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RESEARCH ARTICLES

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FLORISTIC RICHNESS AND CONSERVATION STATUS OF BOGINDA FOREST, SOUTHWESTERN ETHIOPIA.

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ABSTRACT: The main objective of this study was to assess the conservation status of Boginda forest and identify the endangered woody plant species for recommending appropriate genetic conservation approaches in the area. Systematic sampling was employed with a total of three parallel transects. A total of 29 sample quadrats were established and duly investigated. These sample quadrats were distributed within specified location fixed at regular intervals of 50m drop of altitude. The stand structure was enumerated in the 10x50m quadrats. All woody species were recorded and analysed. In setting the priority rank, the Important Value Index (IVI), population structure of species and regeneration status criteria were considered. Using these criteria, the woody species *Canthium oligocarpum, Cassipourea malosana, Ficus exasperate* and *Schefflera volkensi* were found to be the top priorities to be considered for conservation. Boginda forest was also found to be highly threatened by human pressure and needs attention for its conservation and sustainable utilization. From this research, an easy and manageable woody species prioritization and conservation approach is presented for threatened forests.

Key words/phrases: Boginda Forest; Density; Floristic; Frequency; Important Value Index.

INTRODUCTION

The conservation and sustainable utilization of endangered species has received the attention of scientists (Noss, 1983; Shackleton, 2000). This is due to the fact that in the geologic history of the earth, the present rate of species loss represented the sixth great extinction event (May *et al.*, 1995). The previous five extinctions were caused by natural processes, but the present fast rate of biological diversity loss is driven by anthropogenic activities (Chapin *et al.*, 2000). The increasing habitat change and degradation, mainly due to agricultural expansion and development, are the main causes of species diversity decline (Sala *et al.,* 2000). Dramatic increases in deforestation have produced numerous small and fragmented habitats especially in the tropics.

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Habitat fragmentation has a tremendous impact on the biodiversity of tropical forests with respect to species loss and, more recently, to a reduction of species diversity (Laurance and Bierregaard, 1997; White *et al.,* 2002). The impact of such habitat fragmentation on the genetic structure and gene flow within the fragmented landscapes is poorly understood. It is obvious that fragmentation decreases the size and increases the spatial isolation of populations, and its effect on the dynamics of gene flow can directly influence the genetic structure within a forest fragment (White *et al.*, 2002). Genetic isolation can cause a reduced gene flow among fragments and eventually has determinant consequences on the evolutionary variability of populations by way of increased levels of inbreeding and random genetic drifts (Young *et al.*, 1996; Wolf, 1999; White *et al.*, 2002). The montane forests in southwestern Ethiopia are facing such phenomena at present.

The Southwestern Montane Forests of Ethiopia are repositories and gene pools for several domesticated and/or wild plants and wild relatives of domesticated crops as well as wild animals and microbes. The few remaining high forests are, at present, threatened by pressure from investors who are converting these areas into other land use systems, such as coffee and tea plantations. A huge proportion of the Bonga and Masha-Anderacha forests have been cleared without any assessment of the economic and environmental contribution and significance to biodiversity in general and forestry in particular (Taye Bekele *et al.*, 2001). The role of investment in economic development is undeniable, but it should be done without harming the environment and should be accompanied by an appropriate environmental impact assessment before and after intervention.

Boginda Forest, one of the hotspots in southwestern part of Ethiopia, is penetrated by Diri-Masha road. The highest rate of deforestation of Boginda forest could lead to higher forest genetic erosion as in other parts of the country. The results obtained from the socio-economic survey of Consulting for Coffee Conservation (Anonymous, 1998) showed that the major causes of deforestation in Boginda forest are clearing/burning of the natural forest for cultivation of food crops, planting coffee, settlement, chasing of wild animals, pit-sowing, cutting of trees/shrubs for fuel wood, construction materials and cutting of big trees to harvest honey. The same report also confirmed that *Cordia africana* and *Pouteria adolfi-friederici* are in an endangered state as a result of heavy exploitation. This destructive exploitation of the forest has caused tremendous forest degradation leading to decrease and final extinction of the forest species. Taking these challenges into account, the main objective of the present study was to assess the conservation status of Boginda Forest and identify the endangered woody plant species for recommending appropriate genetic conservation approaches in the area.

MATERIALS AND METHODS

Study area

Boginda Forest covers some 7500 ha of natural high forest and is administratively located in Gimbo Woreda, Kafa-Shaka Zone in Southern Nations, Nationalities and Peoples Region. Medabo Kebele and Oromia Region border the area to the north while it is bordered by Gomma and Saja Kebeles to the south, respectively. Geographically, the forest is situated between $7^{0}29.000'$ to $07^{0}33.400'$N latitude and $36^{0}02.580'$ to $36^{0}06.570'$E Longitude.

Materials

The woody plant inventory of Boginda forest was carried out from December 26, 1999 – January 03, 2000. Geographic location of each quadrat was determined using Garmin GPS 48. The same instrument was also used to determine the position of the beginning of each quadrat. The altitude of each quadrat was recorded using an Alpin-El altimeter and the aspect (exposure) was measured by using a compass.

Methods

Systematic sampling was employed for this study. The optimum number of the transect lines, their spatial distribution and the total coverage was determined following a preliminary reconnaissance of the forest. A total of 3 parallel transects were selected. Each of these transect lines begin at the top of Saja escarpment that marks the highest altitude (2270m a.s.l.) as well as the southern boundary of the area and tend north to the bottom of Gojeb valley (1600m a.s.l.). The beginning and end points (the latitude and longitude) of the selected transects were marked using GPS as well as on the topomap of 1:50,000.

A total of 29 sample quadrats were established and duly investigated. These sample quadrats were distributed within specified location fixed at regular intervals of 50 m drop of altitude. The stand structure was enumerated in the 10x50 m quadrats along the direction of the transect.

Each woody plant within the quadrats was measured and plant specimens were collected for every woody species. Most woody species encountered in the quadrats were recorded using both scientific and local names, and whenever scientific names were not identified, the woody species were recorded using their local names.

The diameter and height of all tree and shrub species > 2.5cm in diameter were measured for the 10 x 50m quadrats. The type of ligneous plant was also defined using the following codes: S = Shrub, T = Tree and L = Liana. The DSH (diameter at stump height) (at a height of 0.3 m from the ground) and DBH (Diameter at breast height) (1.3 m from the ground) was measured over bark using a caliper. The DSH measurement was taken for shrub species and DBH measurement was done for tree species. The heights of all tree/shrub species were measured by Suunto clinometer and were estimated when it was difficult to measure. For Liana species, only their scientific and/or local names were recorded.

All seedlings and saplings were also enumerated by species from two (2 x 10m) sub-quadrats inside each quadrat. The sub-quadrats (2 x10m) were laid at the beginning and endpoints of the quadrats (i.e., 1m on each side of the base line of the 50 m) and for each quadrat 40m^2 of sub quadrats were laid and the number of seedlings and saplings encountered were counted in these sub-quadrats.

Data analysis

The vegetation, physiographic and anthropogenic data analysis were performed by Access and Excel software. The structural analysis of the woody plants, basal area and dominance calculations were also performed by using this software. Accordingly, the density was calculated using equation 1 and the relative density using equation 2.

$$d = \frac{\sum t}{s_{ha}}$$ Equation 1

where d is density of all tree/shrub species, t total number of stems of all tree/shrub species, s_{ha} = sample size in hectare

$$rd = \frac{\sum t}{ts}$$ Equation 2

where rd is relative density of each individual tree/shrub, t is total number of stems of all tree/shrub species, ts is total number of stems of all tree/shrub.

The frequency (equation 3), relative frequency (equation 4), basal area (Ba) (equation 5), dominance (equation 6) and relative dominance (equation 7) and importance value index (equation 8) were also calculated for each tree/shrub species with DBH/DSH >2.5cm.

$$f = \frac{nQ}{tQ} \times 100$$

Equation 3

where f is frequency, nQ is number of quadrats in which a species recorded and tQ is total number of quadrats.

$$rf = \frac{f}{\sum tf}$$

Equation 4

where rf is relative frequency, f is frequency of a species and $\sum tf$ is sum frequency of all tree/shrub species.

$$Ba = 22 \times \frac{d^2}{28}$$

Equation 5

where Ba is = basal area and d is diameter at breast height or stump height.

$$Do = mBa \times d$$

Equation 6

where Do is dominance, mBa is mean Ba per tree/shrub species and d is *density of a tree/shrub species*.

$$rDo = \frac{mBa}{\sum mBat} \times 100$$

Equation 7

where rDo is relative dominance, mBa is mean Ba per tree/shrub species and $mBat$ is mean BA of all tree/shrub species.

$$IVI = rd + rf + rDo$$

Equation 8

where IVI is importance value index, rd is relative density, rf is relative frequency and rDo is relative dominance.

