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Structure and Regeneration of Gendo Moist Montane Forest, East Wellega Zone, Western Ethiopia

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Abstract

Gendo Forest vegetation is one of the moist montane forests found in East Wellega Zone, Ethiopia, containing diverse animals and plant species. The objectives of the present study is to investigate forest structures along regeneration status and finally recommending sound conservation strategies based on conservation priorities. Seventy two plots of 20 m x 20 m (400 m^2) were laid along eight transect lines and along altitudinal gradient following systematic sampling. About 100 plants species were recorded; out of which 38 were selected for structural analysis of forest structural studies that included DBH, height, classes, and regeneration status of Gendo forest. Structures were compared with some other similar forests found in Ethiopia. Four population distribution structures and four conservation priorities were described from DBH class analysis. Moreover, since the forest is yet not recognized as forest priority areas in the country, the forest is recommended to be included in forest priority areas for further conservation and management practices that leverage the problems of sustainable forest management issues.

Key Words: Gendo Forest, moist montane forest, regeneration, structure

INTRODUCTION

Ethiopia is one of the land locked African country located between 3-15^{0}N latitude and 33- 48^0 easts, longitude. The country stretches between 126 m below sea level in Danakil depression in Afar - 4620 m asl in Ras Dejen mountain (MoA, 1986). The country has heterogenous topography, terrain characters and climate all which accounts for hosting heterogenous diversity of plants and animals. As a result, Ethiopia is one of the countries in the world with high level of biodiversity. Owing to the long history Ethiopia is again one of the 12 Vavilov centers of crop genetic diversity of agriculture and the diversity of the environment and hence possessing about 10% of endemic vascular plants (Ensermu and Sebsebe, Personnel Com.; PGRC, 1996; Vivero *et al.* (2005). Types and distribution of vegetations in Ethiopia are determined by geology, topography (altitude, slope and aspect), edaphic (soil) and climatic factors, specifically the seasonal distribution of rainfall than the amount of rainfall (Vernede, 1955). Endemic species are usually common in lowlands, afroalpine and subafroalpine vegetation types. However afromontane forests and Ogaden areas also contributed a lot (Ensermu *et al.*, 1992; EPA, 2003). Ethiopia therefore has remained as one of the 12th Vavilovian center of many crops genetic diversity in the world (Vavilov, 1997).

Dansereau and Lems (1957) defined vegetation structure as" the organization in space of the individuals that form a stand and by extension a vegetation type or plant association". They stated that the "primary element of vegetation structure is: growth forms, stratification and coverage". There are three components of vegetation structures namely: Vertical, horizontal and quantitative structure which includes cover (Fosberg, 1967; Mueller-Dombois and Ellenberg, 1994). At some stages in the last thousands of years, all ecosystems were undisturbed by humans, they were pristine or virgin. However, many of anthropogenic and natural factors may alter this natural vegetation structures and compositions along landscape.

Deforestation has taken place and will be taking place in the proportions that were many and varied than the past, thus the remaining forests have also been continuously threatened (Kidane, 2002). Among these, over harvesting, over grazing, habitat loss, fragmentation, introduction of exotic species, inappropriate investment practices, deliberate fire, misguided state policy, shifting agriculture are all anthropogenic causes of deforestation (Nurhussien, 1994; Daba, 2001; Dash, 2003; Mathias, 2004; Mesfin, 2004; Matheos and Yoseph, 2004; Teshome and Ensermu, 2013a & 2013b; Teshome and Ensermu, 2014; Teshome, 2015). Thus many peoples living in natural environment especially in Africa, wild plants are indispensible to their daily existence (Lykke, 2000). In the processes of interaction with natural ecosystem for his own agriculture, man has modified the natural ecosystem. The reduction of forests vegetation to a few scattered patches, the decline of animals and difficulty of germinations were followed by massive soil erosion and nutrient depletion, resulting in widespread of deficiency diseases of crop plants, animals and reduction of agricultural productivity (Legesse, 1995; Demel, 2004).

Climatically, wet montane forests are vegetation types have large and soft leaved species delimited as having a period of at least six months of rainfall in one period with at least 1700 mm precipitation. While dry montane forests dominated by hard-leaved evergreen species are either a mixture of *Juniperus procera* or predominantly *Podocarpus falcatus*, both with some elements of broad leaved species (IBD and GTZ, 2004). They possess drought period of half the year in one or two periods with precipitation between 400- 1700 mm. Vegetation classification provides: better communications among professionals, greater understanding of plant-environment interactions and serving as a useful aid in land and resource management (Desta, 2001). By affecting temperature, radiation, moisture and atmospheric pressure influence the growth, distribution and development of vegetation (Toumey, 1944; cited in Lisanework, 1987). Slope angle influences soil depth; acidity and drainage. Steeper slopes usually have thinner soil, less water logged and less acidic than gentle slopes. Aspect, the orientation of slope also alters sun light and temperature, where south facing slopes in northern hemisphere being more favorable to plant growth than those facing north (Moriel *et al.,* 2006).

Five of agro-climatic regions called: *bereha* (very hot), *qola* (hot), *weyina dega* (moderate temperature), *dega* (cool), and *wurch* (very cool) (Zerihun, 1985; MoA, 1986) hosts eight catagories based on climatic, topographic and geologic factors. These are: 1) Afro-alpine and sub Afro-alpine, 2) Dry evergreen Afromontane 3) Moist evergreen Afromontane, 4) Broad leaved deciduous woodland (*Combretum-Terminialia*), 5) Low land semi- evergreen forests (dry peripheral semi-deciduous Gunio Congolian), 6) Riverine, riparine and swamp, 7) *Acacia Commiphora* woodland and 8) Desert and semi-desert Scrub land forests (Friis, 1992; Sebsebe *et al.,* 2004). Moist evergreen forests which are the focus of this study are traditionally referred to as Afromontane rainforests, humid broad leaved, wet and mixed type of vegetations in which *Pouteria adolfi-friederici* and *Podocarpus falcatus* (about 30-46 m tall) are forming closed upper canopy. Based on evidence from the altitudinal range, which was between 1500-2600 m a.s.l., annual temperature which was 18^0C- 25^0C, annual rainfall, which was 1,500-2,000 mm and the vegetation compositions described (Friis, 1992; Sebsebe *et al.,* 2004). Moist montane forests get rain all round the year and consist of important tree species: *Pouteria* *adolfi-friederici, Podocarpus falcatus*, *Albizia schimperiana, Cordia africana* and *Ficus sur*. Afromontane forests are one of the seven endemic sites of Tropical Africa including Ethiopia (Huntley, 1988; cited in Mulugeta and Demel, 2004).

