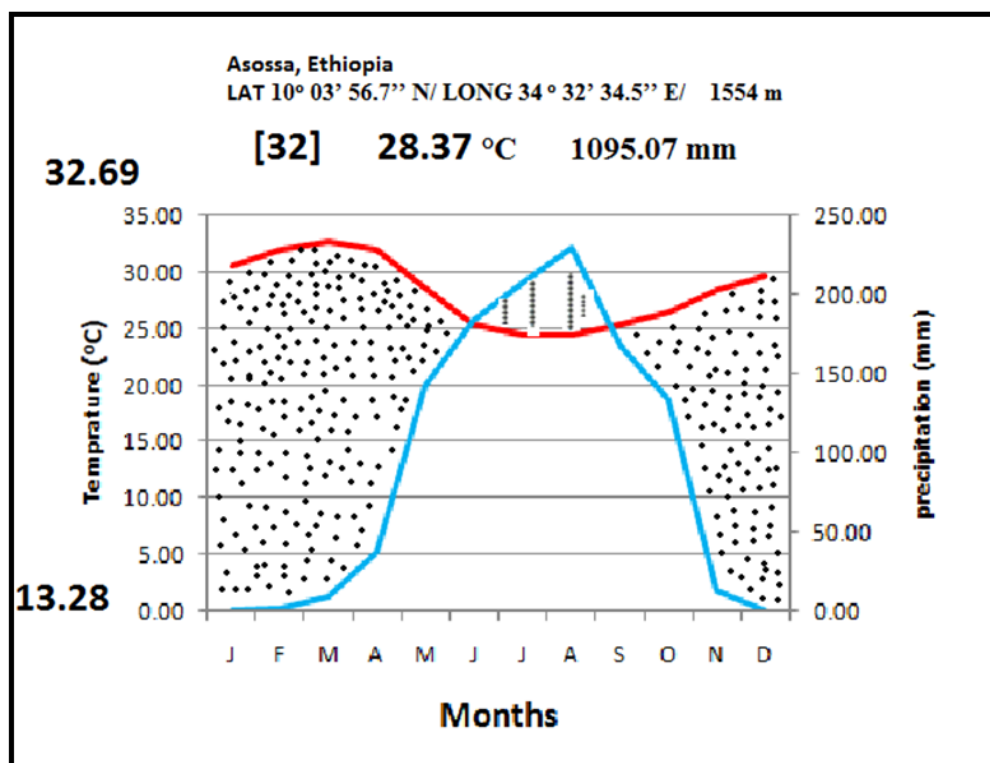


Figure 2 Climate Diagram of Asossa

Data Source: [National Meteorological Agency \(2016\)](#) Personal Communication

Figure 3

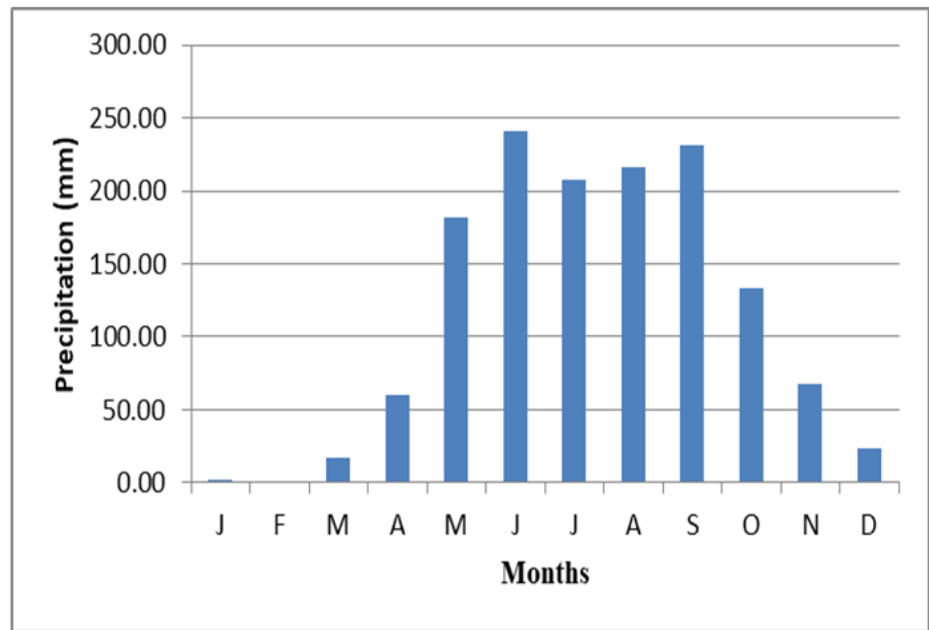


Figure 3 Monthly Rainfall Pattern of Amba 16

(Data Source: [ENMSA, 2015](#), [Personal Communication](#))

- **Vegetation**

The altitudinal variation in Anbessa forest is very low; there is no as much variability in the vegetation type. In general, the Anbessa forest can be characterized as *Combretum-Terminalia* woodland. The forest is dominated by *Oxytenanthera abyssinica* (lowland bamboo) stands with scattered *Combretum - Terminalia* Woodland vegetation. Major characteristic species such as *Albizia malacophylla*, *Combretum collinum*, *Combretum molle*, *Dombeya quinqueseta*, *Entada africana*, *Erythrina abyssinica*, *Gardenia ternifolia* and *Syzygium guineense* subsp. macrocarpum and others present in the area.

2.2. SOCIOECONOMIC CHARACTERISTICS

According to the 2007 population and housing census of the Ethiopian Population Census Commission [Ethiopian Population Census Commission \(2007\)](#), the population of the BGNRS is ca. 784,345 of which 13.50% (105,926) are settled in the urban areas and the rest 86.50% (678,419) in the rural areas.

This shows that the rural urban population ratio of the region is a little bit higher than the national averages of the country which is 83.92%. The population of Bambasi district where the Anbessa forest is found is 48,694 of which 18.78% (9,146) lives in urban areas specifically in the Bambasi town and the rest 81.22% (39,548) lives in the rural area [Ethiopian Population Census Commission \(2007\)](#). On the contrary, Bambasi district has lower rural urban population ratio, which is lower than that of the regional as wells the national average. Among the population of the district 70.73% (34,491) are economically active and available to be engaged in the production of economic goods and services.

Concerning the energy source of the Bambasi town, which has direct relation to the natural resource of the Anbessa forest, among the total 2,171 house-holds, only 2.58% (56 house-holds) uses electricity as energy source for cooking. The great majority of the population which is 89.36% (1940 house-holds) and 52.97% (1151 house-holds) uses fire wood and charcoal, respectively as energy source for cooking [Ethiopian Population Census Commission \(2007\)](#).