RESULTS AND DISCUSSION

Floristic composition

A total of 73 woody plant specimens were identified from Boginda Forest, of which 70 were within the sample plots and three were outside the sample plots. Out of 73 specimens encountered in this forest, 66 have been identified to the species level, four to the genus level and three have been left unidentified. The specimen identified belongs to 60 genera and 36 families.

The most diverse family of this forest was Rubiaceae followed by Euphorbiceae, Celasteraceae and Fabaceae (represented by six, five, four and four species respectively). About 47% of the families were represented by one species. The three species recorded using local names were “Chamo”, “Dio” and “Tio”. These three species were also found to be liana in their growth habit.

The Humid Montane Jibat Forest, which has close floristic similarity with the Moist Evergreen Montane forests of southwestern Ethiopia, has 53 tree and shrub species (Tamrat Bekele, 1994), and when these two forests were compared, Boginda Forest is said to be much richer than Jibat Forest.

The growth habit distribution of all the woody species recorded in Boginda Forest showed that 48% were trees, 23% were trees/shrubs, 12% were shrub, 14% were lianas and two species were encountered as regeneration. The species that were found as regeneration only were *Vangueria sp* and *Vernonia amygdalina.*

The upper canopy of this forest was dominated by *Pouteria adolfi-friedericii*, *Polyscias fulva*, *Prunus africana* and *Macaranga capensis*. The middle canopy is also dominated by *Croton macrostachyus*, *Ficus sur*, *Elaeodendron buchananii*, *Syzygium guineense*, *Trema orientalis*, *Apodytes dimidiata*, *Bersama abyssinica*, *Trilepsium madacascariense*, *Allophylus abyssinicus*, *Millettia ferruginea*, *Maesa lanceolata*, *Olea capensis*, *Pittosporum virdiflorum*, *Ilex mitis*, *Canthium oligocarpum*, *Albizia gummifera* and *Ehretia abyssinica*.

Some species such as *Albizia schimperiana, Blighia unijugata* and *Ocotea kenyensis* were reported to be dominating the upper canopy in the southwestern forests as a whole, and species such as *Erythrina brucei*, *Drcaena fragrans, Oxyanthus speciosus, Rithiea albersii, Phyllanthus limuensis,* and *Whitfieldia elongata* were found to be dominating in the middle, lower canopy and shrub stratum (Fris, 1992) were not encountered at all during this woody plant inventory survey. On the other hand four species namely, *Dalbergia lactea, Elaeodendron buchanani, Phyllanthus reticulates* and *Trilepsium madagascariensis* have never been reported to exist in southwestern forests as a whole. Therefore, Boginda forest may be the place where the marginal populations of these species exist and special attention should be given concerning these species.

The woody species recorded in this forest had also unequal abundance (here defined as the number of individuals of each tree/shrub species in 1.45 ha) and the forest area is dominated by few species (Fig. 1). *Millettia ferruginea*, which alone accounted for 301 (13%) of the total 2275 individuals), was 2.4 times more abundant than the fourth abundant species, *Vepris dainellii*. At the other extreme, there were 15 species with less than five individuals. The reasons for the unequal distribution of these species could be the exploitation of some species, which have potential for commercial or local use of the woody products. Moreover, some species may require special habitat for their regeneration and this may contribute to the different number of individuals of each species as well as the rare species, which are rare, which could be recent immigrants from population centers outside the forests (Tadesse Woldemariam, 1998).

Frequency

All the woody species encountered in Boginda forest were grouped into five frequency classes. These frequency classes are: woody species with frequency value of 81 – 100 = A, 61 – 80 = B, 41 – 60 = C, 21 – 40 = D and 0 – 20 = E (Fig. 2).

The frequency gives an approximate indication of the homogeneity or heterogeneity of a stand. Lamprecht (1989) pointed out that high values in frequency class A/B and low values in D/E indicated constant or similar species composition. On the other hand, higher values in lower frequency classes and lower values in higher frequency classes indicated a higher degree of floristic heterogeneity. In this regard, only 10% of the species recorded in Boginda forest were found in frequency class A/B and 79% of the species were found in frequency class D/E. Therefore, it is possible to say that Boginda forest has heterogeneous species composition.

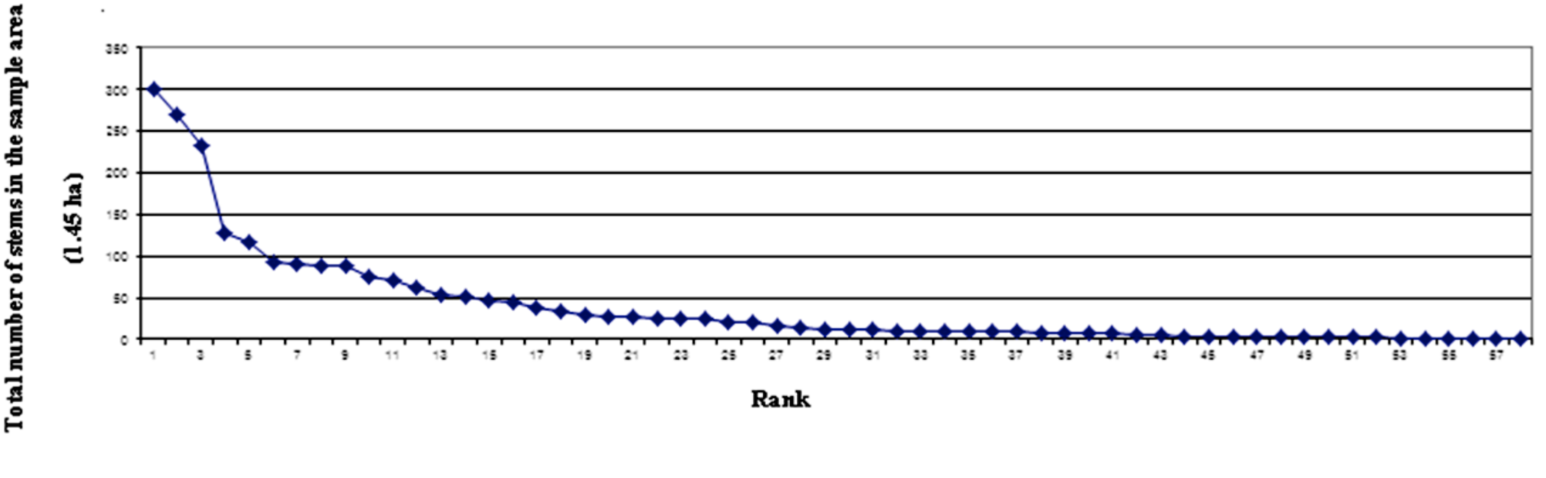

Fig. 1. Number of individuals against their rank (abundance curve) of the woody species recorded in all quadrats.

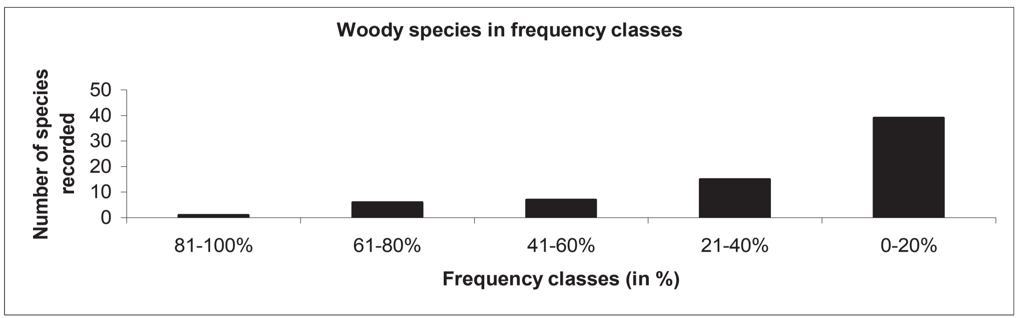

Fig. 2. Frequency class distribution of all species recorded in Boginda Forest.

The most frequent species in this forest were: *Millettia ferruginea, Chionanthus mildbraedii, Vepris dainellii, Bersama abyssinica* and *Galinera saxifraga* (with a frequency of 86.2, 79.3, 75.9, 75.9 and 72.4%, respectively). Apart from these, the following woody species were recorded in more than 50% of the assessed quadrats: *Dracaena afromontana, Dracaena steudneri, Croton macrostchyus, Psychotria orophila and Pouteria adolpfi-friedericii.* Interestingly, the most frequent tree species in this forest, *Millettia ferruginea*, was the least frequent and rarest species in Chaffey's (1982) reconnaissance survey of the southwestern forest as a whole. This indicates that Boginda Forest and its surroundings might be the natural territory of *Millettia ferruginea*.

The least frequent woody species of this forest were: *Cassipourea malosana*, *Acanthus sennii*, *Deinbolia kilimandscharica*, 'Tio', *Tiliacora funifera*, *Schefflera volkensii*, *Rubus apetalus*, *Rhamnus prinoides*, *Dalbergia lactea*, 'Dio', *Ficus exasperata*, *Euphorbia candelabrum* and *Euphorbia abyssinica* (with frequency value of 3.45%) and *Tiliacora troupinni*, *Phyllanthus reticulates*, *Phoenix reclinata*, *Jasmiium abyssinicum*, *Embelia schimperi*, *Dmbeya torrida*, 'Chamo', *Canthium oligocarpum* and *Albizia grandibracteata* (with frequency value of 6.9%). It is shown that 15% of the woody species had a relative frequency of 3 – 6%, 36% of them had 1 –3%, and 49% of them had a relative frequency of <1%.