Different plants experienced different regeneration strategies such as formation of vegetative propagules (bulbils, tubers, and gemmae), seed production, vegetative expansion (by layering) and seasonal regeneration in a vegetative gap. The regeneration status of moist montatne forests of the southwest Ethiopia is generally lower than that of dry afromontane forests (Poorter *et al.,* 1996; Taye *et al.,* 2002). Micro-habitats of the upper slope profoundly affect the recruitment, establishment and growth of the appearing vascular plants by determining soil moisture contents (Moriel *et al.,* 2006). When the forest‘s resource base has been declined; the vitality of regeneration has been reduced (EFAP, 1994). For a successful regeneration a sufficient volume of variable seeds, appropriate climatic and edaphic conditions for germination and establishment are indispensible (Taye, *et al.,* 2002). A tree species with no seedling and sapling in a forest is under risky condition and it is suggested that these species are under threat of local extinction (Taye *et al.,* 2002). Over all vegetative regeneration of forest gaps can be affected by size of gap, shape of gap, soil type, topography, soil seed bank, orientation of the gap to the sun, height and species composition of the surrounding vegetation, extent of damage to vegetation upon formation of the gap, temperature aspect of the gap, spatial disturbances (Struhsaker, 1997; Gemedo and Masresha, 2004; Demel, 2005). The present study is there for aimed to produce floristic list for previous unstudied Gendo Forest, to investigate: population structures and regeneration status of Gendo Forest.

MATERIALS AND METHODS

Study Site

The study was conducted in Oromia National Regional State, East Wellega Zone, and Gida Ayana District in Gendo (Gura Tirigni) moist montane forest (Figure1) located at 422 km west of Addis Ababa. It is situated at $9^{0}49.5'$ - $9^{0}59.6'$ N and $36^{0}40.'$ - $36^{0}43'$ E, having a total area of 16 hectares (including 4-6 ha community plantation on east and south edges). The forest is located along Nekemte – Bure road between altitudinal ranges of 2183 and 2300 m a.s.l (Ethiopian Mapping Agency, 1986; Encarta Premium, 2006; GPS reading during field survey, 2008).

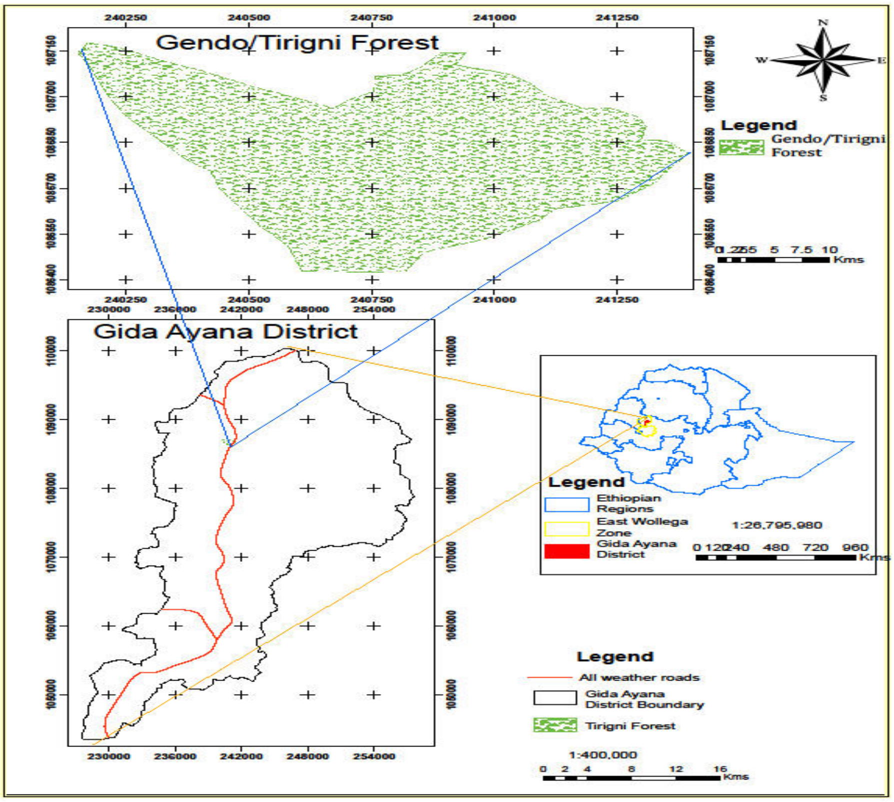


Figure 1: Map of Gendo Forest

Even though no specific study on the geology and soil character of the study area was conducted, the topography, geology and soil of the study area fits with that of *weyina dega* agroclmatic zones described by MoA (1986) and Mesfin (1998). According to basic data of Gida Ayana Agriculture and Rural Development Office, about 12,265.27 ha of land is plain (flat), 101,325.77 ha is hill slope, 6,319.5 ha is gentle gorge, 7,322.55 ha is swamps and 1,830.64 ha is other land forms (GAARDO, 2009). The study forest is characterized by gentle slope from south to north sides of hill foot with flat upper surface (Personal observation). The soil of the study area is pale brown to dark reddish and red in color, clay and clay-loam in texture.(Murphy, 1959). There are two types of agroclimatic zones in the *Wereda*: Kola about 51% and *Weyina Dega* 49% of the total land area (GAARDO, 2009). Annual rainfall of the study site is between 1487 – 2119 mm while the average annual rainfall is 152.6 mm. Monthly maximum and minimum temperature recorded was 27.5^{0}C (in February) and 12.8^{0}C (in December), while the average annual temperature is about 18.9^{0}C respectively (Ethiopia National Meteorological Service Agency, 2006). The climate diagram of the study area is provided in Figure 2.