2.3. SAMPLING DESIGN AND DATA COLLECTION

Systematic sampling design was used according to [Mueller-Dombois and Ellenberg \(1974\)](#) and [Kent and Coker \(1992\)](#) and 30 plots were systematically laid along 4 transect lines. The size of the sampling plots was 20 m x 20 m for trees, 5 m x 5 m for shrubs and 1 m x 1 m for herbs and laid along the transect at every 50 m altitudinal drop for hilly areas and at every 200 m for flat areas.

All woody vascular plant species encountered in each sample plot were recorded and their cover abundance was recorded by visual estimation of the percentage foliage cover of each species in the sampling plot and recorded as percentage in order to do analysis related to plant community types. Then the percent cover was transformed to ordinal scale and assigned to one of the nine cover classes according to modified 1-9 Braun-Blanquet scale [Van der Maarel \(2004\)](#). Plant specimens were collected and brought to the National Herbarium (ETH) of Addis Ababa University for identification. The specimens were properly dried and identified using authenticated specimens, consulting experts, and referring the published volumes of Flora of Ethiopia and Eritrea. Nomenclature followed the publications of the Flora of Ethiopia and Eritrea. All the plant specimens were properly labelled and deposited in the National Herbarium (ETH) Addis Ababa University.

Species diversity, richness, and evenness

The diversity of woody species in Anbessa forest was determined according to [Kent and Coker \(1992\)](#), using the Shannon-Wiener diversity index (H') and evenness or equitability index (E) based on cover/abundance value of the species as input data.

3. RESULTS AND DISCUSSION

3.1. FLORISTIC COMPOSITION

A total of 118 plant species were identified which belongs to 97 genera from 46 families ([Table 1](#) and [Appendix 1](#)). Out of the 118 identified plant species, 39 species (33.05 %) were trees, 14 species (11.86 %) were shrubs, 14 species (11.86 %) were climbers, and the rest 51 species (43.22 %) were herbs. [Table 1](#) below show the growth habit or life forms of collected plants and their percentage.

Table 1

Table 1 Number, percentage, and life forms of plant species collected from Anbessa forest

S. No	Life form	Number	Percentage
1	Trees	39	33.05
2	Shrubs	14	11.86
3	Climbers	14	11.86
4	Herbs	51	43.22
Total		118	100

As shown in [Appendix 2](#), out of 97 identified genera and 46 families; 14.41 % were Fabaceae represented by 17 species, followed by Asteraceae 11.86 % represented by 14 species, Poaceae 8.47 % represented by 10 species and Lamiaceae 5.93 % represented by seven species. The rest 42 families have 3.39 % up to 0.85 % and represented by number of species ranging from four to one, among which eight families have been represented by two species and 26 families by only one species ([Appendix 2](#)).

3.2. ENDEMIC PLANTS AND NEW RECORDS FROM ANBESSA FOREST FOR WELLEGA (WG) FLORISTIC REGION OF ETHIOPIA

The result also revealed that, Anbessa forest harbors nine endemic plant species of Ethiopia which belongs to seven Families ([Table 2](#)). Moreover 29 plant species collected from Anbessa forest were recorded as new records for WG Floristic Region of Ethiopia according to the published Flora of Ethiopian and Eritrea volumes and voucher specimens of the National Herbarium (ETH) ([Table 3](#)). This makes the forest, important alternative in situ conservation sites for such species as well as for others.

Table 2

Table 2 List of Endemic plant species of Ethiopia recorded from Anbessa forest			
No.	Scientific Name	Family	Habit
1	<i>Albizia malacophylla</i> (A. Rich.) Walp. var. <i>malacophylla</i>	Fabaceae	Tree
2	<i>Berkheya chiesiana</i> Chiov.	Asteraceae	Herb
3	<i>Crinipes abyssinicus</i> (Hochst. ex A. Rich.) Hochst.	Poaceae	Herb /Grass
4	<i>Dombeya aethiopica</i> Gilli.	Sterculiaceae	Tree
5	<i>Lippia adoënsis</i> Hochst. ex Walp.	Verbenaceae	Shrub
6	<i>Mucuna melanocarpa</i> Hochst. ex A. Rich	Fabaceae	Climber
7	<i>Pimpinella heywoodii</i> Abebe	Apiaceae	Herb
8	<i>Tragia abortiva</i> M. Gilbert	Euphorbiaceae	Shrub
9	<i>Tragia doryodes</i> M. Gilbert	Euphorbiaceae	Climber

Table 3

Table 3 List of species recorded as new records for Welega floristic region			
No	Scientific Name	Family	Habit
1	<i>Acacia polyacantha</i> subsp. <i>campylacantha</i> (Hochst. ex A. Rich.) Brenan	Fabaceae	Tree
2	<i>Acacia robusta</i> subsp. <i>usambarensis</i> (Taub.) Brenan	Fabaceae	Tree
3	<i>Aframomum alboviolaceum</i> (Ridl.) K. Schum.	Zingiberaceae	Herb
4	<i>Ageratum conyzoides</i> subsp. <i>latifolium</i> (Cav.) M.F. Johnson	Asteraceae	Herb
5	<i>Albizia malacophylla</i> (A. Rich.) Walp. var. <i>malacophylla</i>	Fabaceae	Tree
6	<i>Asparagus scaberulus</i> A. Rich.	Asparagaceae	Climber
7	<i>Brachiaria lachnantha</i> (Hochst.) Stapf	Poaceae	Herb/Grass
8	<i>Citrullus colocynthis</i> (L.) Schrad.	Cucurbitaceae	Climber
9	<i>Clematis hirsuta</i> Perr. & Guill.	Ranunculaceae	Climber
10	<i>Crinipes abyssinicus</i> (Hochst. ex A. Rich.) Hochst.	Poaceae	Herb/Grass
11	<i>Crinipes longifolius</i> C.E. Hubb.	Poaceae	Herb/Grass
12	<i>Dombeya aethiopica</i> Gilli.	Sterculiaceae	Tree
13	<i>Entada africana</i> Guill. & Perr.	Fabaceae	Tree

