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FLORISTIC COMPOSITION AND STRUCTURE OF ARBA MINCH RIVERINE FOREST, SOUTHERN ETHIOPIA: AN IMPLICATION FOR FOREST GENETIC RESOURCE CONSERVATION

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ABSTRACT: A study on woody species composition and structure was conducted in Arba Minch Riverine Forest. The objective was to investigate the floristic composition, structure, regeneration status and prioritize the threatened woody species for conservation. Sixty two sample plots, each measuring 50 m by 10 m were laid in an interval of a 100 m horizontal distance. Ninety six species were identified. Diameter and height were measured for all trees and shrubs having a diameter at breast height above 2.5 cm. The analysis of vertical structure using IUFRO classification scheme revealed that highest density of individuals and high number of species was found in the lower layer. Ecologically important and dominant species were identified based on basal area, $m^2.ha^{-1}$ and IVI values independently and the two parameters showed 80% correlation for the first 10 dominant species. The current conservation status of each species was evaluated using general criteria, combining: Importance Value Index (IVI), population structure of species (based on stand diameter and height profiles) and regeneration status. A total of thirty two species were identified as threatened and hence, recommended for *in situ* conservation.

Key words/phrases: Basal Area, Conservation, Important Value Index, Population structure status, Priority species regeneration.

INTRODUCTION

"Riverine forest vegetation" has been described by different authors using different terminologies. Lamprecht (1989) put the riverine forest vegetation under two separate groups: 'Inundation forest' and 'galley forest'; and Friis (1992), Evans *et al*. (1992), Richard (1995) and Claudia (1998) used the term 'riverine forest'. Regardless of these differences, the author has adopted and used the term "riverine forest" throughout this report.

The Ethiopian Riverine forests fall into two main subtypes, namely: Upland (1,500 – 2,000 m a. s. l.) and Lowland (400-1,500 m.a.s.l.) Riverine forests (Friis, 1992). Riverine forests have been recognized among the nine major vegetation types of the country (NCS, 1994). Despite their very diverse nature (Evans *et al*., 1992; Richard, 1995; Claudia, 1998), riverine forests of

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Ethiopia have received little attention. The only documented information on riverine forests in the country includes: the Dawa river at Melca Guba (Cuffodontis, 1940), the Awash river (Pichi-Sermolii, 1957; Sebald, 1972), Lake Zeway and the upper part of the Blue Nile (Pichi-Sermolii, 1957), the Baro, the Gojeb and the Genale Dorira rivers (Friis *et al.,* 1982), the Argoba river in Gamo Gofa (Haugen, 1989), Lakes Abbaya and Chamo (White, 1983; Evans *et al.*, 1992; Friis, 1992; Claudia, 1998).

Though the above-mentioned authors had generally reported on the floristic composition of the forests, none of them considered the structural and regeneration components of the forests. Moreover, no relevant empirical data is available to provide adequate information on the actual extent, geographical distribution, ecological status and/or socio-economic importance of the country's riverine forest vegetation.

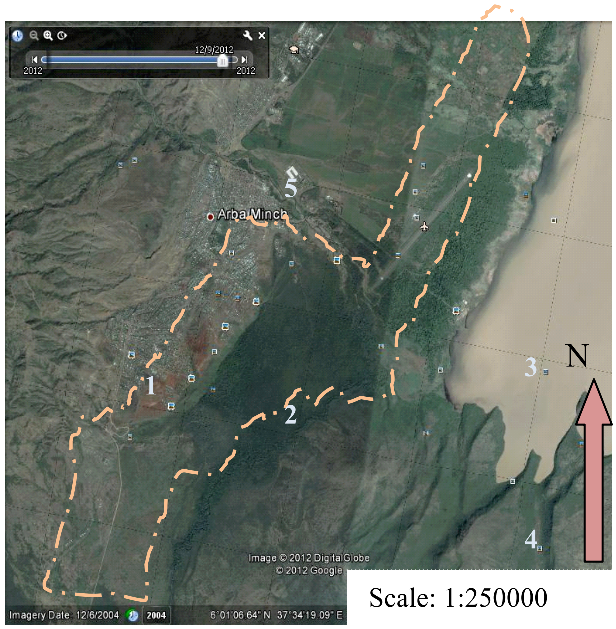
There is, therefore, a need to study the country's riverine forests in terms of their species diversity, structural elements and identification of ecologically important and threatened species, which are in need of high attention for conservation. The present study aims at investigating the floristic composition, structure, regeneration status, and prioritization of the threatened woody species for conservation.

MATERIALS AND METHODS

Study area

The forest covers some 2,120 ha situated in the Arba Minch 'Zuria Woreda' (subdistrict) of Gamo Gofa Zone, Southern Nations Nationalities and People's Region (SNNPR). It borders the southwestern shore of Lake Abaya and lies in the westernmost section of the Nech Sar National Park (NSNP) in the Southern Rift Valley. Its territory extends between 05º59.00'- 06º30.00N' and 35º59.527'- 36º06.970'E (Evans *et al.*, 1992).

Arba Minch Forest has been classified among 58 National Forest Priority Areas since early 1980s (EFAP, 1996), and as such it forms part of the Nech Sar National Park. A flat valley bottom characterizes the topography of the forest with considerably little variation in its elevation (1100 - 1160 m a.s.l.). It comprises three types of relief elements: a narrow belt of steep foot slopes below the escarpment, a gently sloping piedmont plain, and flat lacustrine plain with a high water table. The geology of the area is made up of quaternary volcanic colluvial deposits and lacustrine clay; consisting of both trachyte flows and, felsic ignimbrites (LURDP, 1992). The soil is composed of fluvisols, gleysols and vertisols. The riverine/ground water forest vegetation typically covers areas with fluvisol and gleysol.