GidaAyana (2180) [10]   18.7 ^{0}C   152.6

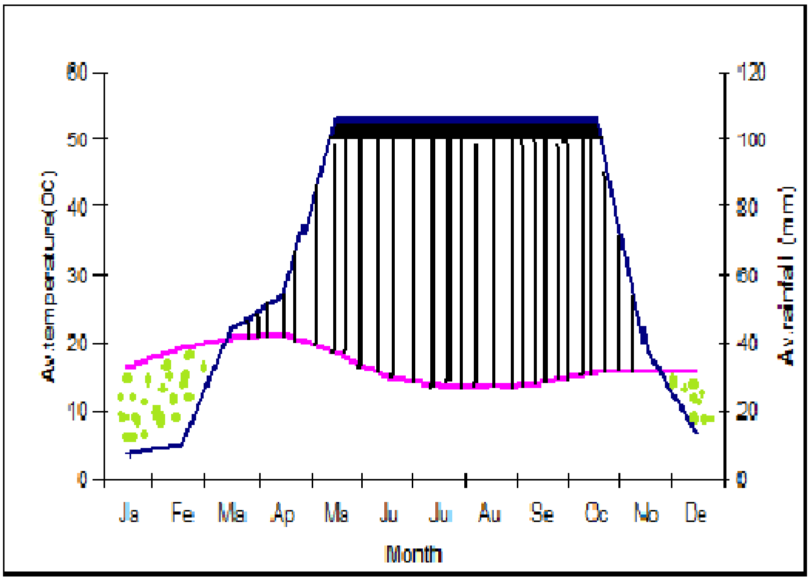


Figure 2: Climatic Diagram of Gidda Ayana (the nearst meteorological station to Gendo Forest)

Regarding to the people and the economy of the study site, the total human population size of Gida Ayana District (1996) was 101, 766, of this, 50,805 were males and 50,961 were females (CSA, 1996). The total area of land in the *Wereda* is about 183,063.73 ha which was used for: various activities by local community. The major proportion (36%) of the total land is used for agriculture, 26% for forest and 17% for pasture. The economy of the people is based on income generated from mixed farming systems, crop production and livestock rearing. When evaluated by its altitudinal range (2183 -2300 m a.s.l), rainfall distribution pattern and amount (1487 - 2119 mm), Gendo forest is typically moist montane forests.

Data Collection

Reconnaissance survey and data collection of the study forest was conducted between November 18 – 20 /2008 and November 21 – December 14 / 2008 respectively. Seventy two quadrats, each 20 m x 20 m, 400 m^2 were used for trees, shrubs and seedlings, saplings while small subplots of 2 m x 2 m (4 m^2) nested plots at representative sites for herbaceous plants (Mueller-Dombois and Ellenberg, 1974). On hillsides with large sample sizes, continuous belt transect can be used preferentially than others sampling method (Kellman, 1980). Eight transect lines 100 m far apart from each other were laid systematically following uphill to ensure a uniform assessment through out all the plots. Depending on the length of transect line belts (350 m, the shortest to 2,160 m the longest), the number of quadrats laid on each transect belt may vary from 3-18. Vernacular names of all species, DBH, height and of trees at breast height, cover value estimates, are measured(estimated) and recorded in order to describe vegetation structure of the study forest (Mueller-Dombis and Ellenberg, 1974; Westhoff and van der Maarel, 1979; Crawley, 1997).

Trees, shrubs, herbs seedlings and saplings are defined conventionally in this study in the manner described by: Mueller-Dombois and Ellenberg (1974); Westhoff and van der Maarel (1978) as follows: Tree - single stemmed woody plant taller than 5m, Shrub - multiple stemmed woody plant with height between 30 – (50) cm - 5 m, herb non woody plant less than 30 cm to 1 m, seedling a young woody species less than 1.3 m while sapling extends from 1.3 m on wards but whose DBH is less than 2.5 cm. The cover values of the study forest for all species was first estimated visually, then recorded and later converted into the Braun-Blanquet 1-9 modified scale (van der Maarel, 1979) as follows: 1 = one or few individuals, 2 = occasional and less than 5% cover, 3 =abundant and with very low cover or less abundant but with higher cover, in any case less than 5% cover, 4 = very abundant and less than 5% cover, 5 = cover values between 5 - 12.5% irrespective of number of individuals, 6 = cover values between 12.5 - 25%, 7 =cover values between 25 - 50%, 8 = cover values between 50 - 75%, and 9 = cover values between 75 - 100% of the total plot area.

Trees with many branches below 1.3 m were measured separately. Hemi-parasites (partial plant parasites) and ferns on branch and trunk were also recorded whenever encountered. Any anthropogenic and natural disturbances like logging timber, natural tree fall were recorded when ever encountered. Physiographic variables such as altitude and location were recorded using Garmin navigation UTM – GPS system (Geographical Position System). Silva Clinometer was used to measure slope and tree height, while aspect is simply judged from reference of, the direction of sunset and sun rise in association with north-south orientation of the forest topography. Plant specimens were collected, pressed, dried and brought to the National Herbarium (ETH) of AAU for identification. In fact plant identification begun at the field, proceeded in villages (by asking local people for vernacular names) while the final identification of species, habits, endemicity and nomenclature were made following all volumes of the published Flora of Ethiopia and Eritrea in ETH of AAU as well as by referring to Honey bee Flora (Fichtl and Adimasu, 1994) and Useful trees and Shrubs of Ethiopia for some vernacular names (Azene, 2007) were used. Finally some of voucher specimens were mounted labeled and deposited (preserved) in ETH of AAU for documentation.

Data analysis

Vegetation data (height, DBH), BA, Density, species richness, IVI, Dominancy and community types were analyzed following some standard methods and conversion formulas used by ecologists. Accordingly, vertical structure of trees in Gendo Forest was described following the International Union for Forestry Research Organization (IUFRO) classification scheme (Lamprecht, 1989), where upper story includes trees with height greater than 2/3 of the tallest tree, middle storey between 1/3-2/3 of the tallest tree and lower canopy below 1/3 of the tallest tree. DBH is obtained by dividing the circumference of each tree recorded in the field by π or by its equivalent value (3.14) and converted to another important measurement called basal area (BA), which is the actual space covered by the tree stems. Basal area was calculated from the general formula i.e., $BA = \pi d^2/4$, where, BA= basal area, d = diameter at breast height, π = mathematical symbol (3.14) (Mueller-Dombois and Ellenberg, 1974; Kent and Coker, 1992). Population density is the total count of the number of all individual plants per species within the quadrat were determined and analyzed following Kent and Coker (1992). Frequency is the number of times species occurred in a given number of repeatedly placed quadrats. It gives a certain indication of uniformity in distribution rather than density (Mueller-Dombois and Ellenberg, 1974).

$$\% F \text{ is given by: } \frac{\text{numbers of occupied quadrats by species}}{\text{Total numbers of quadrats examined}} \times 100$$

$$\text{Relative frequency} = \frac{\text{frequency of species}}{\text{Total frequency of all spp}} \times 100$$

Dominance, the stem cover, usually synonymous with basal area, which was the most abundant species in the area (Botkin *et al.,* 1987). Dominance is the product of mean basal areas of trees with the total numbers of trees per species while relative dominancy (RDO) was given by the formula:

$$\text{RDO} \quad \frac{\text{Dominance of tree species}}{\text{Dominance of the whole species}} \times 100$$

RESULTS AND DISCUSSION

The height, DBH, dominance, IVI values, vegetation distribution patterns, regeneration status and analysis of the forest were presented separately.