14	<i>Faurea speciosa</i> Welw.	Proteaceae	Tree
15	<i>Ficus ingens</i> (Miq.) Miq.	Moraceae	Tree
16	<i>Ficus platyphylla</i> Del.	Moraceae	Tree
17	<i>Habenaria armatissima</i> Rchb. f.	Orchidaceae	Herb
18	<i>Hyparrhenia anthistiriodes</i> (Hochst. ex A. Rich.) Stapf.	Poaceae	Herb/Grass
19	<i>Lannea fruticosa</i> (A. Rich.) Engl.	Anacardiaceae	Tree
20	<i>Lepistemon owariense</i> (Beauv.) Hall. f.	Convolvulaceae	Climber
21	<i>Murdannia simplex</i> (Vahl) Brenan	Commelinaceae	Herb
22	<i>Ocimum spicatum</i> Deflers	Lamiaceae	Small shrub
23	<i>Oxalis obliquifolia</i> A. Rich.	Oxalidaceae	Herb
24	<i>Pennisetum trachyphyllum</i> Pilg.	Poaceae	Herb/Grass
25	<i>Reichardia tingitana</i> (L.) Roth	Asteraceae	Herb
26	<i>Sporobolus pyramidalis</i> P. Beauv.	Poaceae	Grass
27	<i>Tacca leontopetaloides</i> (L.) O. Ktze.	Taccaceae	Herb
28	<i>Tamarindus indica</i> L.	Fabaceae	Tree
29	<i>Terminalia laxiflora</i> Engl. & Diels-	Combretaceae	Tree

3.3. PLANT COMMUNITY CLASSIFICATION

The vegetation data matrix was analyzed and classified to analyze pattern of variation in species composition. The data set consisting of 30 woody plant species in 30 relevés were used in plant community classification. The species codes are explained in Appendix C.

The woody vegetation of Anbessa forest was classified into four clusters using a simple ordination plot (Fig. 4). The first vertical axis separated the riverine vegetation which is found near River "Selga" with characteristic species of *Pittosporum viridiflorum* and *Syzygium guineense* subsp. *afromontanum* with that of the two non-riverine vegetation types dominated by lowland Bamboo (*Oxytenanthera abyssinica*) and that of the wooded grassland. The second horizontal axis separated the wooded grassland which has no *O. abyssinica* into two communities with *Piliostigma thonningii* and *Terminalia macroptera* as a characteristic species on the one side and *Combretum collinum*, *Dombeya quinqueseta* and *Securidaca longepedunculata* as characteristic species on the other side. Four associations were identified which represent the plant communities in Anbessa forest. These plant communities have been named as follows by two or three dominant species based on highest mean cover/abundance value that appears within a group. Even though, *Oxytenanthera abyssinica*, *Terminalia laxiflora*, *Lannea welwitschii*, *Syzygium guineense* subsp. *macrocarpum*, *Entada africana*, *Dombeya quinqueseta*, *Albizia malacophylla*, *Piliostigma thonningii*, *Bridelia micrantha* and *Combretum collinum* have a wide distribution, there is no single species that appeared in all plant communities.

Figure 4

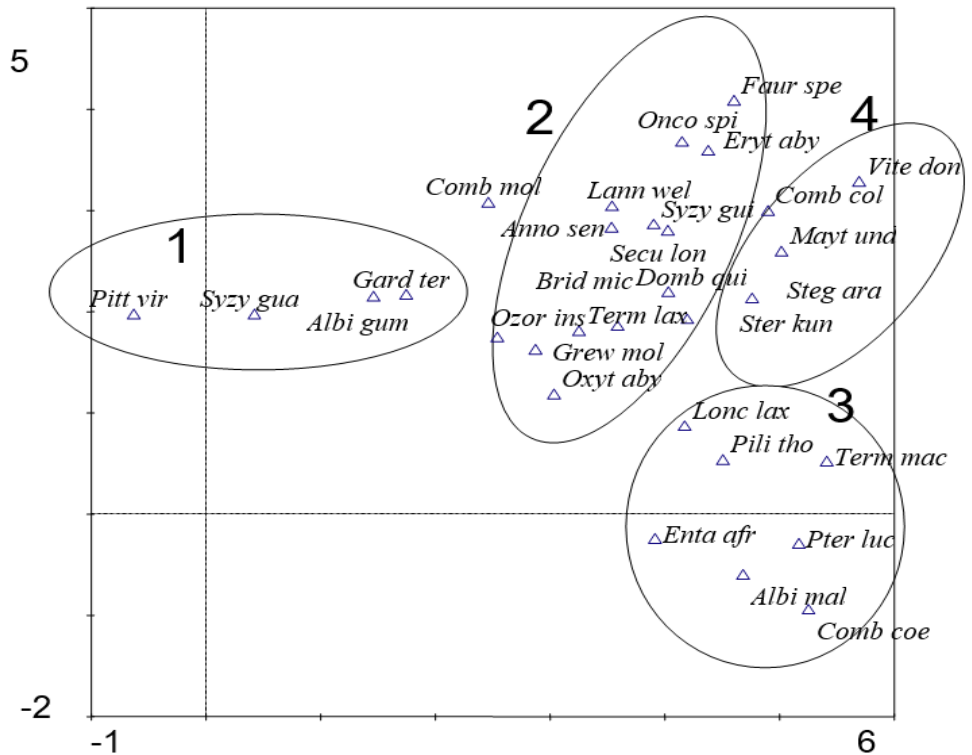


Figure 4 Species, Scatter Plot Diagram for 30 Species Arranged by DCA Axes 1 and 2. The x-axis is Axis 1 (Eigen value = 0.783), the y-axis is Axis 2 (Eigen value = 0.422). The Axes are Scaled in S.D Units. The Circles and Bold Numbers Represent the Four Plant Communities of Anbessa Forest.

- ***Pittosporum viridiflorum* - *Syzygium guineense* subsp. *afromontanum* Community**

This plant community occurs near River “Selga”. Though this plant community continues following the river Selga, the transect crossed it at once and the community was recorded only in one plot which is the lowest place of all the plots with elevation of 1292 m.a.s.l. This community includes trees such as: *Pittosporum viridiflorum*, *Syzygium guineense* subsp. *afromontanum*, *Albizia gummifera* and *Gardenia ternifolia*. The ground layer is dominated by *Aframomum albviolaceum*.

- ***Oxytenanthera abyssinica* - *Combretum molle* - *Syzygium guineense* subsp. *macrocarpum* Community**

This plant community occurs within a larger part of Anbessa forest. It was recorded between 1413 to 1563 m.a.s.l. This community includes trees and shrubs such as: *Oxytenanthera abyssinica*, *Combretum molle*, *Syzygium guineense* subsp. *macrocarpum*, *Annona senegalensis*, *Lannea welwitschii*, *Dombeya quinqueseta* and others.