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Legend: Forest boundary line: Important features: **1**= 40 Springs, **2** = Kulfo River, **3** = Lake Abaya, **4** = Nech Sar National Park, **5** = Arba Minch Town.

Fig.1. Location map of Arba Minch Forest.

The forest territory falls within Abaya and Chamo lakes drainage basins. The northern section is traversed by Hare River, which ultimately empties into Lake Abaya. The Kulfo River and its tributaries drain much of the area in an east to west direction, and ultimately flow into the Lake Chamo (Evans *et al.*, 1992).

Table 1. Summary of rainfall and temperature data from Meteorological Station.

	Monthly period												
Parameters	J	F	M	A	M	J	J	A	S	O	N	D	Total
Mean Presssure, mm	39	43	52	153	138	64	57	56	67	126	63	38	886
Mean Min.T^0C	17	17	19	18	18	18	18	17	18	17	16	16	17.37±0.78
Mean Max. T^0C	32	33	33	31	29	28	27	29	31	30	31	31	30.3±1.53

Source: Ethiopian Meteorological Service Agency (EMSA, 2001).

The area receives a mean annual rainfall of 886 mm, which is characterized by bi-modal distribution: with two rainy and two drier seasons occurring intermittently. The first rainy season falls mainly in April and May; and the second rainy season falls mainly in October (EMSA, 2001). The mean minimum and mean maximum temperature values amount to 17.37 ºC ± 0.78^0C and 30.30^0C ± 1.53^0C, respectively.

White (1983) and, and later on, Evans *et al.* (1992) describes the natural vegetation of the Arba Minch Riverine Forest as follows: 1-Riverine forest, including the gallery forest along the Kulfo River and the ground water forest, which is mainly associated with the 40 springs; 2-Acacia-Commiphora deciduous bushland/thicket, which occupy areas between the gallery forest and the ground water forest; 3-Xerophilous bush shrub thicket, which occur on the steep slopes escarpment; 4-Open-wooded grassland, occupying well-drained undulating ground to the west of the ground water forest; and 5-Fresh water/ swamp and aquatic vegetation.

Data collection

Sampling design

A reconnaissance survey was carried out across the forest territory to obtain firsthand information of the on-site conditions and accessibility, and to identify sampling sites. The external forest boundaries were determined from topo map (Scale 1: 150,000) and five long transects, each measuring variable total length (of horizontal distances) was delineated on the topo-map sheet. The geographical coordinates of the beginning and end points of the transect lines were fed into Garmin 48 GPS. Transects were located on the ground using the GPS navigation system. A total of sixty two sample quadrates, each measuring 500 m^2 (50 m X 10 m), were laid in an interval of 100 m horizontal distance. This is equivalent to 3 ha, which is about 0.15 % of the total area (2,120 ha).

In each sample plot, all woody species were recorded. Specimens were collected and identified at the National Herbarium, Addis Ababa University. The nomenclature of the species follows Hedberg and Edwards (1989); Edwards *et al*. (1995); Hedberg and Edwards (1995) and Edwards *et al.* (2000). Diameter was measured for every individual tree and shrub having diameter at breast (DBH), and stump (DSH) height greater than 2.5 cm using a diameter tape and tree caliper. If the tree branched at breast height or below, the diameter was measured separately for the branches and averaged. In case where the tree boles were buttressed, diameter measurements were related to the point just above the buttresses. Height was measured for the same individuals as well using a Suunto clinometer. Visual estimation was applied where crown structure made it difficult to use the instrument. Vegetation data entry form was developed using Microsoft Access Program. The vertical structure of the forest was described using the International Union for Forestry Research Organization (IUFRO) classification scheme (Lamprecht, 1989). Using this system, three vertical structures were distinguished: Upper layer (tree height > 2/3 of the top height recorded in the forest); middle layer (tree height between 1/3 and 2/3 of the top height); and lower layer (< 1/3 of the top height). The data of the sample quadrate data was pooled by plots to estimate density (N-stems.ha^{-1}), frequency (%), total basal area (BA.m^2) species^{-1}, as well as, their corresponding relative values per species (Muller-Dombois and Ellenberg, 1974). Density, frequency, basal area (BA) and Important Value Index (IVI) were computed for all tree and shrub species with DBH > 2.5 cm. Absolute frequency (AbFr) per species was determined by dividing the number of sample quadrates (in which a given species is recorded) by sum of all sample quadrates and then multiplying it by 100. The emerging data was used to classify the component woody species into the following five frequency classes: A≥80%; B<80≥60-80%; C<60≥40%; D =<40≥20%; and E = <20%. Density (N.ha^{-1}) and basal area (BA, m^2) per species[1] and dominance (BA, m^2.ha^{-1})[2] were calculated for all tree species. Densities (N.ha^{-1}) of shrubs, saplings, and seedlings were also calculated on a per hectare basis. The relative importance of a species in the plant community was calculated following the method of Curtis and McIntosh (1951) who proposed an Importance Value Index (IVI). The sum of the three structural parameters, were calculated as:

$$\text{Relative frequency (RFr)} = \frac{\text{AbFr per species}}{\text{Sum of AbFr of all species}} \times 100,$$

$$\text{Relative density (RDe)} = \frac{\text{Density (N.ha}^{-1}\text{) per species}}{\text{Sum of density of all the species}} \times 100,$$

$$\text{Relative dominance (RDo)} = \frac{\text{Basal area.ha}^{-1}\text{ per species}}{\text{Sum of all species basal area.ha}^{-1}} \times 100.$$

Thus, IVI per species = RF + RDe + RDo = 300%.