Height class distribution

Eight height classes were conventionally established (Table 1). The forest height class was range between 3-5 m because heights below 1.30 m and above 1.3 m with DBH < 2.5 cm are defined for seedlings and saplings in previous portion. The tallest tree observed in the forest was *Pouteria adolfi-friederici* and *Podocarpus falcatus* (about 30-46 m tall). Only 21 individuals (5.1%) were recorded within the last two highest height classes, constituting 2/3 of the total storey in the forest, i.e., above 30.7 m tall). However, *Albizia schimperiana, Ficus sur, Croton macrostachyus, Dracaena steudneri, Syzygium guineense, Allophylus abyssinicus* and *Cassipourea malosana* about 265 (13.2%) individuals were constitute the middle storey (between 15.33-30.7 m tall which fall between 1/3-2/3) of the tallest tree belonging to height classes 4-6 in this forest and lastly *Bersama abyssinica, Erythrina brucei, Millettia ferruginea, Vepris dainellii, Teclea nobilis, Cordia africana,* etc. were about 1619 (84.98%) individuals were constituted the lower storey (below 15.33 m) i.e., less than 1/3 of the tallest tree. The total height of Gendo Forest is summarized into three layers (storey). According to the result indicated in Table 2, the numbers of individuals in each successive height class were decreasing beginning from the first lower height class to the highest height classes (see Table 1). The majority of individuals contributing to the first height class came from *Justicia schimperiana, Solanceio gigas, Albizia schimperiana,* and *Clausena anisata* respectively. Thus, the height distribution pattern of Gendo Forest was characterized by fewer individuals at mature stage than middle and young aged population, suggesting that the forest was dominated by low stature individuals, confirms with reversed (inverted) J shaped pattern showing stable size distribution which was common in natural forests (Poorter *et al*., 1996).

Table 1: Height classes (1) 3- 5 m, 2) 5.01-10 m, 3) 10.01-15 m, 4) 15.01-20 m, 5) 20.01-25 m, 6) 25.01-30 m, 7) 30.01-35 m, and 8) h > 35.01 m).

Height classes	Class intervals	Density	%
1	1.01-5 m	702	36.85
2	5.01-10 m	660	34.64
3	10.01-15 m	257	13.49
4	15.01-20 m	86	4.5
5	20.01-25 m	63	3.3
6	25.01-30 m	116	6.08
7	30.01-35 m	4	0.20
8	H >35 m	17	0.89

DBH distribution

A total of 1351 individuals whose height > 3 m and DBH >2.5 cm were recorded in Gendo forest for DBH analysis. Eight DBH classes were established where few individuals of *Podocarpus falcatus, Pouteria adolfi-friederici Albizia schimperiana*, *Albizia gummifera, Syzygium guineense* and *Croton macrostachyus* were encountered in the higher DBH classes. Some missed values at the middle classes for *Podocarpus falcatus, Syzygium guineense, Ficus sur and Pouteria adolfi-friederici* were indicating a sign of ecological disturbance in the forest. On the other hand the density of individuals in each DBH classes was abruptly decreased after the second DBH class on wards. High proportion of DBH density was contributed by *Croton macrostachyus, Teclea nobilis, Vepris dainellii*, and *Albizia schimperiana* at the lower DBH classes because of the fact that *Croton macrostachyus* and *Albizia* spp. are dominant species and distributed almost in most of the plots in the forest. More over *Croton macrostachus* is the most successional species being abundant and hence account for high proportion of DBH. *Albiziz schimperiana* and *Albizia gummifera* have multi-regeneration adaption and highest regeneration status, it accounts for such high proportion of DBH in the forest. Very few individuals of *Podocarpus falcatus* and *Pouteria adolfi-frederici* were constituted the last two higher DBH classes while *Ficus sur, Croton macrostachyus, Syzygium guineense, Albizia gummifera and Albizia schimperiana* were constitute the middle classes. The majority of the populations, 929 (68.8%), were found in the first lower DBH class, while the rest were found between DBH classes 2 - 6 respectively (Table 2). This was a normal DBH distribution pattern when viewed from the whole set of plant community, confirming reversed J shape but there would be variation with respect to individual species when it was analyzed and separated.

Table 2: DBH classes of Gendo Forest

DBH classes	Class intervals	Density	%
1	2.5—20	929	68.87
2	20.01-40	226	16.73
3	40.01-60	71	5.26
4	60.01-80	54	3.99
5	80.01-100	35	2.59
6	100.01-120	8	0.59
7	120.01-140	14	1.03
8	DBH >140.01	17	1.26

The ratio of the density of individuals with DBH >10 cm to that of >20 cm was used as a standard to measure the proportion of small and large individuals with respect to size class distribution (Grubb *et al.*, 1963). Accordingly this ratio is about 313.10/134.83 individuals' ha^{-1}, which equals to 2.32. This high value indicated that there were more individuals at lower DBH classes than at higher ones. Similarly, the ratio of density of individuals with DBH >10 cm (represented by a) to that of >20 cm (represented by b) for some other similar forests in Ethiopia with Gendo Forest was computed and the results were summarized below (Table 3). As the result of comparison (Table 4) indicated in the table, Gendo Forest's ratio of density of trees whose DBH >10 cm: >20 cm was more or less similar to that of Menagesha Suba and Masha-Andracha but greater than that of Alata-Bolale, Wof-Washa, Dodola, Dindin and Gura Farda and lower than that of Chilimo forests (authors are in the table 3).

Table 3: Comparisons of trees whose DBH >10 cm to >20 cm in different forests of Ethiopia

No	Forest name	DBH >10 cm(a)	DBH> 20 m(b)	Ratios (a/b)	Source
1	Alata-Bolale	365	219	1.7	Woldeyohannis Enkosa, 2008
2	Menagesha Suba	484	208	2.3	Tamrat Bekele, 1994
3	Chilimo	638	250	2.5	Tamrat Bekele, 1994
4	Wof-Washa	329	215	1.5	Tamrat Bekele, 1994
5	Masha Andaracha	385.7	160.5	2.4	Kumilachew Yeshitela & Taye Bekele, 2003
6	Dodola	521	321	1.6	Kitessa Hundera, 2008
7	Dindin	437	219	2.	Simon Shibru & Girma Balcha, 2004
8	Gura Farda (Bibit)	500	263	1.9	Dereje Denu, 2007
9	Gendo	413.1	134.84	2.3	The present study

Basal area

BA (basal area) refers to the total area of land occupied by stem or above ground plant part. BA was derived from DBH values and hence about 1351 individuals were incorporated in Gendo Forest. The total basal area of Gendo Forest was about 55.25 $m^2 ha^{-1}$ (Table 4). The majority (40.61%), of the total BA was contributed only by the two highest basal area classes, *i.e.,* BA classes 4 and 5 even though they contain only few individuals and species in the community (Table 4).