Density

The total density of the woody species (with DBH/DSH >2.5cm) in Boginda forest was 1569 individuals (stems) per ha. Density of tree/shrub species over 10cm DBH >600 is normal for virgin rain forest in Africa (Richard, 1966, cited in Lamprecht, 1989). The density of all species with DBH/DSH over 10cm in Boginda forest was found to be 478.6. Therefore, the stems per ha coverage of Boginda Forest is below normal coverage and this may be due to serious exploitation in the past.

The density of all the species recorded were assessed and grouped into five density classes. These density classes are: woody species with stem numbers per ha of >100 = A, 50.1 – 100 = B, 10.1 – 50 = C, 1.1 – 10 = D and <1 = E. Only 5% of the species were represented with >100 stems per ha, while 54% had an average density of less than 10 stems per ha (Fig. 3).

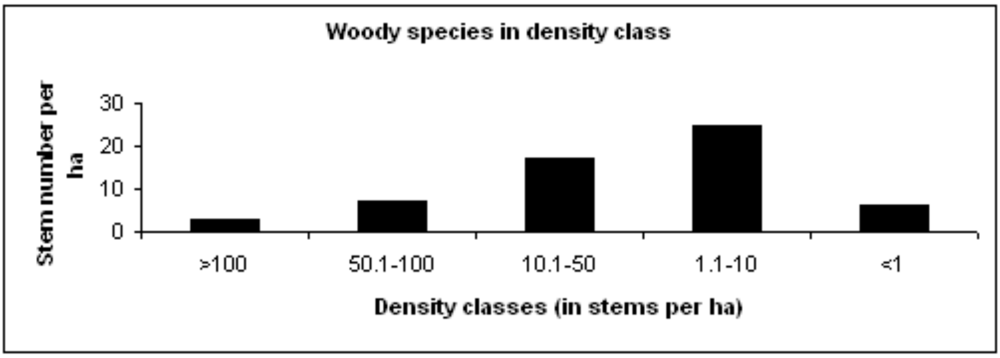

Fig. 3. All woody species in different density classes.

The woody species with <1 stem per ha were: *Cassipourea malosana, Dalbergia lactea, Euphorbia abyssinica, Euphorbia candelabrum, Hypericum sp.* and *Schefflera volkensii.* About 19% of the woody species in this forest had also a relative density of 3 –13%. These include *Millettia ferruginea, Dracaena afromontana, Chionanthus mildbraedii, Vepris dainellii, Bersama abyssinica, Galinera saxifraga, Macaranga capensis, Coffea arabica, Psychotria orophila, Dracaena steudneri* and *Clausena anisata.* About 59% of the woody species had a relative density of less than one. Some of the woody species with least relative density were: *Dalbergia lactea, Cassipourea malosana, Schefflera volkensii, Ficus exasperata, Albizia grandibracteata, Canthium oligocarpum, Dombeya torrida, Deinbolia kilimandscharica, Maytenus gracilipus, Appodytes dimidiata, Olea capensis* and *Cordia africana.*

Basal area and Dominance

The total basal area (m^2/ha) of all species with DBH/DSH >2.5cm of Boginda forest was 63.5. The normal value of basal area for virgin tropical rain forest in Africa is 23 – 37m^2 ha^{-1} (Dawkins, 1959, cited in Lamprecht, 1989). Therefore, it could be said that the basal area per ha coverage of Boginda Forest is very high.

Schefflera abyssinica accounted for the highest proportion of mean basal area in this forest, followed by *Pouteria adolfi-freidrcii, Prunus africana, Olea capensis, Polyscias fulva and Schefflera volkensii* (with mean basal area values of 0.94, 0.86, 0.50, 0.31, 0.27, and 0.11 m^2, respectively). The following woody species were found to be with smaller mean basal area: *Phyllanthus reticulates, Acanthus eminens, Justicia schimperiana, Maytenus gracilipes, Acanthus sennii, Rhamnus prinoides* and *Solanecio gigas* (with mean basal area value of <0.0016 m^2).

About 73% of the total basal area of Boginda Forest was contributed by the highest diameter class (>42.5 cm) and the remaining diameter classes have roughly a uniform distribution of basal areas (Fig. 4).

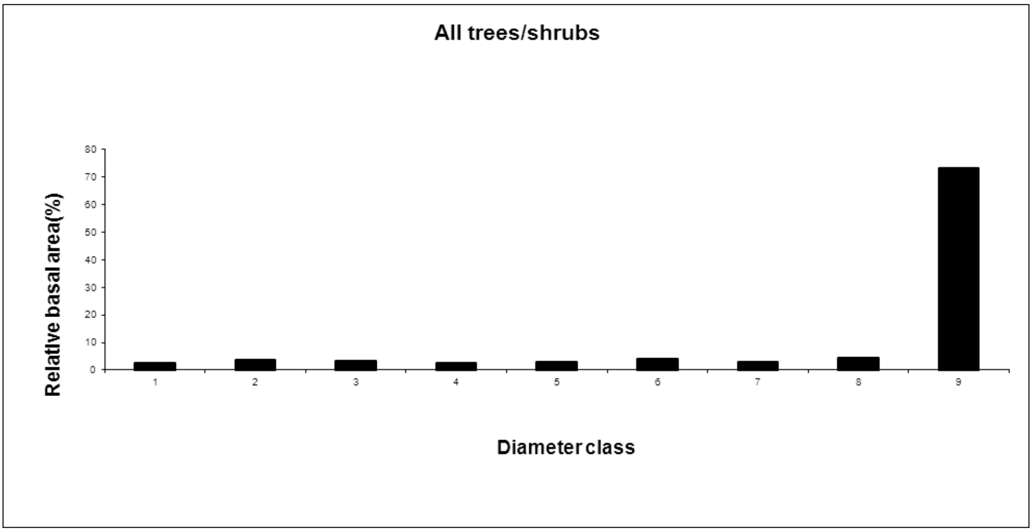

Fig. 4. Basal area distribution in diameter class of Boginda forest 1= 2.6 - 7.5; 2= 7.6 - 12.5; 3= 12.6 - 17.5; 4= 17.6 - 22.5; 5= 22.6 - 27.5; 6= 27.6 - 32.5; 7= 32.6 - 37.5; 8=37.6 - 42.5; 9= >42.5

Species dominance is the mean basal area per ha coverage of each individual woody species in the forest. About 89% of the dominance was accounted by 12 woody species of the forest. These include: *Pouteria adolfi-friedericii, Schefflera abyssinica, Millettia ferruginea, Prunus africana, Macaranga capensis, Syzygium guineense, Dracaena afromontana, Dracaena steudneri, Polyscias fulva*, *Croton macrostachyus, Olea capensis* and *Trilepsium madagascariense*.

The woody species with least dominance value in this forest were *Hypericum* sp., *Euphorbia abyssinica*, *Dalbergia lactea*, *Acanthus eminens*, *Acanthus sennii*, *Rhamnus prinoides*, *Maytenus gracilipes*, *Cassipourea malosana*, *Phyllanthus reticulates*, *Albizia grandibracteata*, *Justicia schimperiana* and *Dombeya torrida*.

Importance Value Index (IVI)

Importance Value Index (IVI) is useful to compare the ecological significance of species (Lamprecht, 1989). The Importance Value Index of all species with DBH/DSH >2.5 cm was calculated for all tree/shrub species. The most important tree/shrub species in Boginda forest were: *Pouteria adolfi-friederici, Millettia ferruginea, Dracaena afromontana, Chionathus mildbraedii, Schefflera abyssinica, Vepris dainellii, Macaranga capensis, Dracaena steudneri* and *Bersama abyssinica* (with IVI values of >10).

The most important woody species, *Pouteria adolfi-friedericii*, was 2 times more important than the second ranked species, *Millettia ferruginea*, and 2.5 times more important than the third important woody species *Dracaena afromontana.* It can be observed from Fig. 5 that *Pouteria adolfi-friederici* got the highest value of IVI due to its high relative dominance. Though the diameter distribution of this species was not normal, there were extremely huge trees in inaccessible areas of the forest.

In the prioritization of the species for genetic conservation, the woody species with higher IVI value will probably get less priority for conservation. In Boginda Forest, *Pouteria adolfi-friederici* is with the highest value of IVI, therefore, it gets less priority. In reality, it is one of the woody species that was poorly represented in diameter class distribution and it was also not totally encountered in sapling assessment. Therefore, the scoring matrix developed for the prioritization of the woody species should consider diameter class distribution and regeneration status of the species in question for genetic conservation.