The population structures of some selected woody species were analyzed and the pattern that emerged was interpreted as an indication of variation in population dynamics in the forest. Regeneration status of species was assessed based on population size of seedlings and saplings of species following Khan *et al*. (1987). It is considered: Category I = "good regeneration", if seedlings > saplings > adults; Category II = "fair regeneration", if seedlings > or ≤ saplings ≤ adults; Category III = "poor regeneration", if the species survive only in sapling stage, but no seedlings (saplings may be <, > or = adults); Category IV = "no regeneration", if a species is present, only in an adult form; and Category V = "species considered as new", if the species has no adults but exists as seedling or sapling only.

RESULTS AND DISCUSSION

Species composition

A total of 94 woody plants were recorded in the Arba Minch Riverine Forest, of which 87 were identified at a species and 7 at a genus level. The 87 woody species, along with 7 specimens, which were identified at the genus level (assumed as different species), belonged to 66 genera and 32 families.

Fabaceae was the most dominant family consisting of 8 (8.1%) genus and 16(17%) species. The second dominant family Euphorbiaceae was represented by the same number of genus, as Fabaceae, but contained only 8 (8.5%) species. A total of 12 (35.5%) families were each represented by a single genus and a single species. Of the 66 genera, 51 were represented by single species. Along with its eight species, the genus Acacia alone exhibited the highest species richness (8.5 %), followed by Ficus and Grewia, with 4.2 % of the total species each.

Owing to their dimensions, the predominant species were *Ficus sycomorus* L., *Ficus vasta* Vahl., and *Ficus sur* Forssk. Additional larger abundant species were *Lecaniodiscus fraxinifolius* Bak., *Diospyros abyssinica* (Hiern.) F. White, *Trichilia dregeana* Sond., *Manilkara butugi* Chiov. and *Celtis africana* Burm. f.

The most common shrubs included *Acalypha psilostachya* Hochst., *Cadaba farinosa* Forssk, *Carissa edulis* Vahl., *Crotolaria pallida* Ait., *Dichrostachys cinerea* (L.) Wight & Arn, *Dovyalis verrucosa* (Hochst.) Warb., *Grewia mollis* Juss., and *Harrisonia abyssinica* Oliv. The common lianas were *Acacia brevispica* Harms, *Hippocratea africana* (Willd.) Loes., *Iacazzea apiculata* Oliv., *Paullinia pinnata* L. and *Phytolacca dodecandra* L'Herit.

In general, the woody species composition was made up of 6(6.4%) species of liana, 15 (15.9%) species of shrubs and 50 (53 %) species of trees; while 26 (27.6 %) species were represented both as a tree and/or shrub. The woody species encountered in the area were all angiosperms. The characteristic major tree species in the riverine forests such as *F. sycomorus*, *Kigelia africana* (Lam.) Benth, *L. fraxinifolius* and *T. indica* (Mesfin Taddesse, 2000) were also represented in the present study site. These species, except *L. fraxinifolius,* were also reported from Tanzanian riverine forests (White, 1983). Species composition of the riverine forests along eastern Gamo Gofa was described by Haugen (1989). Among these, *C. africana, T. emetica, B. micrantha, E. buchananii, F. sycomorus, L. fraxinifolius, M. butugi, S. guineense, T. indica, V. dainellii, C. malosana, D. abyssinica, M. undata,* and *S. mitis* were recorded from Arba Minch riverine forest. But species such as *A. grandibracteata, A. gummifera, P. adolfi-friederici, Bersama abysssinica* Fresen*, M. kumel, P. reclinata and S. ellipticum* were absent from the study area.

The floristic composition of the Arba Minch forest showed a mixture of riverine species (*F. sycomorus, T. indica, T. emetica*) and elements of other vegetation types such as *V. dainellii* and *Millettia ferruginea* (Hochst.) Bak*, D. abyssinica*, *Allophylus abyssinicus*, *Prunus africana* (Hooke.f.) Kalkam, and *T. nobilis* from Afromontane evergreen forest, *M. butugi* from lowland humid montane forest, *C. albiflora* Engl., *C. farinosa* Forssk*, A. mellifera, A. nilotica, G. villosa* from Acacia-Commiphora bushland, *Combretum* spp., from Woodland, and *P. capensis* and *C. edulis* Vahl from evergreen and semi-evergreen bushland vegetation types. Related studies from elsewhere, around the world, showed similar cases. For instance, Capon (2005) from Australia reported that plant diversity in riparian habitats comprises a range of taxonomic groups, life forms and functional groups, and includes only plants found in riparian areas, as well as, those that can move between environments. This mixture could come from the very nature of the riverine forest in that species from the highlands and the nearby lowlands could disperse due to flooding and/or following the rivers: Kulfo and Hare. Although some species might be confined to the riverine forest habitats, many of the species, constituting these forest habitats come from a variety of other forests and bushland types, a combination that gives this forest type a greater diversity than any other upland forest vegetation units (Richard, 1995).

Some of the species of the area were part of the Red List of Vascular Plants for the country: *V. dainellii* and *M. ferruginea*, which are endemic to Ethiopia (Ensermu Kelbessa *et al*., 2000); and *M. butug* and *C. africana*, which are among the list of endangered species in the country (Hilton-Taylor, 2000), without any specification as to their conservation status. Hilton-Taylor (2000) reported *P. africana* and *M. arbutifolia* as among the vulnerable species while *C. albiflora* as among the least risk species of the country.

Vertical structure

The highest density of stems was found in the lower storey and the lowest density was found in the upper storey (Table 2). Similarly, more species were found in the lower and middle storey while the upper storey was being occupied by fewer species. Although density was lower in the upper storey, there was heterogeneity of species. High density value in the lower storey was due to the predominance of *L. fraxinifolius, A. fruticosa and E. divinorum*. About 12.2% of the species were found frequently in all storeys. Species of this kind were described as "species with regular vertical distribution"(Lamprecht, 1989). Both pioneer and climax species were represented in this group, and most of them (*C. africana, A. nilotica, C. africana, F. sycomorus, D. abyssinica, L. fraxinifolius, M. butugi,* and *T. dregeana*) are both ecologically and economically important.