As indicated in Table 4, basal area of Gendo Forest was greater than that of Dindin Forest with 49 $m^2 ha^{-1}$ (Simon and Girma, 2004), Menagesha Suba Forest with 32 $m^2 ha^{-1}$ and Jibat Forest with 47 $m^2 ha^{-1}$ (Tamrat, 1994) but less than that of Masha –Andaracha Forest (81.9 $m^2 ha^{-1}$ Kumilachew and Taye, 2003), Wof-Washa Forest with 100.3$m^2 ha^{-1}$(Tamrat, 1994) and more or less similar with that of Sheko Forest with 54 $m^2 ha^{-1}$ (Feyera *et al.,* 2007) and Alata-Bolale with 53.30 $m^2 ha^{-1}$ (Woldeyohannis, 2008)

Table 4: Basal area classes of Gendo Forest where class 1) 0.01- 0.1 m, 2) 0.1- 1 m, 3) 1.01- 5 m, 4) 5.01- 10 m, 5) BA >10 m.

BA classes	Class interval	Density	% Den	No. spp.	% BA /SPP.
1	0.01-0.1	1086	80.45	9	0.38
2	0.1- 1	194	14.46	18	5.96
3	1.01- 5	37	2.74	4	8.38
4	5.01- 10	26	1.92	3	17.38
5	BA >10	8	0.52	2	23.23

Density

The density of the 38 selected mature woody species with height > 3m in Gendo Forest, incorporated about 2053 individuals was found to be 707.7 stems ha^{-1}. Five density classes: 1) D < 20 individual $ha^{-}1$, 2) 20-40 individuals' ha^{-1}, 3) 40-60 individuals' ha^{-1}, 4) 60-80 individuals ha^{-1} and 5) D > 80 individuals ha^{-1}.respectively were established (Table 5). The majority of individuals with great contribution to the total density came from the third (middle), the first and the second density classes respectively (Table 6). Much of the density was contributed by: *Justicia schimperiana* 366 (126.2%) individuals ha^{-1}, *Solanecio gigas* 210 (72.4%) individuals ha^{-1}, *Albizia schimperiana* 170 (58.6%) individuals ha^{-1}, *Pouteria adolfi-friederici* 127 (43.8%) individuals ha^{-1}, *Teclea nobilis* 120 (41.4%) individuals ha^{-1} and *Albizia gummifera* 117 (40.0% individuals $ha^{-1)}$. The density of seedling and sapling was about 1003.4 and 346.9 individuals' ha^{-1} respectively. The total density of all woody species in Gendo Forest was about 1,827.6 individuals ha^{-1}, which was greater than that of Jibat Forest with 275 individuals ha^{-1} and Menagesha Suba, about 276 individuals ha^{-1} (Tamrat, 1994), Jima about 1,817.67 individuals ha^{-1} (Fufa, 2008) but less than that of Sheko Forest, about 16,433 individuals ha^{-1} (Feyera *et al.,* 2007).

Table 5: Density Classes of Gendo Forest

Density classes	Class intervals	Density	%
1	1-20	416	20.26
2	20-40	366	17.84
3	40-60	695	33.85
4	60-80	210	10.22
5	D>80	366	17.79

Frequency

The total frequency of all woody species in Gendo Forest was about 651 which were classified into five frequency classes (Table 6). Five frequency classes were established and summarized in Table 7 below. Many species in the forest, like *Croton macrostachyus, Pouteria adolfi-friederici, Solanecio gigas, Justicia schimperiana, Maytenus addat, Albizia schimperiana, Albizia gummifera* were continuously distributed (in more than 75% of the total plots and hence have high frequency values. On the other hand some species, like *Apodytes dimidiata, Ekebergia capensis, Flacourtia indica, Erythrina brucei, Millettia ferruginea, Dombeya* spp., etc were found rarely in the forest and hence have the least frequency. In fact species that were few in number and small in cover but spread over large area sparsely might have high frequency value.

Table 6: Frequency classes of Gendo Forest where classes **1)** 1-20, 2) 20-40, 3) 40-60, 4) 60-80 and 5) 80-100

Frequency classes	Class interval	Density	%
1	1-20	181	27.85
2	20-40	111	17.05
3	40-60	176	27.03
4	60-80	63	9.7
5	80-100	120	18.43

Important value index

IVI is ecologically important and a key structural parameter in vegetation ecology. It is the most realistic aspect in vegetation ecology and used to compare the ecological significance of species (Lamprecht, 1989). Five IVI classes were established for Gendo Forest (Table 7). IVI for some selected woody species indicating variations among dominant tree species, suggesting the existence of variable competitive ability to both biotic and abiotic factors resulting from their specific adaptive selection (Feyera and Demel, 2003). Accordingly, 10 species with highest IVI values were selected from 38 species used for comparison of IVI value (Table 8) in order to describe the species population structure. Among them *Croton macrostachyus, Pouteria adolfi-friederici and Albizia schimperiana* were the first three with higher IVI values respectively. As indicated in Table 8, the majority of IVI (percentage value, i.e., 41.08%) and 31.28% was contributed by the highest and middle IVI classes (IVI classes 5 and 3 respectively

Table 7: IVI Classes of Gendo Forest where classes 1) IVI< 1, 2 1.01-5, 3) 5.01-10, 4) 10.01-15, 5) IVI > 15.01

IVI classes	*Class interval*	*No. spp.*	*Density*	*%*	**TIVI value**
1	< 1	11	155	7.55	7.81
2	1.01- 5	10	121	5.89	17.52
3	5.01- 10	9	647	31.5	66.9
4	10.1- 15	3	283	13.8	36.61
5	> 15.01	5	851	41.45	163.7

Dominant Species

Dominant species were selected based on their rank in IVI values indicated in Table 8 above. Species having 1-10 IVI values are referred as dominant because of the relative economical and ecological importance they played in the forest ecosystem and also their abundance in distribution within the forest (Curtis and Mcintosh, 1950; cited in Feyera and Demel, 2003). Accordingly, *Croton macrostachyus, Pouteria adolfi-friederici, Abizia schimperiana, Solanecio gigas, Albizia gummifera, Justicia schimperiana, Clausena anisata, Teclea nobilis* and *Vepris dainellii* were identified as dominant species of the Forest.