- ***Piliostigma thonningii* - *Terminalia macroptera* community**

This plant community occurs relatively to the lower part of Anbessa forest. It was recorded around 1338 m.a.s.l. This community includes trees such as: *Piliostigma thonningii*, *Lonchocarpus laxiflorus*, *Terminalia macroptera*, *Terminalia laxiflora*, *Entada africana*, *Albizia malacophylla*, *Combretum collinum* and others.

• ***Combretum collinum* - *Dombeya quinqueseta* - *Securidaca longepedunculata* Community**

This plant community occurs in intermediate elevation. It was recorded at an altitude of 1442 m.a.s.l. This community includes trees such as: *Combretum collinum*, *Dombeya quinqueseta*, *Entada africana*, *Maytenus undata*, *Pterocarpus lucens*, *Securidaca longepedunculata*, *Steganotaenia araliacea*, *Stereospermum kunthianum*, *Terminalia laxiflora* and *Vitex doniana*.

4. ORDINATION

4.1. DETRENDED CORRESPONDENCE ANALYSIS

Detrended Correspondence Analysis (DCA) ordination was done (Figure 5) by using computer program Canoco Version 4.55 (ter Braak and Smilauer, 2002).

Figure 5

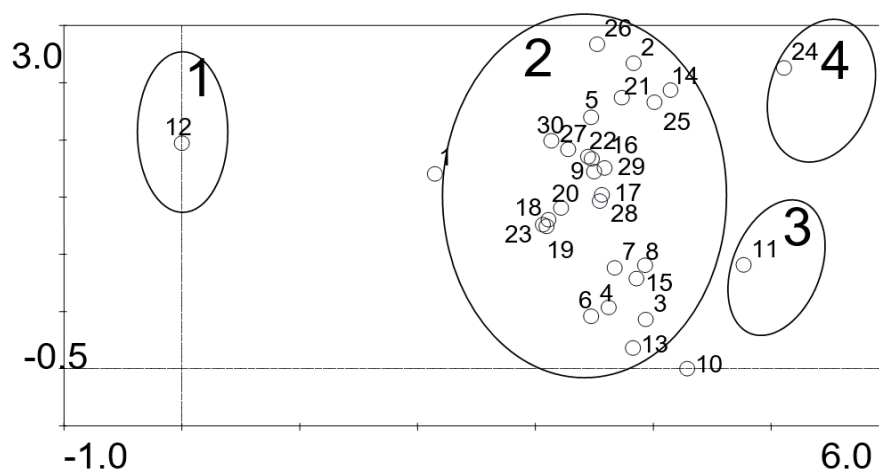


Figure 5 Detrended Correspondence Analysis (DCA) Ordination Diagram of 30 Plots, Arranged by DCA Axes 1 and 2. The x-axis is Axis 1 (Eigen value = 0.783), the y-axis is Axis 2 (Eigen value = 0.422). The Axes Are Scaled in S.D Units. The Circles and Bold Numbers Represent the Four Plant Communities.

Similar grouping of sample plots was observed as that of species since both were computed using species cover and abundance in the sample plots. The total inertia of the ordination was 4.11547. The first axis had an Eigen value of 0.783, which represents the long gradient (5.109 S. D unit) explained 19% of the total variation (total inertia) in the dataset. This gradient separated communities 3 and 4 from the others which are 1 and 2. The second axis had an Eigen value of 0.422 and 2.837 S. D units, which explained 10.3% of the remaining variation. This gradient has separated community 3 from community 4 which were not clearly separated by axis 1. The third and fourth DCA axes are not presented here as they have low Eigen values.

4.2. CANONICAL CORRESPONDENCE ANALYSIS

Canonical Correspondence Analysis (CCA) ordination was done (Figure 6) by running a computer program Canoco Version 4.55 (ter Braak and Smilauer, 2002) for different environmental variables. CCA-biplot of plant community types and environmental variables shows the relationships of variation of the plant communities along the environmental gradients.

Figure 6

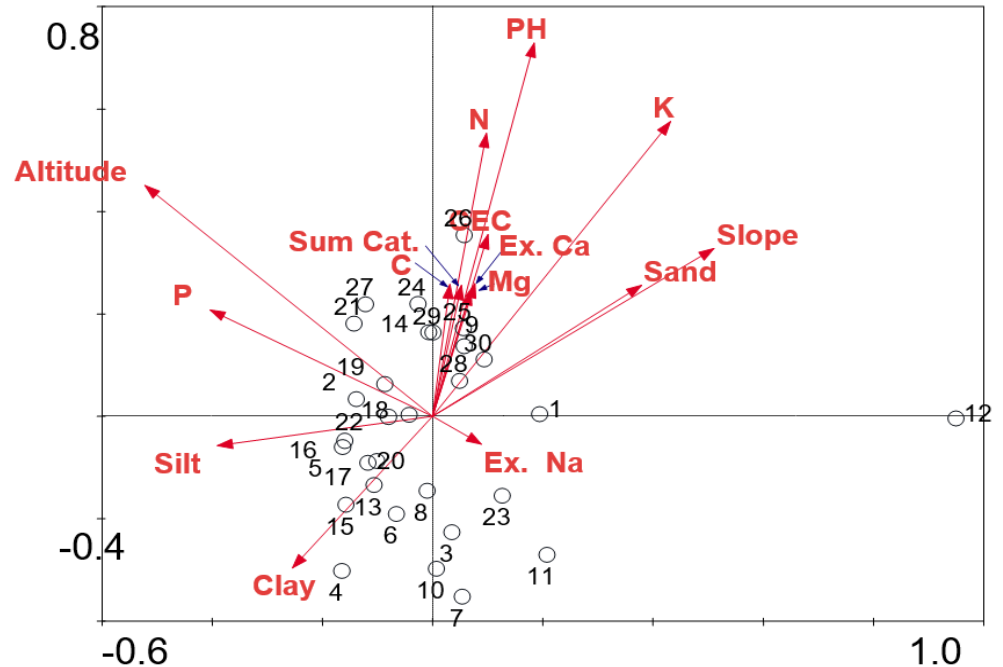


Figure 6 CCA Ordination Biplot Produced Using CANOCO, Axis 1 (horizontal) and Axis 2 (vertical). Arrows Represent Environmental Variables. Each Arrow Points Toward the Direction of the Steepest Increase in Environmental Gradients. The Angles Between Arrows Indicate Correlations Between Individual Environmental Variables. Relevé Numbers are Indicated. Overlapping Relevés were Slightly Moved. C = Carbon, N = Nitrogen, P = Phosphorus, K = Potassium, CEC = Cation Exchanging Capacity.