Table 2. Distribution of species numbers and density of stems against vertical profile.

	Strata			
Parameters	LS	MS	US	Sum
No of species	78	30	14	86
% of species	91	35	16	100
No of stems.ha^{-1}	1,979	166	14	2,158
% of stems.ha^{-1}	92	7.7	0.6	100
No of stem: No of species	1:25	1:5.5	1:1	1:25

Note: LS = Lower storey, MS = Middle storey, US = Upper storey

Only one species, *F. vasta* was confined to the upper storey. Lamprecht (1989) described such species as “long-lived" or "late secondary species" These species could survive in the upper storey for a longer time, but could regenerate only under exceptional conditions. Such types of species are removed from the community due to old age or other factors (Lamprecht, 1989). Therefore, *ex situ* conservation measure is highly recommended for such species.

The ratio of individuals to species in Arba Minch Forest showed that, species in the lower storey, on average, were represented by many individuals while those in the middle and upper storey were represented by fewer number of individuals. At 25:1 on average, the individuals to species ratio were quite variable between layers and showed a decreasing trend with layer.

Species frequency

Species frequency exhibited a wide range of variation (1.8 % - 72.6%). The species were grouped into five frequency classes, with 20 % intervals (Table 3). In the present study site, there was no single species representation in the highest frequency class (A). Likewise, the second highest class (B) consisted of only one species *L. fraxinifolius* (72. 6 %); and the intermediate class (C) was formed by only three species, namely: *D. abyssinica* (56.5 %), *M. senegalensis* (43.6 %) and *E. divinorum* (40.4 %). Therefore, these four species were the most frequent and more regular in their horizontal distribution.

The remaining two classes (D and E) were made up of 9 and 73 species, respectively. Therefore, findings such as a high percentage (>80 %) of species in the lowest two frequency classes (E and D), a total absence of any species in the first class (A), and classes B and C being represented by not more than four species: suggested that the study area harbours a remarkable degree of species heterogeneity.

Table 3. Distribution of species numbers and frequency values by frequency classes.

Parameters	Frequency class					Grand Total
	A	B	C	D	E	
No of Species		1	3	9	73	86
Absolute frequency		73	47	29	5	10
Relative frequency		8%	16%	30%	46%	100%

N.B. Frequency Class: A = 80-100%, B = 60-80%, C = 40-60%, D =20-40%, E = 0-20%.

Frequencies give approximate indication of the homogeneity of a stand (Lamprecht, 1989). Accordingly, higher values in higher frequency classes (Classes A and B in this case) and lower values in lower frequency classes (E and D) indicated constant or similar species composition, while higher values in lower frequency classes and lower values in higher frequency classes, on the other hand, indicated a high degree of floristic heterogeneity. The species that appeared in the lower frequency classes had irregular occurrence whereas those appearing in higher classes had regular horizontal distribution.

Species density and density ratio

The total density of the woody species in Arba Minch forest was 2,159 stems/ha. However, densities of individual species showed a wide range of variation (from 0.32 to 410 stems/ha). A total of 25 species had densities less than 1 stem/ha, while another group of 18 species was represented by 1,292 stems/ha (Table 4).

L. fraxinifolius,D. abyssinica, *A. fruticosa*, *E. divinorum*, *M. senegalensis*, and *R. natalensis,* in particular, exhibited one of the highest abundance values. The density ($N.ha^{-1}$) of these species was 411, 347, 222,195,137, and 105, respectively. On the other hand, species showing extremely low stem densities (i.e. less than 0.5 $stem.ha^{-1}$) were *A. drepanolobium, A. seyal, A. leiocarpa, Celtis sp, C. myricoides, Combretum sp, Combretum molle* R. Br. ex D. Don*, F. vasta, Flueggea virosa* Voigot.*, Ocimum sp, Trema orientalis* (L.) Blume and *Vernonia amygdalina* Del.

Table 4. Woody species density and density ratios by DBH Class.

	Number of Species		$N.ha^{-1}$	
DBH Class	N	%	N	%
A	74	86	2,158	100
B	49	57	450	20.8
C	36	42	313	14.5
D	1.36	1.36	1.44	1.44

Note: A= $N.ha^{-1}$,with DBH/DSH ≥2.5 cm, B = $N.ha^{-1}$, with DBH >10 cm, C = Density ($N.ha^{-1}$), with DBH >20cm, and D = Density Ratio, B: C

The ratio of stem densities with DBH between 10 and greater than 20 cm was used by various authors, including Tamrat Bekele (1994), as an indicator for the assessment of woody vegetation structure. Only 49 of the tree/shrub species, with a total density of 450 stems.ha^{-1} had reappeared in the list of woody species, of which their DBH values exceed 10 cm. Likewise, a total of 36 tree/shrub species, represented by a total of 313 stems.ha^{-1}, had formed the group of species having DBH >20 cm. The resulting ratio of density >10 cm to density >20 cm was 1.4. These quite low values imply lower predominance of smaller-and/or medium-sized individuals in the forest and suggests the paucity of stem numbers in the intermediate-sized classes.

Density of woody species over 10 cm DBH greater than 600 stems ha^{-1} is normal for virgin rainforest in Africa (Richards, 1966). Since the value is below the normal in the present study site, it can be concluded that the forest under investigation might have been experiencing forest disturbance.

The socio-economic survey report by Lemlem Aregu and Fassil Demeke (2006), as well as, the case study report by Aramde Fetene *et al.* (2012) revealed that fuel wood and timber extraction by people from the Arba Minch town are the most important determinate factors for the depletion of the Arba Minch Forest.