Table 8: IVI data matrix of Gendo Forest

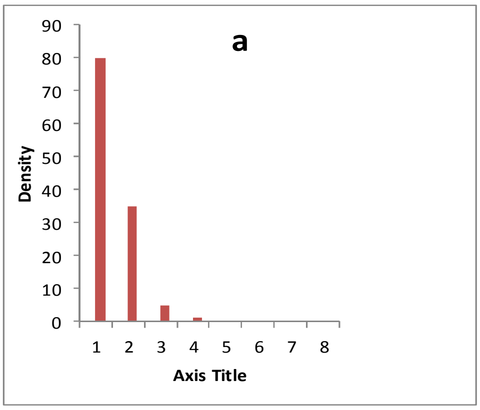
No.	**Botanical Name**	**RD**	**RF**	**RDO**	**IVI**
1	*Croton macrostachyus*	7.84	9.06	38.225	54.5
2	*Pouteria adolfi-frederici*	6.19	6.91	31.452	44.06
3	*Albizia schimperiana*	8.28	6.3	9.254	23.17
4	*Justicia schimperiana*	17.83	5.22	0.142	21.78
5	*Albizia gummifera*	5.69	6.3	8.526	20.06
6	*Solanecio gigas*	10.23	4.61	0.152	14.18
7	*Ficus sur*	2.29	3.53	5.942	11.58
8	*Clausena anisata*	1.55	9.37	0.059	10.85
9	*Teclea nobilis*	5.85	3.69	0.717	9.79
10	*Vepris dainellii*	5.65	3.69	0.354	9.24
11	*Bersma abyssinica*	3.5	5.68	0.049	8.95
12	*Dracaena steudneri*	3.7	4.61	0.096	8.12
13	*Syzygium guineense*	2.78	3.23	1.888	7.67
14	*Carissa spinarum*	3.5	2.92	0.061	6.21
15	*Celtis africana*	1.41	4.45	0.025	5.77
16	*Podocarpus falcatus*	1.02	2	2.666	5.6
17	*Cordia africana*	1.37	4.3	0.013	5.57
18	*Saba comorensis*	1.65	1.38	0.131	3.46
19	*Calpurnia aurea*	1.95	0.92	0.016	2.73
20	*Maytenus addat*	0.78	1.38	0	2.1
21	*Acacia etbaica*	0.54	1.08	0.004	1.57

22	*Allophylus abyssinicus*	0.58	1.08	0.004	1.61
23	*Cassipourea malosana*	0.64	0.92	0.006	1.51
24	*Maesa lanceolata*	0.73	0.61	0.003	1.29
25	*Macaranga capensis*	0.44	0.77	0.001	1.17
26	*Nuxia congesta*	0.48	0.61	0.026	1.07
27	*Juniperus procera*	0.48	0.46	0.107	1.01
28	*Ekebergia capensis*	0.34	0.61	0.001	0.92
29	*Flacourtia indica*	0.3	0.61	0.001	0.881
30	*Erythrina brucei*	0.44	0.46	0.012	0.87
31	*Pittosporum viridiflorum*	0.4	0.46	0	0.82
32	*Acacia abyssinica*	0.34	0.46	0.005	0.77
33	*Millettia ferruginea*	0.3	0.46	0.036	0.76
34	*Schefflera volkensii*	0.24	0.46	0.017	0.69
35	*Apodytes dimidiata*	0.2	0.46	0.01	0.65
36	*Grevillea robusta*	0.24	0.31	0.00	0.53
37	*Dombeya torrida*	0.14	0.31	0	0.44
38	*Dombeya schimperiana*	0.1	0.31	0	0.4

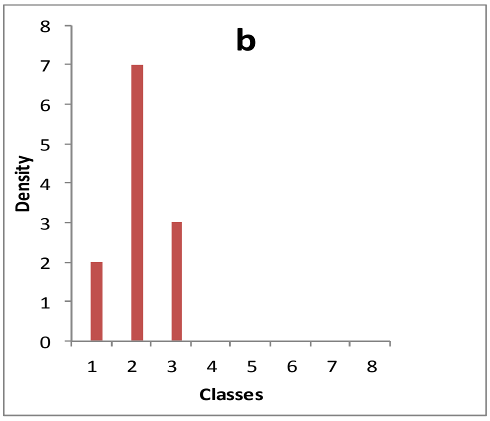
Species Population Distribution Patterns of Gendo Forest

DBH distribution analyses of Gendo Forest based of the eight DBH classes resulted into four distinct structural patterns of distribution. The first pattern of distribution was for those species having high density in the lower DBH classes and progressively decreased in the higher DBH classes, representing inverted J-shaped distribution scheme. The species recorded under this scheme have good reproduction and recruitment opportunities in the forest. More than 14 (43.75%) of the total species in the forest have this distribution pattern. For instance, *Justicia schimperiana, Solanecio gigas, Clausena anisata, Acacia abyssinica, Millettia ferruginea, Cordia africana, Vepris dainellii, Celtis africana, Teclea nobilis, Bersama abyssinica, Macaranga capensis, Acacia etbaica, Dombey schimperiana, Flacourtia indica, Pittosporum viridiflorum, Maytenus addat, Grevillea robusta, Allophylus abyssinicus* and *Dracaena steudneri* (Figure 3a).

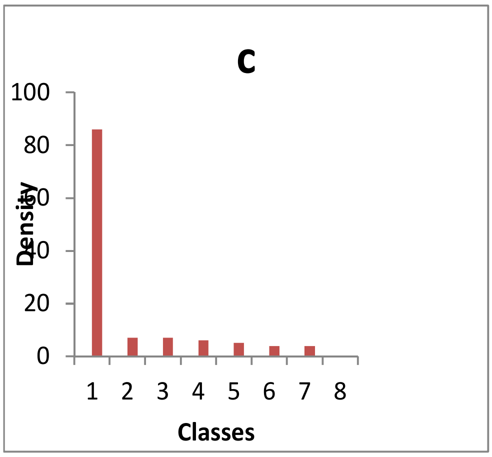
The second pattern was a gauss-type (bell shaped) pattern of distribution in which the lowest DBH class has low density followed by high density and then subsequently decreases in the third DBH class onwards. Species included under this pattern were: *Erythrina brucei, Schefflera volkensii, Acacia abyssinica,* and *Dombeya torrida* were found within this distribution pattern, which are characterized by hampered reproduction and recruitment (Figure 3b). The third pattern was represented by species having more or less regular density after abruptly decreased from the second DBH class on wards. This pattern suggests a good reproduction and recruitment potential. Important species under this pattern includes: *Albizia schimperiana, Albizia gummifera* and *Croton macorstachyus* (Figure 3c). The fourth recognized pattern indicates a good reproduction but discontinuous or humpered recruitment which is represented by those species having high density in the lower DBH classes forming a broken reversed J-shaped pattern with gaps (missed values) in their higher DBH classes and further ending with only few individuals at higher DBH classes due to the prevailing disturbances (including selective cutting) at middle and mature aged individuals. eg. *Syzygium guineense, Ficus sur, Pouteria adolfi-friederici* and *Podocarpus falcatus* (Figure 3d) which are hunted by the local people for their timber value.