As the CCA-biplot of plant community types and environmental variables indicates it is possible to visualize the correlation between plots or plant communities and environmental variables. *Pittosporum viridiflorum*-*Syzygium guineense* subsp. *afromontanum* Community (Community 1) and *Piliostigma thonningii*-*Terminalia macroptera* Community (Community 3) are negatively correlated with altitude and amount of Phosphorus in the soil, while they are positively correlated with Slope and Sand. Whereas the other two plant communities: *Combretum collinum*-*Dombeya quinqueseta*-*Securidaca longepedunculata* Community (Community 4) and *Oxytenanthera abyssinica* - *Combretum molle* - *Syzygium guineense* subsp. *macrocarpum* Community (Community 2) are positively correlated with Altitude and amount of Phosphorus in the soil and negatively correlated with that of Slope and sand as opposed to Communities 1 and 3.

Species diversity, richness, and evenness

Shannon-Wiener diversity indices, species evenness and richness were computed for the four-plant community of Anbessa forest (Table 4).

Table 4**Table 4 Shannon–Wiener Diversity Index, species richness and evenness of plant communities in Anbessa forest**

Communities	Species richness	Diversity index (H')	Evenness (J)
I	4	1.88	0.90
II	30	0.16	0.04
III	10	2.70	0.90
IV	12	2.90	0.91

Where: I = *Pittosporum viridiflorum*-*Syzygium guineense* subsp. *afromontanum* community

II= *Oxytenanthera abyssinica* -*Combretum molle*-*Syzygium guineense* subsp. *macrocarpum* community

III= *Piliostigma thonningii*-*Terminalia macroptera* community

IV= *Combretum collinum*-*Dombeya quinqueseta*-*Securidaca longepedunculata* community

The Shannon-Wiener diversity index was computed for the four plant communities in Anbessa forest (Table 4) and showed that *Combretum collinum*-*Dombeya quinqueseta*-*Securidaca longepedunculata* community is the most diverse with H' 2.90, followed by *Piliostigma thonningii*-*Terminalia macroptera* and *Pittosporum viridiflorum*-*Syzygium guineense* subsp. *afromontanum* communities with H' 2.70 and 1.88, respectively, whereas *Oxytenanthera abyssinica*-*Combretum molle*-*Syzygium guineense* subsp. *macrocarpum* community is the least diverse community with H' 0.16. Regarding species richness, which is a measure of alpha diversity, *Oxytenanthera abyssinica* -*Combretum molle*-*Syzygium guineense* subsp. *macrocarpum* community is the most species rich with 30 species, whereas *Pittosporum viridiflorum*-*Syzygium guineense* subsp. *afromontanum* community is the least species rich with four species.

5. DISCUSSION

5.1. FLORISTIC COMPOSITION, DIVERSITY AND STRUCTURE OF ANBESSA FOREST

Floristic diversity

As the result in Table 4 shows, there is a high variation of species richness and evenness between the different plant communities in the Anbessa forest. Regarding species richness, which is a measure of Alpha diversity, community 2 (*Oxytenanthera abyssinica* -*Combretum molle*-*Syzygium guineense* subsp. *macrocarpum* community) is the most species rich community, but on the contrary, it is the least diverse with the lowest Shannon-Wiener diversity index of 0.16518 and also the least even community with the evenness value J = 0.040344. Evenness is a measure of equitability, and it attempts to quantify the unequal representation of species in a community against a hypothetical community in which all species are equally common. Therefore, Community 2 is more unevenly distributed species. This is mainly because of the high number of Bamboo stands (up to 12,000/ha) as compared to other species. Low diversity index also shows that, there is a high natural and human disturbance in this community such as unsustainable Bamboo extraction, fire, and others.

On the other hand, community IV (*Combretum collinum*-*Dombeya quinqueseta*-*Securidaca longepedunculata* community) is the most evenly distributed community with J= 0.913903 and with relatively high Shannon–Wiener Diversity Index (H')

value of 2.90. This community is relatively with fewer disturbances as compared to community 2 (*Oxytenanthera abyssinica* -*Combretum molle*-*Syzygium guineense* subsp. *macrocarpum* community).

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSIONS

The Anbessa forest represents different vegetation types of the country such as *Combretum-Terminalia* woodland and wooded grassland and Riverine vegetations. Also, they harbor a number of endemic plant species. The high number of new plant species recorded for Wellega floristic region shows that, this floristic region was not adequately explored.

Several tree species such as *Albizia gummifera*, *Entada africana*, *Erythrina abyssinica*, *Faurea speciosa*, *Lannea welwitschii*, *Oncoba spinosa*, *Pittosporum viridiflorum*, *Syzygium guineense* subsp. *Afromontanum*, *Syzygium guineense* subsp. *Macrocarpum* and *Vitex doniana* are at higher risk, since they have no seedings and saplings recorded.

In addition to the invaluable ecosystem services such as flood damage control, water purification, source of foods and feeds, supply of goods and services and others, which they are being providing, the forest can play a significant role in the mitigation of climate change as a carbon sink, since it can store huge amount of carbon. Therefore, proper management of the forest and enabling the forest to continue such ecosystem services is very important.

6.2. RECOMMENDATIONS

- The present study focused on plant diversity, while many aspects of the Anbessa forest are still untouched and needs further study.
- Since Anbessa forest harbors nine endemic plant species of Ethiopia, it is important to give conservation priority particularly for these endemic species. The forest can be used as *in-situ* conservation site for these endemic species.
- The plant community "*Pittosporum viridiflorum*-*Syzygium guineense* subsp. *Afromontanum*" which represents the riverine vegetation also needs special conservation attention, since it is present in a small area near the "Selga" river.
- In Anbessa forest it is important to have a well-planned and well managed extraction of the Bamboo resource which does not affect the regeneration capacity of the species.

CONFLICT OF INTERESTS

None.