Stand diameter and height profiles

The stand diameter and height profiles, as depicted in Fig. 2 and Fig. 3, showed distribution of species density (N stems.ha^{-1}) against DBH/DSH, on the one hand, and against height classes, on the other hand.

From the stand diameter-frequency profile shown in Fig. 2, it can be seen that the total density of tree/shrub species.ha^{-1} in Arba Minch Forest declines, somewhat, abruptly from about 1,600 stems.ha^{-1} in the first, to 250 and 100 stems.ha^{-1} in the second and third DBH/DSH classes, respectively. However, the trend appears to be rather gradual all across the rest of DBH/DSH classes, except the last one. An apparently higher density (18 stems.ha^{-1}) (DBH>42.5) shown by the last DBH/DSH class was due to the fact that all possible records of diameter greater than 42.6 cm being incorporated in this class.

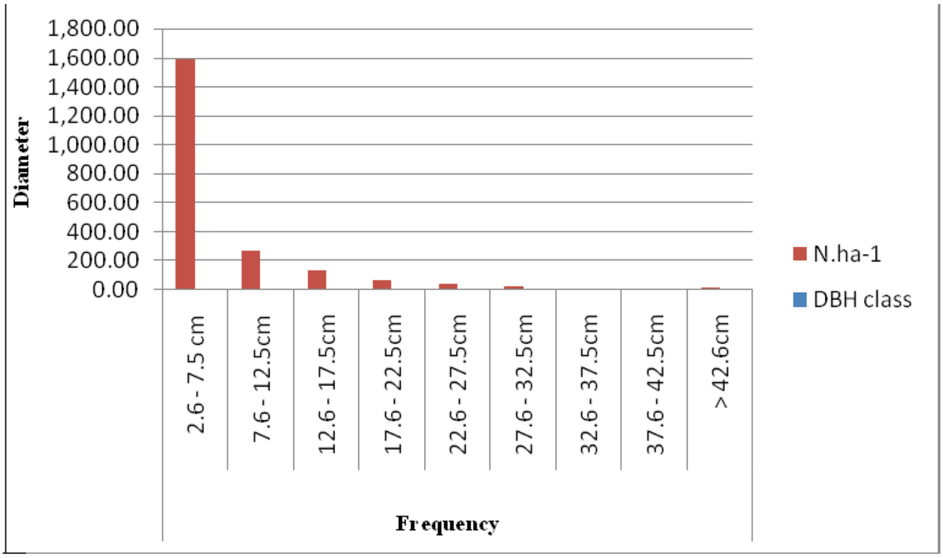

Fig. 2. Diameter-frequency distribution.

On the other hand, from the stand height-frequency profile shown in Fig. 3, it can be seen that the decline in the stem mean densities across the first three height classes was less drastic compared to that of Fig. 2. The apparent difference between the two profiles was probably due to overlapping of certain diameter classes with more than one height class.

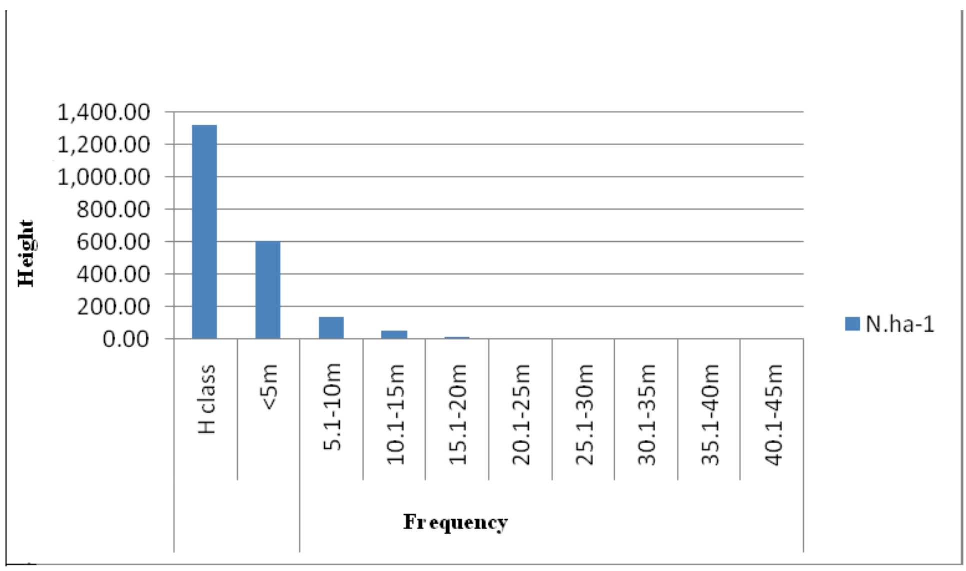

Fig. 3. Height-frequency distribution.

Mean basal area and mean dominance

In the sampled areas of Arba Minch Riverine Forest, only 11 species with a mean dominance of 3.1 $m^2.ha^{-1}$ accounted for 52.8% of the total species dominance, which may be considered the most dominant, and hence, ecologically the most important tree species. These group include: *F. sycomorus, L. fraxinifolius, D. abyssinica, T. dregeana , M. senegalensis, E. divinorum, T. emetica, F. vasta, A. tortilis and S.kunthianum* Cham.

Higher dominance values of *F. sycomorus*, *T. dregeana*, *T. emetica*, *F. vasta*, and *A. tortilis* were largely due to their proportionally bigger dimensions, than their corresponding stem densities. Conversely, the value of *L. fraxinifolius*, *D. abyssinica*, and *M. senegalensis* were due to equally high proportions of both parameters.