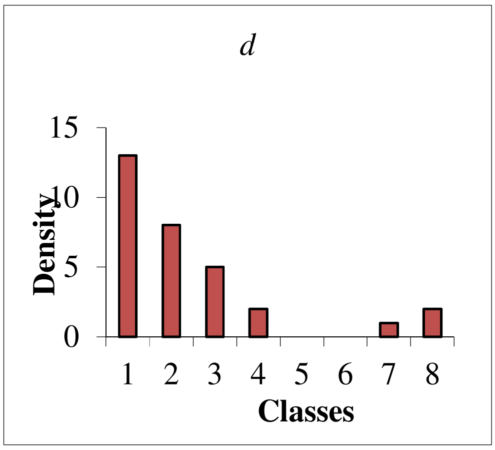
Inverted J shape



Bell shape



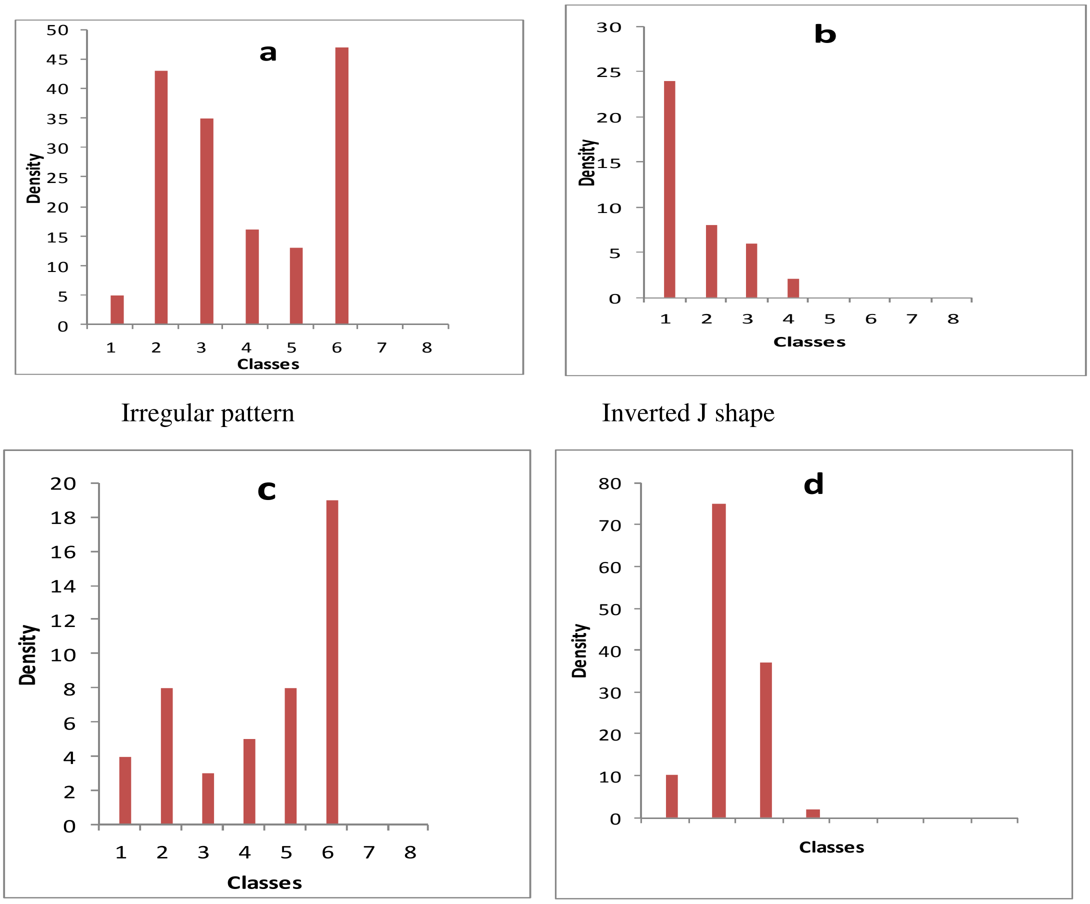
Inverted J shape



V-shaped

Figure 3a-d: Species population DBH distribution pattern of: *Vepris dainellii (a), Acacia abyssinica* (b), *Albizia schimperiana* (c) and *Pouteria adolfi-friederici (d) in Gendo Forest*

Apart from DBH distribution patterns described so far, Gendo forest height class analysis of also depicts four distinct height structural distributions patterns. The first pattern encompasses those species whose density at the first lower height class was low, then increased in the second height class followed by irregular increase or decrease after wards. *Croton macrostachyus, Pouteria adolfi-friederici, Albizia schimperiana, Albizia gummifera* and *Ficus sur* are within this pattern (Figure 4a). The second patter included those species having high density in the first lower height classes and successively decreased toward the higher height classes (inverted J shaped). *Pittosporum viridiflorum Acacia abyssinica, Millettia ferruginea, Cordia africana, Celtis africana, Bersama abyssinica, Macaranga capensis, Acacia etbaica, Dombeya schimperiana, Flacourtia indica* were categorized under this pattern (Figure 4b). The third pattern consists of those species having J shaped pattern of distribution, having low density at lower height classes and then increased along higher height classes (Figure 4c). eg. Ficus sur. The forth pattern include those species having bell shaped pattern of height distribution. Species like *Teclea nobilis, Vepris dainellii* have this J shaped pattern of distribution.



Irregular pattern   Inverted J shape

J shaped   Bell shaped

Figure 4a-d: Species population height distribution patterns of: *Croton macrostachyus* (a). *Cordia africana, Clausena anisata* (b), *Ficus sur* (c) and Vepris *dainellii* (d) in Gendo Forest

Some species like *Justicia schimperiana, Solanecio gigas, Clausena anisata and Calpuria aurea* have values only at the first height class due to their limited growth nature and hence have no distinguishable distribution pattern. Thus the population species structure, IVI value and regeneration status were used as a criterion to establish conservation priority classes among species in Gendo Forest. Similar study and conclusion was undertaken in Dindin Forest (Simon and Girma, 2004) to determine priority species for conservation purpose. Accordingly, four conservation priority classes I, II, III and IV were established.