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APPENDIX

Appendix 1

Appendix 1 List of Plant Species Recorded from Anbessa Forest, with their Family, Local Name, and Growth Habit					
S. No.	Scientific Name	Family	Habit	Local Name	Language
1	<i>Acacia polyacantha</i> subsp. <i>campylacantha</i> (Hochst. ex A. Rich.) Brenan	Fabaceae	Tree	Qudu	Berta
2	<i>Acacia robusta</i> subsp. <i>usambarensis</i> (Taub.) Brenan	Fabaceae	Tree	Ashifudi/ Shibil	Berta
3	<i>Acanthus polystachius</i> Delile	Acanthaceae	Shrub	Yeqedo	Berta
4	<i>Aframomum albobolaceum</i> (Ridl.) K. Schum.	Zingiberaceae	Herb	Penpe Amesimu	Berta
5	<i>Ageratum conyzoides</i> subsp. <i>latifolium</i> (Cav.) M.F. Johnson	Asteraceae	Herb	Shekot	Berta
6	<i>Albizia malacophylla</i> (A. Rich.) Walp. var. <i>malacophylla</i>	Fabaceae	Tree	Kender /Gender	Berta
7	<i>Ampelocissus schimperiana</i> (Hochst. ex A. Rich.) Planch.	Vitaceae	Climber	Mangug	Berta
8	<i>Andropogon gayanus</i> Kunth.	Poaceae	Grass	Gnerbiru	Berta
9	<i>Annona senegalensis</i> Pers.	Annonaceae	Tree	Adegella	Berta

10	<i>Asparagus scaberulus</i> A. Rich.	Asparagaceae	Climber	Moro	Berta
11	<i>Asplenium aethiopicum</i> (Burm.f.) Bech.	Aspleniaceae	Herb		
12	<i>Becium obovatum</i> E. Meyer. ex Benth. in E. Mey.	Lamiaceae	Herb		
13	<i>Berkheya chiesiana</i> Chiov.	Asteraceae	Herb	Duduro	Berta
14	<i>Bidens prestinaria</i> (Sch. Bip.) Cufod.	Asteraceae	Herb	Atsekatsia hudu	Berta
15	<i>Brachiaria lachnantha</i> (Hochst.) Stapf	Poaceae	Grass	Ashinshilo	Berta
16	<i>Breonadia salicina</i> (Vahl.) Hepper & Wood	Rubiaceae	Tree	Digil	Berta
17	<i>Bridelia micrantha</i> (Hochst.) Baill.	Euphorbiaceae	Shrub	Tentse / Tsende	Berta
18	<i>Cayratia gracilis</i> (Guill. & Perr.) Suesseng.	Vitaceae	Herbaceous climber		
19	<i>Citrullus colocynthis</i> (L.) Schrad.	Cucurbitaceae	Climber	Embabayaquriyo	Berta
20	<i>Clematis hirsuta</i> Perr. & Guill.	Ranunculaceae	Climber	Ashiro Balu	Berta
21	<i>Clerodendrum alatum</i> Gürke	Lamiaceae	Herb	Dudu Shigniru	Berta
22	<i>Clerodendrum cephalanthum</i> Oliv.	Verbenaceae	Shrub	Hallale	Berta
23	<i>Clerodendrum umbellatum</i> Poir.	Lamiaceae	Herb		
24	<i>Coccinia grandis</i> (L.) Voigt	Cucurbitaceae	Climber	Fesh	Berta
25	<i>Combretum collinum</i> Fresen. (1837) subsp. elgonense (Engl.) Okafor	Combretaceae	Tree	Sistsia Begneni	Berta
26	<i>Combretum molle</i> R. Br. ex G. Don	Combretaceae	Tree	Kushmindari	Berta
27	<i>Crinipes abyssinicus</i> (Hochst. ex A. Rich.) Hochst.	Poaceae	Grass	Gnere Bello	Berta
28	<i>Crinipes longifolius</i> C.E. Hubb.	Poaceae	Grass	Fitti	Berta
29	<i>Crotalaria</i> sp.	Fabaceae	Herb		Berta
30	<i>Cyphostemma adenocaulis</i> (Steud. ex A. Rich.) Desc. ex Wild & Drummond	Vitaceae	Climber	Enqulenchi	Berta
31	<i>Cyphostemma cyphopetalum</i> (Fresen.) Desc. ex Wild & Drummond	Vitaceae	Climber	Wishibi	Berta
32	<i>Dicoma sessiliflora</i> Harv.	Asteraceae	Herb		
33	<i>Dioscorea abyssinica</i> Hochst. ex Kunth	Dioscoreaceae	Climber	Qyesa	Berta
34	<i>Dioscorea schimperiana</i> Kunth	Dioscoreaceae	Climber	Awade	Berta
35	<i>Diplolophium africanum</i> Turcz.	Apiaceae	Herb	Feleqet	Berta
36	<i>Dolichos kilimandscharicus</i> Taub.	Fabaceae	Herb	Qembu	Berta
37	<i>Dolichos sericeus</i> E. Mey.	Fabaceae	Climber	Amermoto	Berta
38	<i>Dombeya aethiopica</i> Gilli.	Sterculiaceae	Tree	Fodok	Berta
39	<i>Dombeya quinqueseta</i> (Del.) Exell	Sterculiaceae	Tree	Fodok	Berta
40	<i>Dorstenia benguellensis</i> Welw.	Moraceae	Herb	Ashehu	Berta
41	<i>Echinops amplexicaulis</i> Oliv.	Asteraceae	Shrub	Asholgeri	Berta
42	<i>Ensete ventricosum</i> (Welw.) Cheesman	Musaceae	Perennial herb		
43	<i>Entada africana</i> Guill. & Perr.	Fabaceae	Tree	Dirtsign / Tsaba Regno	Berta
44	<i>Erythrina abyssinica</i> Lam. ex DC.	Fabaceae	Tree	Amblish	Berta
45	<i>Faurea speciosa</i> Welw.	Protiaceae	Tree	Atete	Berta