On the other hand, a total of 22 species, with a mean dominance of less than 0.004 $m^2.ha^{-1}$ contributed very little to the overall species dominance. Typical representatives include: *Celtis* sp*, Rhus* sp*, S. bicapsularis* (L.) Roxb.*, E. abyssinica, C. farinosa, S. guineense, C. molle, C. zenkeri* Engl.*, Ocimum* sp*, C. myricoides,.A. schimperi* (A. DC.) Schwein*, Combretum* sp*, G. ferruginea, F. virosa, C. edulis* and *V. amygdalina.*

Mean total basal area in Arba Minch Riverine Forest is about 25.2 m^2ha^{-1}, and this value falls within the normal range of basal area for virgin tropical rainforests in Africa. Dawkins (1958) reported that value of the latter tends to vary between 23 and 37m^2 ha^{-1}.

The highest mean basal area value was attained for fewer numbers of larger-sized individuals, i.e. with DBH greater than 42.6 cm in this regard. *Ficus sycomorus,* followed by *L. fraxinifolius*, *D. abyssinica*, *T. dregeana* and *M. senegalensis*, were the most dominant tree species in Arba Minch Reverine Forest.

The contribution of the above-mentioned five species to the total basal area, important value index, total frequency and density, accounted for 75%, 58%, 36% and 57%, respectively. Some species with low importance value index (IVI) such as *F. vasta* and *A. tortilis* were ranked among the top ten in the case of basal area. This could be due to the fact that these species were represented only by fewer, but larger and older individuals (low density and frequency).

Species with the highest basal area do not necessarily have the highest density and this indicates the size difference between species. A typical example called *A. fruticosa*, though more densely represented in the area, showed low contribution to basal area. Likewise, *F. sycomorus,* though represented by fewer individuals, its contribution to the overall basal area of the forest was exceptionally high. Basal area provides a better measure of the relative importance of the species than simple stem count (Cain and Castro, 1959). Therefore, species with the largest contribution to the total basal area can be considered as the most important woody species in the forest.

High density and high frequency indicated regular horizontal distribution of the species in the forest, and such type of distribution were exhibited by *L. fraxinifolius, D. abyssinica, M. senegalensis* and *E. divinorum*. High density, low frequency and low dominance values were typical for under storey species that occurred in clusters such as *A. fruticosa* and *R. natalensis*. High density and high frequency, coupled with high dominance, implies the overall dominance of a species in a given forest, and this was exhibited by *L. fraxinifolius* and *D. abyssinica* in the case of Arba Minch Reverine Forest.

Importance Value Index (IVI)

Importance Value Indices (IVI) of the tree/shrub species in Arba Minch Reverine Forest showed wide range of variation (0.06-12.9 %). About 78% of the total IVI was contributed by only 18 species (21.2 %), among which the notable woody species were L.fraxinifolius *(*12.6 %), *D. abyssinica (10.9* %), *F. sycomorus (*8.9 %), *M. senegalensis* (6.1 %), *E. divinorum* (6.0 %), *T. dregeana* (5.2 %), A. *fruticosa* (4.7 %), *R. natalensis* (3.4 %), *S. kunthianum* (2.40 %) and *E. trichogyne* (2.13 %). Such high IVI values with respect to species like *F. sycomorus* and *T. dregeana* was due to their relatively big dimensions.

On the other hand, one group of 25 (26.74 %) species was with quite negligible contribution (2.27 %). Another group of 18 species contributed only slightly better percentage (5.7 %) than the preceding group. Thus, about half of the total species were characterized by an extremely low conservation status. Such species, taken together, contributed less than 10% to the total IVI of the entire species.

Importance values are important indices in the characterization of forest vegetation (Cain *et al*., 1956) and are imperative to compare the ecological significance of species (Lamprecht, 1989). Curtis and McIntosh (1951) also stated that a more realistic assessment of the extent of dominance from the structural standpoint may be achieved by computing the species IVI which incorporates measures of basal area, and extent of spatial distribution as well as population size. According to Curtis and McIntosh (1951), IVI indicates the extent of dominance of a species in the structure of a forest stand and the highest importance value of the species are the leading dominants of the forest. Accordingly, the ten leading dominants in the Arba Minch Riverine Forest were *L. fraxinifolius, D. abyssinica, F. sycomorus, M. senegalensis, E. divinorum, T. dregeana, A. fruticosa, R. natalensis, S. kunthiunum* and *E. trichogyne*.

Population structures of some tree species

The analysis of density/ frequency distribution against diameter classes of woody species in Arba Minch Reverine Forest resulted in four general patterns of population structure (Fig. 4). High densities in small diameter classes indicated a good regeneration capacity, while under-representation of these classes indicated limited regeneration capacity. The potential to replace the latter group of species would be very low once the matured individuals disappeared. Population structures of trees and factors affecting their potential regeneration have significant implications to their management, sustainable use and conservation.

The first group (Pattern I) was formed by species having the highest density of stems ha^{-1} in the first and or second DBH class and the pattern showed a gradual decrease in the number of individuals towards the biggest classes. Fig. 4a shows population structure of *C. africana* as a typical example of this pattern. Other species forming this group included *T. dregeana* and *M. senegalensis.*

In the second group (Pattern II), the first one/two classes had the highest density, but the adjacent classes (third/fourth) were badly represented. Density rose again less sharply in the intermediate classes and declined in the upper unit of the DBH range. Fig.4b shows the population structure of *T. emetica* as a typical example of this pattern, and other species under this group such as *M. undata, P. capensis* and *V. dainellii.*

The type III population curve (Pattern III) was characterized by the concentration of the greater part of the individuals (50 % or more) in the first and second size classes, while the remaining classes were poorly represented (reversed "J" curve). Fig. 4c shows population structure of *L. fraxinifolius* as a typical example of this type of pattern and other species under this pattern included *D. abyssinica* and *S. kunthianum.*