Woody species with low IVI values in this forest included: *Euphorbia abyssinica*, *Hypericum* sp., *Dalbergia lactea*, *Cassipourea malosana*, *Euphorbia candelabrum*, *Acanthus sennii*, *Rhamnus prinoides*, *Schefflera volkensii*, *Deinbolia kilimandscharica*, *Ficus exasperata*, *Albizia gradibracteata*, *Phoenix reclinata*, *Dombeya torrida*, *Canthium oligocarpum*, *Phyllanthus reticulates*, and *Trema orientalis* (with priority rank of 1 – 16).

Boginda Forest is selected for coffee conservation in the country and highly known for its mother forest coffee spots. But this commercially known woody species got a priority rank of 45. Other woody species, which are highly known for their timber and log value such as *Pouteria adolfi-friedercii, Millettia ferruginea, Macarnga capensis, Syzygium guineense, Prunus africana, Olea capensis* and *Cordia africana* got a priority rank of 58, 57, 52, 48, 44, 39 and 24, respectively. The IVI class distribution showed that 58% of the woody species have an IVI value of 1.1 – 10, 28% between 0 – 1 and only 14% had an IVI value of >10 (Fig. 5).

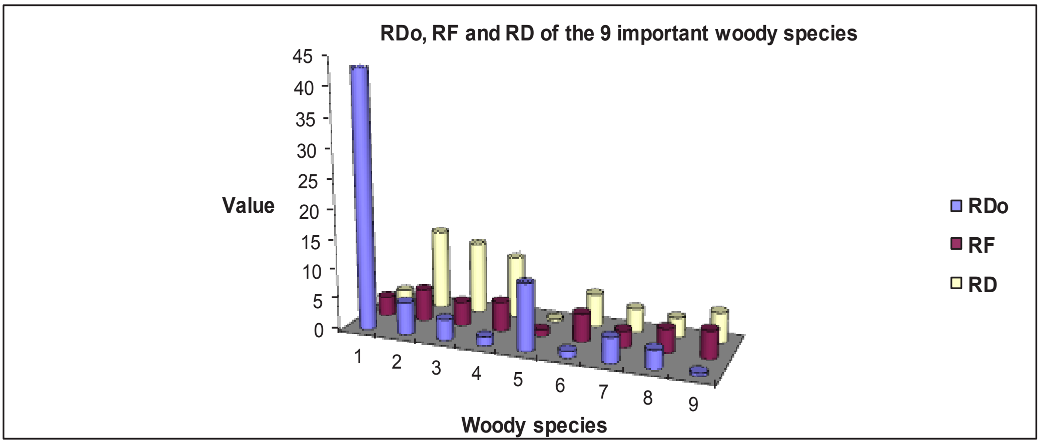

Fig. 5. Relative density (RD), Relative frequency (RF) and Relative dominance (Rdo) of the woody species with IVI value>10; 1: *Pouteria adolfi-friedrci,* 2: *Millettia ferruginea,* 3: *Dracaena afromontana,* 4: *Chionanthus mildbraedii,* 5: *Schefflera abyssinica,* 6: *Vepris dainellii,* 7: *Macaranga capensis,* 8: *Dracaena steudneri,* 9: *Bersama abyssinica.*

Population structures

The population structures of some selected woody species were analyzed. The first six are those with an IVI value of >11 and the rest are valuable timber species. The patterns of population structure of species that emerge can be interpreted as an indication of variation in population dynamics in the forest (Popma *et al.,* 1988 cited in Tamrat Bekele, 1994).

The analysis of population structures of the above 12 woody species resulted in the following three distinct types of structural patterns:

1. Woody species which had bad reproduction and bad recruitment;
2. Woody species which had good reproduction but bad recruitment;
3. Woody species which had good reproduction and good recruitment.

To analyze the conservation status of all woody species of this forest, the types of structural distribution patterns were used and all the woody species encountered were grouped as: Group 1 = Woody species which had bad reproduction and bad recruitment; Group 2 = Woody species which had good reproduction but bad recruitment; and Group 3 = Woody species which had good reproduction and good recruitment.

Accordingly, the following results were obtained from the analysis: about 24% of woody species of Boginda Forest in Group 1, 43% in Group 2 and 33% in Group 3. Based on the analysis of population structure of species, all species in Group 1 were with first priority; species in Group 2 were with second priority and those in Group 3 were with third priority for genetic conservation measures. The list of species under the three groups is given in Table 1.

Table 1. List of species under population structures.

No.	Group 1		No.	Group 2		No.	Group 3	
1	*Albizia*	*grandibracteata*	1	*Acanthus*	*eminens*	1	*Allophylus*	*abyssinicus*
2	*Albizia*	*gummifera*	2	*Acanthus*	*sennii*	2	*Clausena*	*anisata*
3	*Canthium*	*oligocarpum*	3	*Apodytes*	*dimidiata*	3	*Coffea*	*arabica*
4	*Cassipourea*	*malosana*	4	*Bersama*	*abyssinica*	4	*Croton*	*macrostachyus*
5	*Cordia*	*africana*	5	*Brucea*	*antidysenterica*	5	*Cyathea*	*manniana*
6	*Euphorbia*	*candelabrum*	6	*Chionanthus*	*mildbraedii*	6	*Deinbollia*	*kilimandscharica*
7	*Ficus*	*exasperata*	7	*Dalbergia*	*lactea*	7	*Dracaena*	*steudneri*
8	*Ficus*	*sur*	8	*Dombeya*	*torrida*	8	*Ehretia*	*abyssinica*
9	*Phoenix*	*reclinata*	9	*Dracaena*	*afromontana*	9	*Lepidotrichilia*	*volkensii*
10	*Polyscias*	*fulva*	10	*Euphorbia*	*abyssinica*	10	*Macaranga*	*capensis*
11	*Pouteria*	*adolfi-friederici*	11	*Galinera*	*saxifraga*	11	*Maytenus*	*sp*
12	*Prunus*	*africana*	12	*Hypericum*	*sp*	12	*Pittosporum*	*viridiflorum*
13	*Schefflera*	*abyssinica*	13	*Ilex*	*mitis*	13	*Psychotria*	*orophila*
14	*Schefflera*	*volkensii*	14	*Justicia*	*schimperiana*	14	*Rothmannia*	*urcelliformis*
			15	*Maesa*	*lanceolata*	15	*Rytigynia*	*neglecta*
			16	*Maytenus*	*gracilipes*	16	*Solanecio*	*gigas*
			17	*Millettia*	*ferruginea*	17	*Turraea*	*holstii*
			18	*Olea*	*capensis*	18	*Vepris*	*dainellii*
			19	*Phyllanthus*	*reticulatus*	19	*Vernonia*	*auriculifera*
			20	*Rhamnus*	*prinoides*			
			21	*Syzygium*	*guineense*			
			22	*Teclea*	*nobilis*			
			23	*Trema*	*orientalis*			
			24	*Trilepisium*	*madagascariense*			
			25	*Vernonia*	*amygdalina*			

Regeneration status of Bongida Forest

For the regeneration status, seedling (all species with height <=30cm and DBH <=2.5 cm) and saplings (all species with height >30 cm and <2 m and DBH <=2.5 cm) were assessed. A total of 27 woody species were recorded as seedlings in Boginda Forest, which belonged to 25 genera and 18 families. Only 40% of the woody species recorded as matured species were represented in the seedling count in the forest. A total of 45 species were recorded as saplings in this forest, which belonged to 41 genera and more than 23 families. Only 66% of the woody species recorded as matured species were represented in the sapling count in the forest.

To analyze the conservation status and for the sake of priority setting of all the species encountered in this forest, the species were classified into three groups based on total regeneration density. Those species, which were totally absent in the regeneration, were categorized under Group 1; others whose density was greater than zero but less than 50 were categorized under Group 2; and those with density greater than or equal to 50 were categorized under Group 3. Accordingly, those species in Group 1 are with first priority; those in Group 2 are with second priority; and those in Group 3 are with third priority for conservation. Table 2 presents the list of species under these three groups. From all tree/shrub species encountered in this forest, about 29% were found in Group 1, 29% in Group 2 and 42% in Group 3.

Table 2. List of species under regeneration status*.