46	<i>Ficus ingens</i> (Miq.) Miq.	Moraceae	Tree	Babekel	Berta
47	<i>Ficus platyphylla</i> Del.	Moraceae	Tree	Dwe	Berta
48	<i>Ficus</i> sp.	Moraceae	Tree	Gansha / Gnansha	Berta
49	<i>Gardenia ternifolia</i> Schumach. & Thonn.	Rubiaceae	Tree	Aqenda	Berta
50	<i>Gladiolus dalenii</i> subsp. Dalenii van Geel	Iridaceae	Herb	Adebergella	Berta
51	<i>Gladiolus</i> sp.	Iridaceae	Herb/Shrub	Adebergella	Berta
52	<i>Grewia mollis</i> A. Juss.	Tiliaceae	Shrub	Hormotse / Hornotse	Berta
53	<i>Guizotia scabra</i> (Vis.) Chiov.	Asteraceae	Herb	Duda Shiri	Berta
54	<i>Habenaria armatissima</i> Rchb. f.	Orchidaceae	Herb	Fefelu	Berta
55	<i>Hibiscus cannabinus</i> L.	Malvaceae	Herb	Shuri Mugu	Berta
56	<i>Hibiscus corymbosus</i> Hochst. ex A. Rich.	Malvaceae	Herb	Merub	Berta
57	<i>Hyparrhenia anthistiriodes</i> (Hochst. ex A. Rich.) Stapf	Poaceae	Grass	Abendu	Berta
58	<i>Hyparrhenia anthistiriodes</i> (Hochst. ex A. Rich.) Stapf	Poaceae	Grass	Bundur	Berta
59	<i>Hypoestes forskoolii</i> (Vahl) R. Br.	Acanthaceae	Herb	Signdimitssera	Berta
60	<i>Hypoxis villosa</i> complex	Hypoxidaceae	Herb		
61	<i>Indigofera arrecta</i> Hochst. ex A. Rich.	Fabaceae	Herb	Hinealalbelal	Berta
62	<i>Lactuca inermis</i> Forssk.	Asteraceae	Herb	Etseya Meir	Berta
63	<i>Laggera crispata</i> (Vahl) Hepper & Wood	Asteraceae	Herb	Aro	Berta
64	<i>Lannea fruticosa</i> (A. Rich.) Engl.	Anacardiaceae	Tree	Etsiya Urubo	Berta
65	<i>Lannea welwitschii</i> (Hiern) Engl.	Anacardiaceae	Tree	Qua	Berta
66	<i>Lepistemon owariense</i> (Beauv.) Hall. f.	Convolvulaceae	Climber	Adebera	Berta
67	<i>Lippia adoensis</i> Hochst. ex Walp. var. adoensis	Verbenaceae	Shrub	Shinhorihudi	Berta
68	<i>Lonchocarpus laxiflorus</i> Guill. & Perr.	Fabaceae	Tree	Ahutse	Berta
69	<i>Maytenus undata</i> (Thunb.) Blakelock	Celastraceae	Tree	Telemiyo	Berta
70	<i>Moraea schimperi</i> (Hochst.) Pic. Serm.	Iridaceae	Herb	Dungefru	Berta
71	<i>Mucuna melanocarpa</i> Hochst. ex A. Rich	Fabaceae	Climber	Aguba	Berta
72	<i>Mucuna stans</i> Welw. ex Bak.	Fabaceae	Shrub	Dudu Melates	Berta
73	<i>Murdannia simplex</i> (Vahl) Brenan	Commelinaceae	Herb		Berta
74	<i>Ochrocephala imatongensis</i> (Philipson) Dittrich	Asteraceae	Shrub	Telenbey Fidi	Berta
75	<i>Ocimum lamiifolium</i> Hochst. ex Benth.	Lamiaceae	Herb	Beshikiri	Berta
76	<i>Ocimum spicatum</i> Deflers	Lamiaceae	Shrub		
77	<i>Oncoba spinosa</i> Forssk.	Flacourtiaceae	Tree	Abubuqu/ Akuku	Berta
78	<i>Oxalis obliquifolia</i> A. Rich.	Oxalidaceae	Herb		Berta
79	<i>Oxytenanthera abyssinica</i> (A. Rich.) Munro	Poaceae	Tree	Kagu	Berta
80	<i>Ozoroa insignis</i> Del.	Anacardiaceae	Shrub	Ahulo	Berta
81	<i>Pennisetum trachyphyllum</i> Pilg.	Poaceae	Grass	Gnagnaël Mushel	Berta
82	<i>Phoenix reclinata</i> Jacq.	Arecaceae	Palm tree		

83	<i>Piliostigma thonningii</i> (Schumach.) Milne-Redh.	Fabaceae	Tree	Megel	Berta
84	<i>Pittosporum viridiflorum</i> Sims	Pittosporaceae	Tree		
85	<i>Plectranthus barbatus</i> Andrews	Lamiaceae	Herb	Etsenebishu	Berta
86	<i>Protea gaguedi</i> J. F. Gmel.	Protiaceae	Tree	Chedeber	Berta
87	<i>Pseudarthria hookeri</i> Wight & Arn.	Fabaceae	Shrub	Dudu Lesedi	Berta
88	<i>Pterocarpus lucens</i> Guill. & Perr.	Fabaceae	Tree	Miroro	Berta
89	<i>Reichardia tingitana</i> (L.) Roth	Asteraceae	Herb		
90	<i>Rhus glutinosa</i> A.Rich.	Anacardiaceae	Tree	Silkela	Berta
91	<i>Rumex abyssinicus</i> Jacq.	Polygonaceae	Herb	Mankuku	Berta
92	<i>Scleria bulbifera</i> Hochst. ex A. Rich.	Cyperaceae	Sedge	Qenqesh	Berta
93	<i>Securidaca longepedunculata</i> Fresen.	Polygalaceae	Tree	Sheqet	Berta
94	<i>Sesamum orientale</i> L.	Pedaliaceae	Herb	Heshe Fudi	Berta
95	<i>Sida rhombifolia</i> L.	Malvaceae	Shrub	Meshene	Berta
96	<i>Snowdenia polystachya</i> (Fresen.) Pilg.	Poaceae	Grass	Afamere	Berta
97	<i>Solanecio tuberosus</i> (Sch. Bip. ex. A. Rich.) C. Jeffrey	Asteraceae	Herb	Alaberi	Berta
98	<i>Solanum dasyphyllum</i> Schumach.	Solanaceae	Herb	Atunturus	Berta
99	<i>Sopubia ramosa</i> (Hochst.) Hochst.	Scrophulariaceae	Herb		
100	<i>Sporobolus pyramidalis</i> P. Beauv.	Poaceae	Grass	Awishu	Berta
101	<i>Steganotaenia araliacea</i> Hochst. ex A. Rich.	Apiaceae	Tree	Ashinshilo	Berta
102	<i>Stereospermum kunthianum</i> Cham.	Bignoniaceae	Tree	Agulqa / Aqolqa	Berta
103	<i>Syzygium guineense</i> subsp. <i>afromontanum</i> F. White	Myrtaceae	Tree	Bulmetse	Berta
104	<i>Syzygium guineense</i> subsp. <i>macrocarpum</i> (Engl.) F. White	Myrtaceae	Tree	Anzu	Berta
105	<i>Tacca leontopetaloides</i> (L.) O. Ktze.	Taccaceae	Herb		
106	<i>Tamarindus indica</i> L.	Fabaceae	Tree	Mela	Berta
107	<i>Terminalia laxiflora</i> Engl. & Diels	Combretaceae	Tree	Hori	Berta
108	<i>Terminalia macroptera</i> Guill. & Perr.	Combretaceae	Tree	Kebugir	Berta
109	<i>Tragia abortiva</i> M. Gilbert	Euphorbiaceae	Shrub	Menegne Buqeshingi	Berta
110	<i>Tragia doryodes</i> M. Gilbert	Euphorbiaceae	Climber	Aponpolo	Berta
111	<i>Vernonia galamensis</i> (Cass.) Less.	Asteraceae	Shrub	Hesran	Berta
112	<i>Vernonia perrottetii</i> Sch. Bip. ex Walp.	Asteraceae	Herb	Alkamun Dudu	Berta
113	<i>Vernonia purpurea</i> Sch. Bip. ex Walp.	Asteraceae	Herb		
114	<i>Vigna membranacea</i> A. Rich.	Fabaceae	Herb	Dheberimugu	Berta
115	<i>Vitex doniana</i> Sweet	Lamiaceae	Tree	Atsota / Chedo	Berta
116	<i>Ximenia americana</i> L.	Olacaceae	Tree	Babe	Berta
117	<i>Zehneria scabra</i> (Linn. f.) Sond.	Cucurbitaceae	Herb		
118	<i>Ziziphus abyssinica</i> Hochst. ex A. Rich.	Rhamnaceae	Tree	Merqeqo	Berta