The type IV population curve (Pattern IV) included all big canopy tree species, which were found abundantly from this analysis. These species showed a trend of continuous increase towards the biggest DBH classes, but with the smallest classes badly represented. Fig. 4d shows population structure of *Cordia africana* as a typical representative of this pattern, and other species under this pattern included *F. sycomorus, A. polyacantha, A. tortilis, Kigelia africana, Balanites aegyptiaca* and *M. butugi.*

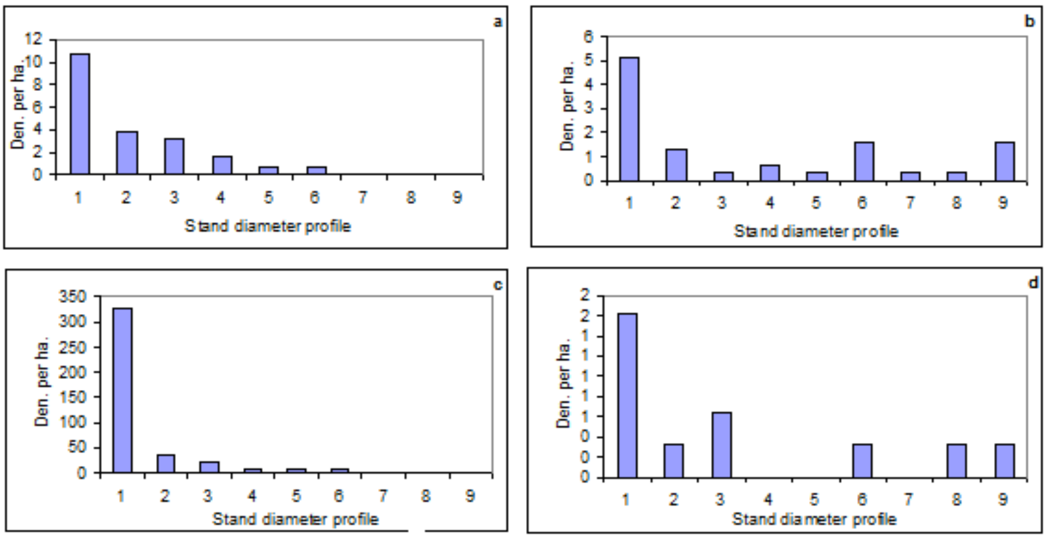

Fig.4. Four representative patterns of population structure of species: a = *C. Africana;* b = *T. emetic*; c = *L. fraxinifolius*; and d = *C. africana*

The result obtained from the socio-economic survey conducted a decade earlier by Safford (1992), and more recently by Lemlem Aregu and Fassil Demeke (2006), and assessment of impact of human activities on this forest by Aramde Fetene *et al*. (2012) revealed that many of the species forming Type I, II and IV patterns were intensively smuggled into the area by a growing number of immigrants living in the Arba Minch town. These woody species would supply the urban population of Arba Minch town with forest products, with a wide variety of uses such as: construction of houses, fences and agricultural implements; furniture making (from a sawn timber); wood curving; and fuelwood and charcoal making.

Regeneration status

Khan *et. al*. (1987) suggested that vegetation was considered having: good regeneration potential if seedlings > saplings > adults; fair regeneration if seedlings > or ≤ saplings ≤ adults; poor regeneration if the species survives only in sapling stage, but with no seedlings (saplings may be <, > or = adults); and no regeneration if a given species is not represented by its own regeneration. As shown in Table 5, less than one-third (only 27 out of 94) of the total woody species in Arba Minch Reverine Forest were represented by their own regeneration. Further detailed analysis of the same data using the methodology suggested by Khan *et al*. (1987) showed that even amongst these 27 species, not more than 10 can be considered as Category I species (i.e. species having good regeneration potential). These were subsequently followed by a group of six more species forming Category II (i.e. species having fair regeneration potential), and 12 species falling under Category III (i.e species having poor regeneration potential). Under Category IV, there were a total of 67 species, of which 63 (67.8%) were not at all represented by their own regeneration; and under the last group (Category V), 4 (4.25%) were represented as seedlings or saplings only, this group consisted of *Prunus africana*, *Dovialis verucosa*, Ballanti (GVN) and Karachi (GVN).

Table 5. Number of species and regeneration density versus species groupings*.

Parameter	Species groupings					Sum
	I	**II**	**III**	**IV**	**V**	
Total Number of Species	10	6	11	63	4	94
% of Total Number of Species	11	6	12	68	4	100
Total Reg. Density ($N.ha^{-1}$)	11,435	4,226	581			16,332
% of Total Reg. Density	70	26	3.6			100

Note: Category I = **“Good Regeneration**” if $N.ha^{-1}$ of Seedlings > $N.ha^{-1}$ of Saplings > $N.ha^{-1}$ of Adults per Species; Category II = **“Fair Regeneration**” if $N.ha^{-1}$ of Seedlings < $N.ha^{-1}$ of Saplings < $N.ha^{-1}$ of Adults per Species; Category III = **“Poor Regeneration**” if there is only Adult population but no Seedlings and Saplings per Species; Category IV = **“No Regeneration”** if a Species lacks any regeneration; Category V = **“Regeneration Only**” if the Species occurs as Seedling or Sapling only.
* Based on population size of seedlings, saplings and adults (Khan *et al.,* 1987)

Even among the species, which were actually represented at the regeneration stage, only 5 (7%) had abundant regeneration. Out of the total density of seedlings and saplings (4,722, and 3,435 ha^{-1}, respectively) recorded in the sampled areas of Arba Minch Reverine Forest, 93% was contributed by only 10 (13%) of the species. The ten most abundantly represented tree species were *L. fraxinifolius, D. abyssinica, E. divinorum, S. kunthianum, M. butugi, T. nobilis, T. dregana, V. dainnelii, A. fruiticosa and E. trychogyne*. Most of these species were typical representatives of the trees, forming the middle strata (MS), but their contribution to the formation of the upper forest strata (US) was much lower. However, only *M. butugi* and *T. dregana*, which might appropriately be considered an exception in this regard, exhibited high regeneration status, irrespective of the high tree density (2,158 $stem.ha^{-1}$). This, in turn, implied dense canopy cover, and probably indicated at least 8 out of the above-mentioned tree species as shade tolerant species. The other two species under this group, namely: *R. communis* and *T. orientalis* were apparently gap species.