No	Group 1	No	Group 2	No	Group 3
1	*Acanthus sennii*	1	*Ilex mitis*	1	*Croton macrostachyus*
2	*Canthium oligocarpum*	2	*Macaranga capensis*	2	*Maytenus addat*
3	*Cassipourea malosana*	3	*Solanecio gigas*	3	*Phoenix reclinata*
4	*Cordia africana*	4	*Trilepisium madagascariense*	4	*Apodytes dimidiata*
5	*Dalbergia lactea*	5	*Turraea holstii*	5	*Lepidotrichilia volkensi*
6	*Deinbolia kilimandscharica*	6	*Vangueria sp*	6	*Brucea antidysenterica*
7	*Dombeya torrida*	7	*Vernonia amygdalina*	7	*Phyllanthus reticulatus*
8	*Ehretiaa abyssinica*	8	*Olea capensis*	8	*Millettia ferruginea*
9	*Euphorbia abyssinica*	9	*Rytigynia neglecta*	9	*Allophylus abyssinicus*
10	*Ficus exasperata*	10	*Elaeodendron buchananii*	10	*Bersama abyssinica*
11	*Ficus sur*	11	*Albizia gummifera*	11	*Teclea nobilis*
12	*Hypericum sp*	12	*Maesa lanceolata*	12	*Pittosporum viridiflorum*
13	*Polyscias fulva*	13	*Syzygium guineense*	13	*Cyathea manniana*
14	*Prunus africana*	14	*Trema orientalis*	14	*Galinera saxifraga*
15	*Rhaminus prinoides*	15	*Vernonia auriculifera*	15	*Maytenus gracilipes*
16	*Schefflera abyssinica*	16	*Albizia grandibracteata*	16	*Vepris dainellii*
17	*Schefflera volkensii*	17	*Rothmannia urcelliformis*	17	*Pouteria adolfi-friederici*
				18	*Clausena anisata*
				19	*Acanthus eminens*
				20	*Justicia schimperiana*
				21	*Dracaena steudneri*
				22	Coffea arabica
				23	Chionanthus mildbraedii
				24	Psychotria orophila
				25	Dracaena afromontana

*NB: Liana species are not included in this list.

Species prioritization for conservation

In this study, woody species with lower IVI values were taken as threatened or rare species that needed conservation measures. Even though some species had higher IVI values, their population structure showed that these species had bad reproduction and bad recruitment. The population structures of all woody species were analyzed and classified into 3 groups (Table 1). The grouping was based on their reproduction and recruitment patterns. The woody species, which were found under Group 1 (the species which have bad reproduction and bad recruitment), are the first priority species to be considered for conservation. To analyze conservation status by regeneration status, all of the species were again classified into three groups based on total regeneration density (Table 2). Those species under Group 1 (the species which were absent in the regeneration assessment) were the first priority species to be considered for conservation.

Accordingly, the woody species in IVI Class C (i.e., those species which had IVI value of <1) were the priority species by IVI selection criteria. The woody species with IVI value <1 in the present forest were: *Euphorbia abyssinica, Hypericum sp., Dalbergia lactea, Cassipourea malosana, Euphorbia candelabrum, Acanthus sennii, Rhamnus prinoides, Schefflera volkensii, Deinbolia kilimandscharica, Ficus exasperata, Albizia gradibracteata, Phoenix reclinata, Dombeya torrida, Canthium oligocarpum, Phyllanthus reticulates* and *Trema orientalis* (with priority rank of 1 – 16).

The woody species which had bad reproduction and bad recruitment were: *Albizia grandibracteata, Albizia gummifera, Canthium oligocarpum, Cassipourea malosana, Cordia africana, Euphorbia candelabrum, Ficus exasperata, Ficus sur, Phoenix reclinata, Polyscias fulva, Pouteria adolfi-friederici, Prunus africana, Schefflera abyssinica* and *Schefflera volkensii.*

The species selected by regeneration status criteria were: *Acanthus sennii, Canthium oligocarpum, Cassipourea malosana, Cordia africana, Dalbergia lactea, Deinbolia kilimandscharica, Dombeya torrida, Ehretia abyssinica, Euphorbia abyssinica, Ficus exasperata, Ficus sur, Hypericum sp, Polyscias fulva, Prunus africana, Rhamnus prinoides, Schefflera abyssinica* and *Schefflera volkensi.*

In setting the priority rank, the IVI selection criteria, population structure criteria of species and regeneration status criteria were considered to have equal values. As observed from the list, the priority species selected by these analyses overlapped in that four species were found in all the three cases.

For further prioritization of these species, the three criteria for threat category selection were given equal weights, and all the species selected by the three criteria were again assessed for these criteria. Therefore, if a species was found in the specified criteria, the species got 1; if not, it got 0.

Then these values were added and the species were prioritized by the total values of the three scores that the species got. The priority species selected by the 3 criteria are presented in Table 3. Out of the 24 priority species selected, 17% were selected by three criteria, 63% by two of the criteria, and 20% were selected by one of the three criteria (Table 3).

Table 3. List of all the species selected by IVI, population structure and regeneration status criteria.

No	Species name	Selection criteria for threat status			Total score	Priority rank
		IVI	Population structure	Regeneration status		
1	*Canthium oligocarpum*	1	1	1	3	1
2	*Cassipourea malosana*	1	1	1	3	1
3	*Ficus exasperata*	1	1	1	3	1
4	*Schefflera volkensi*	1	1	1	3	1
5	*Acanthus sennii*	1	0	1	2	2
6	*Albizia gradibracteata*	1	1	0	2	2
7	*Cordia africana*	0	1	1	2	2
8	*Dalbergia lactea*	1	0	1	2	2
9	*Deinbolia kilimandscharica*	1	0	1	2	2
10	*Dombeya torrida*	1	0	1	2	2
11	*Euphorbia abyssinica*	1	0	1	2	2
12	*Euphorbia candelabrum*	1	1	0	2	2
13	*Ficus sur*	0	1	1	2	2
14	*Hypericum sp.*	1	0	1	2	2
15	*Phoenix reclinata*	1	1	0	2	2
16	*Polyscias fulva*	0	1	1	2	2
17	*Prunus africana*	0	1	1	2	2
18	*Rhamnus prinoides*	1	0	1	2	2
19	*Schefflera abyssinica*	0	1	1	2	2
20	*Albizia gummifera*	0	1	0	1	3
21	*Ehretia abyssinica*	0	0	1	1	3
22	*Phyllanthus reticulates*	1	0	0	1	3
23	*Pouteria adolfi-friederici*	0	1	0	1	3
24	*Trema orientalis*	1	0	0	1	3

CONCLUSION AND RECOMMENDATIONS

The objective of this study was to assess the conservation status of Boginda Forest and identify the endangered woody plant species for recommending appropriate genetic conservation approaches in the area. Accordingly, this forest was found to be threatened. About 73 woody species, which belonged to 60 genera and 36 families, were recorded. The stems per ha coverage of this forest was found to be below normal coverage of virgin rain forest in Africa.

Even though there is limited information on the ecological requirements and mating systems of the species, selection of conservation measures could be done on available knowledge and on an informed guess (Erikson, 1998 cited in Wolf, 1999). Therefore, for the conservation of these woody species in Boginda Forest, the following recommendations were made.

1. Carry out further study on the population and population distribution of the priority species selected for genetic conservation in the area;
2. Establish legal basis for the *in situ* and *ex situu* conservation sites for the conservation of the priority species.
3. Carry out further studies on the patterns of ecosystem functioning, biology and ecology of the key stone species to be able to restore the composition and structure of the forest.

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FLORISTIC COMPOSITION, POPULATION STRUCTURE AND CONSERVATION STATUS OF WOODY SPECIES IN SHASHEMENNE-MUNESSA NATURAL FOREST, ETHIOPIA

Gemedo Dalle[1]

ABSTRACT: The study was conducted in Shashemenne-Munessa Natural Forest in West Arsi Zone, Oromia Regional National State. It was to determine floristic composition, population structure and regeneration status of indigenous woody species. Data was collected in 2003 from 33 sample plots of 500 m^2 established at every 50 m drop in altitude for sloppy or at 200 m interval for flat terrain. All woody species rooted within the sample plots were recorded and their Diameter at Breast Height (DBH) was measured for each. A total of 97 woody species belonging to 44 families and 76 genera were identified. Based on species richness, Fabaceae, Moraceae and Celastraceae were the most important families. The most diverse genera were Ficus, Maytenus, and Acacia. The total tree/shrub density was 446 per hectare with a total dominance of 57.3 m^2ha^{-1}. Species with lower Importance Value Index and therefore, that need high conservation attention included *Pittosporum viridiflorum, Pavetta sp, Discopodium penninervium, Rhus natalensis, Hypericum revolutum, Ehretia abyssinica, Rhus ruspolii, Apodytes dimidiata, Juniperus procera, Strychnos henningsii, Vepris dainellii* and *Phoenix reclinata*. Woody species with bad reproduction and recruitment were *Podocarpus falcatus, Mimusops kummel, Ficus sycomorus, Cordia africana, Prunus africana, Chionanthus mildbraedii* and *Ficus sur*. These species should be given priority both in planning and implementation of conservation activities. It was concluded that there is a high need to conserve those identified priority species using both *in situ* and *ex situ* conservation methods.

Key words/phrases: Density, Importance value index, Species diversity, Regeneration.

INTRODUCTION

Forests are extremely important ecosystems. According to the report by Secretariat of the Convention on Biological Diversity (SCBD) (2011), forests are more biologically diverse than any other land-based ecosystems and if these forests are conserved and sustainably used, more than two-thirds of all land-based animal and plant species can be protected. Forests have

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socio-cultural, economic and ecological importance. Shashemenne-Munessa Forest is one of such forests with diverse uses. The forest is home for many plants and animals, source of timber and firewood, trees and shrubs and also source of many rivers that flow into the central rift valley lakes. The forest serves to control the flow and quality of water and prevent erosion.