Appendix 2**Appendix 2 Plant Families, Number of Genera, Species and their Percentage Recorded from Anbessa Forest**

S. No	Families	Number of General	Number of species	%
1	Fabaceae	14	17	14.41
2	Asteraceae	12	14	11.86
3	Poaceae	8	10	8.47
4	Lamiaceae	5	7	5.93
5	Anacardiaceae	3	4	3.39
6	Combretaceae	2	4	3.39
7	Moraceae	2	4	3.39
8	Vitaceae	3	4	3.39
9	Cucurbitaceae	3	3	2.54
10	Euphorbiaceae	2	3	2.54
11	Iridaceae	2	3	2.54
12	Malvaceae	2	3	2.54
13	Acanthaceae	2	2	1.69
14	Apiaceae	2	2	1.69
15	Dioscoreaceae	1	2	1.69
16	Myrtaceae	1	2	1.69
17	Protiaceae	2	2	1.69
18	Rubiaceae	2	2	1.69
19	Sterculiaceae	1	2	1.69
20	Verbenaceae	2	2	1.69
21	Annonaceae	1	1	0.85
22	Arecaceae	1	1	0.85
23	Asparagaceae	1	1	0.85
24	Aspleniaceae	1	1	0.85
25	Bignoniaceae	1	1	0.85
26	Celastraceae	1	1	0.85
27	Commelinaceae	1	1	0.85
28	Convolvulaceae	1	1	0.85
29	Cyperaceae	1	1	0.85
30	Flacourtiaceae	1	1	0.85
31	Hypoxidaceae	1	1	0.85
32	Musaceae	1	1	0.85
33	Olacaceae	1	1	0.85
34	Orchidaceae	1	1	0.85
35	Oxalidaceae	1	1	0.85
36	Pedaliaceae	1	1	0.85

37	Pittosporaceae	1	1	0.85
38	Polygalaceae	1	1	0.85
39	Polygonaceae	1	1	0.85
40	Ranunculaceae	1	1	0.85
41	Rhamnaceae	1	1	0.85
42	Scrophulariaceae	1	1	0.85
43	Solanaceae	1	1	0.85
44	Taccaceae	1	1	0.85
45	Tiliaceae	1	1	0.85
46	Zingiberaceae	1	1	0.85
Total		97	118	100

Appendix 3

Appendix 3 Species list for the codes used in the DCA analysis for Anbessa forest

S. No	Code	Species name	Family
1	<i>Albi gumm</i>	<i>Albizia gummifera</i>	Fabaceae
2	<i>Albi mala</i>	<i>Albizia malacophylla</i>	Fabaceae
3	<i>Anno sene</i>	<i>Annona senegalensis</i>	Annonaceae
4	<i>Brid micr</i>	<i>Bridelia micrantha</i>	Euphorbiaceae
5	<i>Comb coel</i>	<i>Combretum collinum</i> subsp. <i>elgonense</i>	Combretaceae
6	<i>Comb coll</i>	<i>Combretum collinum</i>	Combretaceae
7	<i>Comb moll</i>	<i>Combretum molle</i>	Combretaceae
8	<i>Domb quin</i>	<i>Dombeya quinqueseta</i>	Sterculiaceae
9	<i>Enta afri</i>	<i>Entada Africana</i>	Fabaceae
10	<i>Eryt abys</i>	<i>Erythrina abyssinica</i>	Fabaceae
11	<i>Faur spec</i>	<i>Faurea speciosa</i>	Protiaceae
12	<i>Gard tern</i>	<i>Gardenia ternifolia</i>	Rubiaceae
13	<i>Grew moll</i>	<i>Grewia mollis</i>	Tiliaceae
14	<i>Lann welw</i>	<i>Lannea welwitschii</i>	Anacardiaceae
15	<i>Lonc laxi</i>	<i>Lonchocarpus laxiflorus</i>	Fabaceae
16	<i>Mayt unda</i>	<i>Maytenus undata</i>	Celastraceae
17	<i>Onco spin</i>	<i>Oncoba spinosa</i>	Flacourtiaceae
18	<i>Oxyt abys</i>	<i>Oxytenanthera abyssinica</i>	Poaceae
19	<i>Ozor insi</i>	<i>Ozoroa insignis</i>	Anacardiaceae
20	<i>Pili thon</i>	<i>Piliostigma thonningii</i>	Fabaceae
21	<i>Pitt viri</i>	<i>Pittosporum viridiflorum</i>	Pittosporaceae
22	<i>Pter luce</i>	<i>Pterocarpus lucens</i>	Fabaceae
23	<i>Secu long</i>	<i>Securidaca longepedunculata</i>	Polygalaceae
24	<i>Steg aral</i>	<i>Steganotaenia araliacea</i>	Apiaceae
25	<i>Ster kunt</i>	<i>Stereospermum kunthianum</i>	Bignoniaceae
26	<i>Syzy guaf</i>	<i>Syzygium guineense</i> subsp. <i>afromontanum</i>	Myrtaceae
27	<i>Syzy guin</i>	<i>Syzygium guineense</i> subsp. <i>macrocarpum</i>	Myrtaceae
28	<i>Term laxi</i>	<i>Terminalia laxiflora</i>	Combretaceae
29	<i>Term macr</i>	<i>Terminalia macroptera</i>	Combretaceae
30	<i>Vite doni</i>	<i>Vitex doniana</i>	Lamiaceae