Regeneration Status of Gendo Forest

The total seedling, sapling and mature woody tree density of those 38 representative species were about 1003.4, 347 and 707.8 individual's ha^{-1} respectively. The ratio of mature individuals to seedlings and sapling was 0.7.and 2.0 respectively. This result indicates that there were more seedling populations than that of mature and saplings. According to this data, most of the seedlings were perishing off before reaching sapling and mature stages for various reasons which might be due to grazers, browsers, environmental stress (moisture, water, temperature, soil light and canopy cover). Regeneration status summarizing numbers of seedlings, saplings and mature woody species were indicated in Appendix 1. The composition, distribution and density of seedlings and saplings are indicating the future regeneration status of the forest. Accordingly, *Croton macrostachyus*, *Calpurnia aurea*, *Syzygium guineense*, *Albizia schimperiana, Albizia gummifera*. *Justicia shimperiana Solanecio* *gigas Carissa spinarum* and *Clausena anisata* have high regeneration status in this forest. *Albizia schimperiana* and *Albizia gummifera* have a multiple regeneration adaptations, where the shallow underground roots exposed to soil give rise to new sprouts as its stems do, seed explosion and dispersal mechanisms. Possible reasons for insufficient seedling for some species in the forest is due to seed predation, grazing and browsing, lack of safe site for seedling recruitment, nature of seeds of certain trees which seek dormancy break, litter accumulation, pathogens, species specificity, and moisture stress or probably they might have other alternative adaptations for propagation and reproduction rather than seed germination. This situation was ecologically and evolutionary hard and difficult, but it was not a new and surprising issue because there are similar findings and reports have occurred on the vegetation study (Dereje, 2007; Simon and Girma, 2004; Abayneh *et al.,* 2003).

Table 9: Four priority classes for conservation where class 1) no seedling and sapling, 2) no seedling but sapling < 5individuals ha^{-1}, 3) seeds < 5 individuals ha^{-1}, 4) seedling >5, but < 15 ind, ha^{-1}).

Priority class I	Priori class II	Priority class III	Priority class IV
Dombeya schimperiana	*Dombeya torrida*	*Cordia africana*	*Podocarpus falcatus*
Celtis africana	*Erythrina brucei*	*Nuxia congesta*	*Vepris dainellii*
Flacourtia indica	*Pittosporum viridiflorum*	*Millettia ferruginea*	*Pouteria adolfi-friederici*
Apodytes dimidiata	*Cassipourea malosana*	*Dracaena steudneri*	*Teclea nobilis*
Ekebergia capensis		*Allophyllus abyssinicus*	
Schefflera volkensii		*Ficus sur*	
		Macaranga capensis	
		Acacia abyssinica	
		Maytenus addat	

Conclusion

Gendo Forest is entirely encompassed within moist montane rain forests with respect to its altitudinal range, vegetation compositions and climatic conditions. The forest has ecological, economic, social and cultural values that local communities obtained from it (including timber trees, hydrological cycle, shadow or shading of villages in its immediate vicinity during hot weather condition, shelter of various wild animals and plant. *Croton macrostachyus, Justicia schimperiana, Solanecio gigas, Albizia gummifera, Albizia schimperiana. Clausena anisata, Vepris dainellii,* etc are mentioned among dominant species recorded in the forest. Most of the lower height and DBH classes were dominated by species having small statures while at the higher height and DBH classes very few individuals of *Pouteria adolfi-friederici, Podocarpus falcatus, Albizia schimperiana Ficus sure* and *Syzygium guineense* were predominant. Gendo Forest consists of three canopy layers, the top emergent trees (*Pouteria adolf-friederici* and *Podocarpus falcatus*), *Albizia schimperiana, Ficus sur, Syzygium guineense and Croton macrostachyus* forming the middle canopy layer while *Teclea nobilis, Vepris dainellii, Bersama abyssinica, Acacia abyssinica, Maytenus addat,* etc form the lower canopy followed by smaller shrubs and groung herbs. Structural analysis of both the height and DBH distribution patterns have more or less similar. However, the height and DBH distribution pattern of representative species were deviated from the entire plant community's distribution pattern. From the evaluation of regeneration status and species population distribution patterns four conservation priority classes were established for Gendo Forest.

Recommendation

- Local people NGOs and other concerned bodies should promoting plantation on all sides of the forest edge (established buffer zones) to the central natural forest as they did during the millennium to foster Gendo Forest conservation in particular and biodiversity conservation in general.
- Being rapid population increment was revealed, there would be high pressure on this forest resource. There for awareness creation pertains participatory forest conservation and management as well as community based sense of forest ownership to the local community is crucial.
- Further studies on soil analysis, seed physiology and reproductive biology of those species under risky of local extinction should conducted.

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Appendix 1: List and Numbers of Seedling sapling and mature woody species of Gendo Forest

No	*Botanical name*	*Seedling*	*Sapling*	*Mature*	*Total*
1	*Acacia abyssinica*	3	2	7	12
2	*Acacia etbaica*	2	4	11	17
3	*Albizia gummifera*	120	96	117	333
4	*Albizia schimperiana*	256	93	170	519
5	*Erythrina brucei*	0	3	9	12
6	*Millettia ferruginea*	3	3	6	12
7	*Macaranga capensis*	4	6	9	19
8	*Cordia africana*	2	1	28	31
9	*Schefflera volkensii*	0	0	5	5
10	*Vepris dainellii*	23	16	116	145
11	*Teclea nobilis*	31	28	120	159
12	*Syzygium guineense*	218	14	57	289
13	*Dombeya torrida*	0	8	3	11
14	*Dombeya schimperiana*	0	0	2	2
15	*Celtis africana*	0	0	29	29
16	*Ficus sur*	3	18	47	68
17	*Pouteria adolfi-friederici*	25	13	127	165
18	*Allophylus abyssinicus*	6	12	12	30
19	*Flacourtia indica*	0	0	6	6
20	*Pittosporum viridiflorum*	0	5	8	13
21	*Ekebergia capensis*	0	0	7	7
22	*Nuxia congesta*	2	4	10	16
23	*Apodytes dimidiata*	0	0	4	4
24	*Cassipourea malosana*	0	5	13	18
25	*Maesa lanceolata*	3	8	15	26
26	*Juniperus procera*	610	0	10	620
27	*Podocarpus falcatus*	12	42	21	75
28	*Croton macrostachyus*	542	198	161	901
29	*Maytenus addat*	1	6	16	23
30	*Grevillea robusta*	600	6	5	611
31	*Dracaena steudneri*	6	19	76	101
32	*Bersama abyssinica*	32	94	72	198
35	*Clausena anisata*	149	103	32	284
36	*Carrisa spinarum*	23	36	63	102
38	*Calpurna aurea*	234	163	40	437
	Total	2910	1006	1434	5300