Studies have shown that tropical forests are being destroyed at an alarming rate (Hartshorn, 1989; Sabogal, 1992; Legesse Negash, 1995; Demel Teketay, 1996). Deforestation has been contributing to a decline in forest cover, loss of biodiversity both at global and national levels (Skole and Tucker, 1993; EPA, 1997; Kumar, 1997). Poverty and lack of alternative livelihoods have been driving forces of forest destruction. The Forest Genetic Resources Conservation Strategy of Ethiopia (2002) and Proclamation on Forest Development, Conservation and Utilization (2007) had identified deforestation as a major threat to Ethiopia's forest biodiversity. Deforestation of agricultural land as a result of ever-increasing population growth, increasing demand for fuel wood, and construction material, illegal settlements within forests, logging, and the expansion of illegal trade were considered major contributing factors to the loss of forest resources. The reduction in forest cover and loss of forest genetic resources pose a serious threat to conservation of forest biodiversity.

Dry Afromontane forests, including Shashemenne-Munessa (now under Arsi Forest and Wildlife Enterprise) Natural Forest, are among the most threatened natural forests in Ethiopia. SCBD (2011) reported that forests are disappearing partly due to their being undervalued, and failure of market economy to recognize ecosystem services provided by forests. It was also pointed out that more than 1.6 billion people depended on forests for their livelihoods.

Forests are home to an estimated 300 million people around the world; 80 per cent of people in developing countries rely on traditional medicines, of which up to 50% originate from plants found mainly in tropical forests. Forest biodiversity is the basis for more than 5,000 commercial products, ranging from aromatic oil (distilled from leaves) to herbal medicines, food and clothing. Besides, three quarters of the world's accessible fresh water comes from forested watersheds; forests purify drinking water for two-thirds of the major cities in developing countries.

Despite its socio-economic and environmental importance, Shashemenne-Munessa Forest has been under severe threat for years. The forest is easily accessible from the Addis Ababa–Shashemenne highway. Due to the easy accessibility and lack of proper management, the forest has been under heavy exploitation for sawmills (which were established in 'Sole' and 'Jigessa') since the 1930's (Anonymous, 1990). According to Anonymous (1990), the forest has been exploited mainly for *Podocarpus falcatus* since the Italian invasion. Due to forest clearance for cultivation and, to a lesser extent, of logging, the natural forest is now confined largely to the main escarpment. There are smaller and more fragmented patches of forest and woodland on the plain and on the edge of the Hawassa basin to the south and southeast of the forest.

Therefore, the existing situation calls for an urgent mitigation action. Furthermore, studies of the woody plant diversity are essential so as to determine their current conservation status, and hence prioritize the threatened woody species. It is important to suggest and establish appropriate conservation methods for the prioritized species, and then develop and strengthen appropriate conservation strategies for the targeted species. The objective of the current study is, therefore, to determine the floristic composition and diversity of indigenous woody species and determine their conservation status in Shashemenne-Munessa Natural Forest.

MATERIALS AND METHODS

Study Area

Shashemenne-Munessa Forest is located about 200 km south of Addis Ababa at $7^0$13'N, $38^0$37'E along the escarpment east of the Addis Ababa-Hawassa high way in West Arsi Zone of Oromia National Regional State. Shashemenne-Munessa Forest area is divided into three districts; namely Munessa, Shashemenne, and Gambo. The forest area occupies the escarpment and associated highlands lying between the Rift Valley lakes (Abijata, Langano, and Shalla) and the eastern edge of the Rift Valley. The total area of Shashemenne-Munessa Forest was 21,380 ha, of which 15,280 was Natural High Forest. The forest is situated along the altitudinal gradient between 1450 m and 2600 m a.s.l.

Makin *et al*. (1975) and King and Birchall (1975) described the geology and landform of Shashemene-Munessa area. Rocks are volcanic, principally ignimbrite but with basalt in the north and tuff near the southern extremity of the forest, that is, near Wondo Genet. The Duro Mountain at the southeastern tip of the main compact block of the forest, north of Kofele, is a dissected volcano composed of tephra and trachyte (Chaffey, 1978).

Lundgren (1971) investigated in some detail the soils of the Shashemenne-Munessa Forest. The reddish soils are derived from weathered parent rock, freely draining and of medium to heavy texture. Lundgren (1971) described them as ferrisols and his analyses showed that the soils contain high levels of all the available chemical nutrients, except phosphorous, which these soils are deficient. According to the Lundgren (1971), the pH of the soil varies between 5.8 and 6.7, and high level of humus was recorded under Podocarpus forest.

The forest area drains mainly into Lake Langano and Lake Shalla through surface streams and rivers, many of which contain water of good quality throughout the year. The main escarpment contributes to the Langano catchments while drainage from the plain above drains largely into Lake Shalla. The Hawassa basin receives water from the southernmost remnants of the forest, near Wondo Genet.

Some of the major rivers that drain from the Shashemene-Munessa Forest area are Lephis, Gedemso, Huluka, Awade, Shoba, Dalele, Metena, Teji, and Mokonisa (all of which drain into Lake Langano); and Dhadhaaba Guddaa, Dhadhaaba diqqaa, Agemsa, Meti, (all drain to Lake Shalla), and Wosha to Lake Hawassa (Anonymous, 1990).

Vegetation

The principal categories of the forest vegetations are: high forest from approximately 2100 m to 2450 m, Bamboo thicket from 2450 to 2650 m, and low forest and woodland at the edge of and on the plain above the steep slopes occupied by bamboo. On the most gently sloping terrain to south of the main escarpment and / or where the bamboo stratum is absent, there is a less distinct transition in the forest types, and blocks of closed forest extends exceptionally to 3000 m.

Podocarpus falcatus is the dominant tree in both size and frequency in the forest occupying the lower elevations and below the bamboo. Other large trees include *Celtis africana, Olea capensis* and *Prunus africana*. In places where the canopy is low and in former gaps and clearings, *Croton macrostachyus* is a frequent component species (Chaffey, 1978; Gemedo Dalle, 1999). Less common canopy species are *Pouteria adolfi-friederici, Apodytes dimidiata, Ficus sur, Schefflera abyssinica*, and *Syzygium guineense*. Frequent smaller trees are *Allophylus abyssinicus* and *Bersama abyssinica*. Some of the understorey species include *Brucea antidysenterica, Cassipourea malosana, Lepidotrichilia volkensii*, Maytenus spp., and *Vepris* *dainellii*. At or near the forest edge, *Albizia schimperiana*, *Calpurnia aurea*, *Cordia africana*, *Maytenus* species and *Olea europaea* subsp. *cuspidata* are frequent at the forest edge.

Methods

A systematic random sampling design was used to collect the data from sampling plots established at regular intervals along predetermined transects. Six transects were laid systematically and made to cover the major aspects (Southeast, West and North). Vegetation data was collected in 2003 from 33 sample plots of 50m x 10m (500 m^2) that were established at every altitudinal drop of 50m, where there is altitudinal gradient, and at a horizontal distance of 200 m interval for the flat terrains.

Indigenous woody species rooted within each sampling plot were identified and listed. All woody species with DBH > 2.5 cm were measured for their DBH and height. Lianas spp. and other species occurring outside the sampling quadrates were registered as 'present'. Species occurring outside the plot were also recorded to study their floristic composition. The growth habit of each woody species and the physiognomy of the vegetation within each quadrate were described. Regeneration status was also assessed within each quadrate, which involved counting seedlings and saplings on 2 X 2m by 10m sub-quadrates (40m^2) laid at the two endings of the quadrate. Plant specimens were collected, pressed, dried and identified and checked at the National Herbarium of the Addis Ababa University. Nomenclature of plant species followed the published volumes of the Flora of Ethiopia and Eritrea (Hedberg and Edwards, 1989, 1995; Edwards *et al*. 1995, 1997).Voucher specimens were kept in the Ethiopian Biodiversity Institute and National Herbarium of Addis Ababa University.

Data Analysis

Descriptive statistics were used in organizing, summarizing and describing sample data. Access and excel software programs were used for the data analysis.

1. Density was calculated using the equation

$$d = \frac{\sum t}{s_{ha}}$$

where d is density of all tree/shrub species, t total number of stems of all tree/shrub species, s_{ha} = sample size in hectare.

2. Relative density was calculated using the equation

$$rd = \frac{\sum t}{ts}$$

where rd is relative density of each individual tree/shrub, t is total number of stems of all tree/shrub species, ts is total number of stems of all tree/shrub.

3. Frequency = $f = \frac{nQ}{tQ} \times 100$

where f is frequency, nQ is number of quadrates in which a species recorded and tQ is total number of quadrates.

4. Relative frequency = $rf = \frac{f}{\sum tf}$

where rf is relative frequency, f is frequency of a species and $\sum tf$ is sum frequency of all tree/shrub species.