Some of the typical examples of the Category IV (species with no regeneration potential) included: *S. spinosa, T. brownii, A. drepanolobium, A. seyal, A. leiocarpa, C. myricoides, C. molle, C.* sp*, F. vasta, F. virosa, T.orientalis, V. amygdalina, C. zenkeri,* and *P. dodecandra.* The two genera of woody plants, namely: Ficus and Acacia (both represented by an exceptionally high number of species) were among the species, which showed “no regeneration” status. A considerable number of the tree species in this group (e.g. *F. sycomorus*, *F. vasta, F. ovata, T. emetca, A. tortolis, A. nilotica)* were important canopy species.

Lamprecht (1989) reviewed descriptions about irregular distribution and inadequate regeneration of the tree species in a wide range of moist montane formations. In light of Lamprecht (1989) review, three hypotheses were suggested. Out of the three hypotheses suggested to explain this phenomenon, the "hypothesis of long-lived pioneers" appeared to be applicable to the Arba Minch Reverine Forest. According to this hypothesis, forests that plainly had insufficient regeneration/recruitment of certain tree species were not climax formations, but rather secondary forests, in the later stage of succession. Only forests in earlier stages of succession offered suitable regenerative power and growth conditions with an irregular structure of diameter, in compliance with their higher light requirements. But these conditions are virtually non-existent in the later stage of succession. Since these species could reach an advanced age and survive very long in the upper storey, they were described as "long-lived pioneers" or "late secondary species". They only regenerated under exceptional circumstances, and as recruitment from natural regeneration had virtually ceased, they were gradually phased out due to old age and other factors.

In fact, Logan (1946) reported that the Southwest forests of Ethiopia (including Arba Minch Reverine Forest) were essentially secondary formations. The present inventory was conducted exclusively under the existing forest canopy, which meant that, in most cases, the sampled plots represented areas under the existing forest canopy. The fact that the great majority of the woody species in the sampled areas of Arba Minch Reverine Forest showed inadequate and /or total lack of regeneration, and irregular horizontal and vertical distribution of the densities.ha^{-1} (Fig. 4d) reflected that Arba Minch Reverine Forest represented the later stage of secondary forest.

Species prioritization for conservation

The existing conservation status of each species was evaluated from combined criteria based on importance value index (IVI), population structures of species, stand diameter, height profiles, and regeneration status. Selection of priority species for conservation was thus carried out using results of the foregoing evaluation. The approach envisaged was believed to provide scope for more realistic evaluation, and hence rational selection of priority species for conservation. The overall process of selection was performed at two successive stages. First, it was conducted separately with respect to each of the above-stated parameters. Secondly, the emerging priorities were combined together. These species were selected based on the technical criteria, which give preference to those species showing the lowest IVI values. However, this report considered two more denominators, as suggested above. Accordingly, species showing very irregular population structure, and those showing poor and/or no regeneration status were given due preference. In addition to the 26 species, a total of six more species were included: *V. dainellii* and *M. ferruginea*, which were endemic to Ethiopia (Ensermu Kelbessa *et al.*, 2000); *M. butug and C. Africana,* which were among the list of endangered species of the country (Hilton-Taylor, 2000); and *P. Africana* and *M. arbutifolia,* which were among the vulnerable species in the proposed list of priority species for Arba Minch Reverine Forest. Thus, this would make the number of priority woody species 32.

CONCLUSION

The floristic composition revealed that Arba Minch Riverine Forest is made up of about 94 woody species. The analysis of the structural parameters suggested a prevalence of an exceptionally high level of heterogeneity in the woody species. The great majority of the woody species in the forest showed irregular horizontal and vertical distribution of woody species density.

The most apparent shortcoming of using IVI for identification of priority species for conservation implied that species with big dimensions are not threatened. On the contrary, further examination of the population structure had indicated that a considerable number of tree species were characterized by a progressive decline in ecological status irrespective of their high IVI values.

In view of this, recommending species priority for conservation on the basis of IVI alone would lead to erroneous decisions. This study suggested a critical revision of the use of IVI as a criterion for selection of priority species. In this regard, population dynamics of species would offer more reliable picture. However, to overcome the above-mentioned shortcoming, the significance of IVI and basal area so as to identify ecologically dominant species was recognized, as described by Curtis and McIntosh (1951) and Cain and Castro (1959), respectively.

In line with these concepts, the 12 most dominant and important species in maintaining the natural ecosystem of the Arba Minch Reverine Forest were *L. fraxinifolius, D. abyssinica, F. sycomorus, M. senegalensis, E. divinorum, T. dregeana, A. fruticosa, R. natalensis, S. kunthianum, E. trichogyne, T. emetica* and *F. vasta.* Therefore, these species are ecologically important and need due attention for conservation. Besides, species such as *V. dainellii*, *M. ferruginea, M. butugi, P. africana*, *M. arbutifolia, C. albiflora* and *Cordia africana* should also be considered for conservation as they are endemic and among the woody species listed in the Red Book of Ethiopia.

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