5. Basal area $Ba = 22 \times \frac{d^2}{28}$

where Ba is = basal area and d is diameter at breast height or stump height.

6. Dominance $Do = mBa \times d$

where Do is dominance, mBa is mean Ba per tree/shrub species and d is density of a tree/shrub species.

7. Relative Dominance $rDo = \frac{mBa}{\sum mBat} \times 100$

where rDo is relative dominance, mBa is mean Ba per tree/shrub species and $mBat$ is mean BA of all tree/shrub species.

8. Importance Value Index $IVI = rd + rf + rDo$

where IVI is importance value index, rd is relative density, rf is relative frequency and rDo is relative dominance.

RESULTS AND DISCUSSION

Floristic composition

A total of 97 woody species representing 76 genera and 44 families were recorded from Shashemenne-Munessa Natural Forest (Annex 1). Of these, 65 species were recorded within the sample plots and 32 outside the sample plots. The most diverse genera, Ficus, were represented by (six species), Maytenus (four species) and Acacia (three species). Diverse families such as Fabaceae, which was represented by (7 species, belonging to 5 genera), Moraceae (6 species all belonging to a single genus), Celastraceae (5 species belonging to two genera), Oleaceae, Rosaceae, Euphorbiaceae, Loganiaceae and Rubiaceae (four species each), Asteraceae, Boraginaceae, Myrsinaceae, Rutaceae and Apocynaceae (three species each), Meliaceae, Anacardiaceae, Araliaceae, Flacourtiaceae, Sapotaceae and Solanaceae (two species each) were also included.

The predominant species in the forest was *P. falcatus*, which occupied the lower elevations and below the bamboo. This species was dominant both in size and frequency. This is in agreement with Chaffey (1978). Other large broad-leaved species were: *Ficus sycomorus*, *Cordia africana*, *C. macrostachyus*, *Myrsine melanophloëos, Celtis africana*, and other *Ficus spp.* Smaller trees included: *Apodytes dimidiata, Bersama abyssinica*, *Brucea antidysenterica*, *Teclea simplicifolia*, *Vepris dainellii*, *Hypericum revolutum*, *Nuxia congesta*, and *Polyscias fulva.* The common shrubs of the area include: *Carissa spinarum*, *Vernonia auriculifera*, *Euclea racemosa*, *Pavetta abyssinica* and *Rhus natalensis*. The common lianas were *Embelia schimperi*, *Jasminum abyssinicum*, and *Landolphia buchananii*.

Structure

Frequency

There was no species that belonged to the frequency class A. Only *P. falcatus,* which is the most frequent tree species in Shashemenne-Munessa Natural Forest, belonged to the frequency class B, and *Bersama abyssinica* belonged to the frequency class C. Eleven species belonged to the frequency class D while the remaining species belonged to the last frequency class

(Fig. 1). Some of the tree species that were not frequent included *Cordia africana, Ekebergia capensis, Polyscias fulva, Prunus africana, Celtis africana, Juniperus procera, Apodytes dimidiata, Hagenia abyssinica, Mimusops kummel, Croton macrostachyus, Albizia gummifera, Teclea simplicifolia, Cassipourea malosana* and *Schefflera volkensii*.

Fig. 1. Species distribution by frequency classes.

Frequency gives an approximate indication of the homogeneity of a stand. Studies pointed out that high values in the higher frequency classes (Frequency classes A and B in this case) and low values in the lower frequency classes (Frequency classes D and E) indicated constant or similar species composition in the area. High values in the lower frequency classes and low values in the higher frequency classes, on the other hand, indicated a high degree of floristic heterogeneity. In the present study, high values were obtained in the lower frequency classes whereas low values were obtained in the higher frequency classes (Fig. 1). Therefore, according to the above interpretation it is possible to conclude that there exists a high degree of floristic heterogeneity in Shashemenne-Munessa Natural Forest Priority Area. The species that appear in the lower frequency classes have irregular occurrence while those appearing in the higher classes such as *P. falcatus* have regular horizontal distribution.

Density

The total tree/shrub density of Shashemenne-Munessa forest was 446 per ha. Species were classified into 5 density classes, from E to A; where species that belonged to class E have lower density while those in class A have higher density and the intermediates were also assigned accordingly.

Species that belonged to density class E were *Polyscias fulva, Apodytes dimidiata, Juniperus procera, Phoenix reclinata, Pittosporum viridiflorum, Pouteria adolfi-friederici, Rhus ruspollii, Strychnos henningsii* and *Vepris dainellii*. Some of the tree species that belonged to density class D were *Hagenia abyssinica, Prunus africana, Chionanthus mildbraedii, Teclea simplicifolia, Ilex mitis, Cassipourea malosana* and *Ekebergia capensis*. On the other hand, abundant species in the forest were *Maytenus senegalensis, Myrsine melanophloëos, Arundinaria alpina, Acokanthera schimperi,* and *Podocarpus falcatus*.

The density of tree/shrub species over 10 cm DBH and over 20 cm DBH was 230.9 and 144.6, respectively and their ratio was about 1.6. Density of tree/shrub species over 10cm DBH greater than 600 is normal for Virgin Rainforest in Africa (Richard, 1966, cited in Lamprecht, 1989). Density ratio of individuals >10 cm DBH to that of individuals > 20 cm DBH showed prevalence of small-sized individuals for some species but comparable distribution for few and even fewer for others.

Basal area and dominance

Total dominance of Shashemenne-Munessa forest is 57.3 m^2ha^{-1}. The total basal area/dominance of Shashemenne-Munessa forest were greater than that of Jibat, Menagesha and Chilimo forests, which were 49.8, 36.1 and 30.1 m^2ha^{-1}, respectively (Tamrat Bekele, 1994). The highest basal area was recorded for fewer large-sized individuals, especially DBH greater than 42.6 cm. *Podocarpus falcatus* was the most dominant species, followed by *Ficus sycomorus, Maytenus senegalensis, Celtis africana, Maytenus addat, Cordia africana, Schefflera volkensii, Maesa lanceolata* and *Mimusops kummel.* On the other hand, some species such as *Juniperus procera, Apodytes dimidiata, Pouteria adolfi-friederici, Vepris dainellii* and *Cassipourea malosana* have insignificant or no contribution to the total basal area of the forest.

High density and high frequency, coupled with high dominance, indicate the overall dominant species of the forest (Lamprecht, 1989). Accordingly, *Podocarpus falcatus* and *Maytenus senegalensis* were the most dominant species. On the other hand, high density and high frequency indicates regular horizontal distribution in the forest, which was shown by *Podocarpus falcatus*, *Maytenus senegalensis* and *Maesa lanceolata.* High density, low frequency and low dominance are typical for understorey species that occur in clusters. These species included: *Myrsine melanophloëos, Arundinaria alpina, Erythrococca trichogyne* and

Acokanthera schimperi. *Prunus africana, Hagenia abyssinica, Pouteria adolfi-friederici, Juniperus procera, Polyscias fulva, Ekebergia capensis* and *Cassipourea malosana* were some of the tree species with low density, low frequency and low dominance.

Basal area provides a better measure of the relative importance of the species than simple stem count (Cain and Castro, 1959, cited in Tamrat Bekele, 1994). Therefore, species with the largest contribution in basal area can be considered as the most important woody species in the forest. Accordingly, the most important species of Shashemenne-Munessa Forest were *Podocarpus falcatus, Ficus sycomorus, Maytenus senegalensis, Celtis africana, Ficus sur, Maytenus addat, Cordia africana, Schefflera volkensii, Mimusops kummel* and *Maesa lanceolata.*

Importance Value Index (IVI)

For the sake of setting priority using importance value index (IVI) analysis all woody species encountered in the forest were grouped into five classes based on their total IVI values. Those species with lower IVI were grouped into the fifth IVI class while those species with higher IVI value were put under the first IVI class. Those species, which were grouped in the fifth IVI class, need high conservation effort while those grouped in the first IVI class, need monitoring management (Table 1). About 40% of the importance value was constituted by *Podocarpus falcatus, Maytenus senegalensis, Myrsine melanophloëos, Ficus sycomorus*, and *Arundinaria alpina*. The remaining percentage was shared among 44 species (Annex 2).

The importance value index is useful to compare the ecological significance of species (Lamprecht, 1989). It indicates the extent of dominance of a species in the structure of a forest stand (Curtis and McIntosh, 1951). Species with the greatest importance value are the most dominant in the forest (Curtis, 1952 cited in Greig-Smith, 1983). Accordingly, *Podocarpus falcatus, Maytenus senegalensis, Myrsine melanophloëos, Ficus sur, Arundinaria alpina, Celtis africana, Acokanthera schimperi, Maesa lanceolata, Erythrococca trichogyne* and *Calpurnia aurea* were the 10 most dominant species in the forest.

Table 1. List of species under each priority class.

Priority class				
5	**4**	**3**	**2**	**1**
P. viridiflorum	*E. trichogyne*	*M. melanophloëos*	*M. senegalensis*	*Podocarpus*
Pavetta sp	*C. aurea*	*F. sycomorus*		
Discopodium	*B. abyssinica*	*A. alpina*		
Rhus natalensis	*M.obscura*	*Celtis africana*		
Hypericum	*C. macrostachyus*	*A. schimperi*		
Acacia sp.	*Cordia africana*			
Ehretia abyssinica	*Ficus sur*			
Rhus ruspolii	*M. kummel*			
Apodytes dimidiata	*M. addat*			
J. procera	*F. sur*			
Strychnos	*G. saxifraga*			
Vepris dainellii	*P. africana*			
Phoenix reclinata	*S. volkensii*			
	F. vallis-choudae			
	H. abyssinica			
	N. congesta			
	B.antidysentrica			
	I. mitis			
	C. spinarum			
	Vernonia			
	F. ovata			
	D. verrucosa			
	E. capensis			
	A. gummifera			
	L. gebbroa			
	C. mildbraedii			
	Teclea simplicifolia			
	Croton dichogamus			
	Euclea racemosa			

Population structure of species

The population structure of a species can show whether the population has a stable distribution that allows continuous regeneration and recruitment to higher diameter classes. The analysis of density distribution of species by diameter classes has resulted in different patterns (Fig. 2a-h). High densities in small diameter classes indicate a good regeneration capacity, while under representation of these classes indicates little regeneration capacity. The implication is that the potential to replace such species will be very low once the matured individuals have disappeared due to some reasons. That is, the species is endangered and needs conservation action. Population patterns indicating selective removal of individuals (Fig. 2d and 2h) were detected for *P. falcatus* and *P. africana,* respectively. *Podocarpus falcatus* showed peaks at lower size classes, an abrupt decline in the middle and then a rise at larger size class, i.e. a U-shaped population pattern. The decline and/or missing in the population of middle and/or upper height classes clearly showed that there is a selective removal of individual tree species of preferred size.

The local people as well as the saw-millers usually carry out selective removal of these individuals for the purpose of construction, fuelwood, agricultural encroachment and above all for logging (PRA report of the project). The other recognizable pattern indicated a good reproduction but discontinuous recruitment (Fig. 2c). Species with this pattern are *M. melanophloëos*, *Acokanthera schimperi*, *Bersama abyssinica*, *Brucea antidysenterica*, *Nuxia congesta*, *Teclea simplicifolia* and *Cassipourea malosana*. Some species show a gauss type pattern (Fig. 2e). A good example showing this pattern was *Croton macrostachyus*. This species showed good representation in the middle classes but not well-represented in lower and upper diameter classes. The other recognized pattern was an inverted J-shape (Fig. 2b). Species exhibiting this normal diameter class distribution were *Celtis africana*, *Maesa lanceolata*, *Maytenus senegalensis* and *Maytenus obscura*. Some other economically and ecologically important species were represented by abnormal density distribution pattern. Species under this pattern were missing in many of the diameter classes (Fig. 2h). For example, *Prunus africana*, *Cordia africana*, *Ficus* spp., *Chionanthus mildbraedii*, *Schefflera volkensii*, *Hagenia abyssinica*, *Albizia gummifera*, *Apodytes dimidiata*, *Juniperus procera*, *Polyscias fulva*, and *Pouteria adolfi-friederici*, which are economically important for log production, were missing in the DBH classes. Other species in the forest were represented by J-shaped pattern i.e. small representation in lower DBH classes but well-represented by old-aged individuals (Fig. 2f). *Mimusops kummel* was good example of this type that showed poor regeneration and over-representation of large-sized trees, incapable of regeneration. Therefore, there is an urgent need to regenerate these species before their regeneration capabilities are lost.

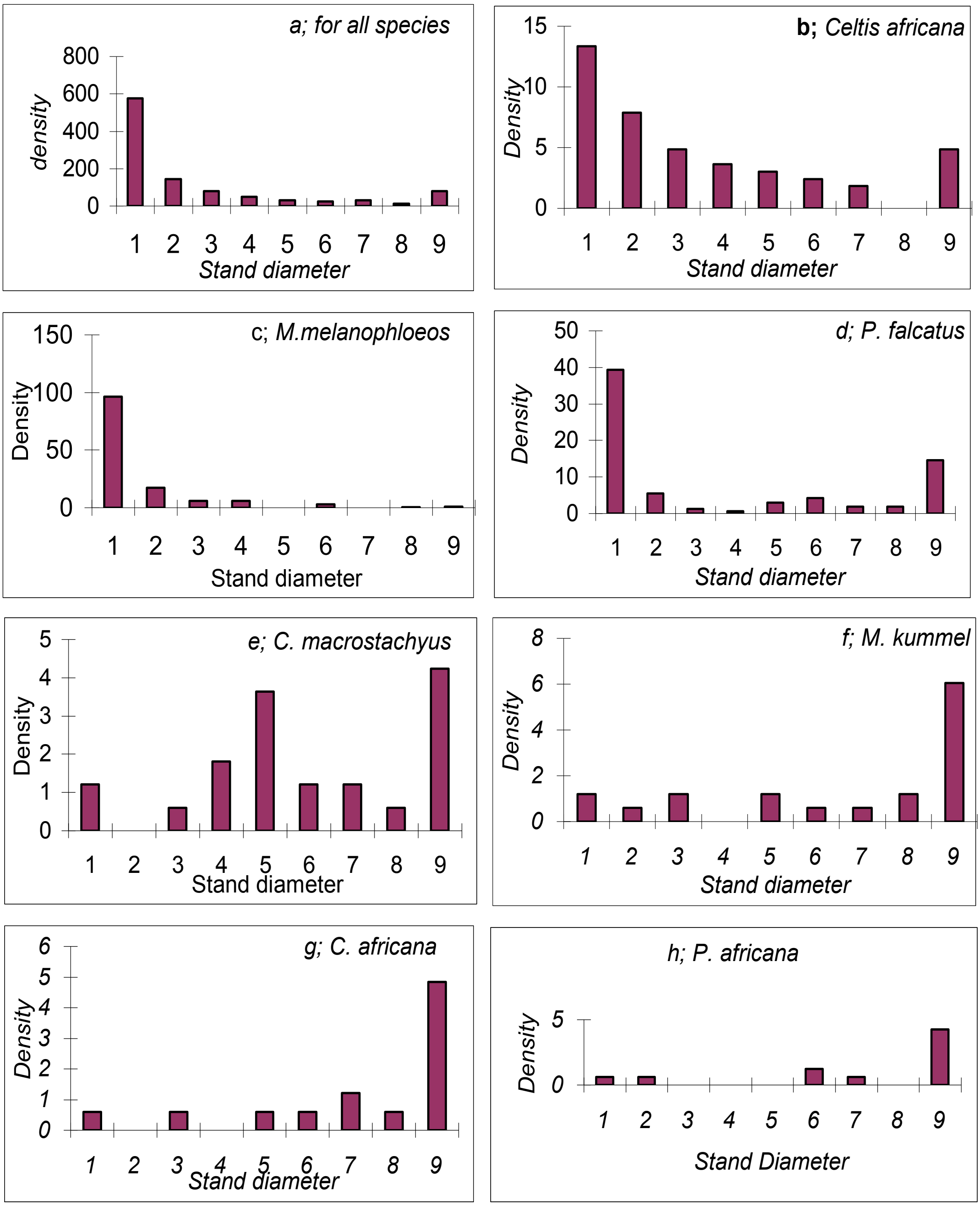

Fig. 2. Population structure of Shashemenne-Munessa Forest and some representative species; wherein stand diameter: 1=2.6-7.5, 2=7.6-12.5, 3=12.6-17.5, 4=17.6-22.5, 5=22.6-27.5, 6=27.6-32.5, 7=32.6-37.5, 8=37.5-42.5, 9=>42.6

In general, the analysis of the population structure of the species in the forest can be summarized into three groups:

1. The first group includes those tree/shrub species with bad reproduction and recruitment (Group I).
2. The second group includes those tree/shrub species with reproduction but bad recruitment (Group II).
3. The third group includes those tree species with good reproduction and recruitment (Group III).

To analyze the conservation status of the species in the forest, the structural distribution pattern was also used and the species were grouped for such purpose. Accordingly, all the species under Group I should be considered the top priority for the genetic conservation measures; and those under Group II are prioritized secondly. The list of species under the three groups is presented in Table 2.

Table 2. List of species according to population structure grouping.

Group I	**Group II**	**Group III**
P. falcatus	*M. melanophloëos*	*M. senegalensis*
M. kummel	*Acokanthera schimperi*	*Celtis africana*
Ficus sycomorus	*Bersama abyssinica*	*Maesa lanceolata*
Cordia africana	*Brucea antidysenterica*	*Galiniera saxifraga*
Prunus africana	*Nuxia congesta*	*Maytenus obscura*
Chionanthus mildbraedii	*Vepris dainellii*	
Ficus sur	*Teclea simplicifolia*	
Ekebergia capensis	*Croton macrostachyus*	
Schefflera volkensii		
Ficus vallis-choudae		
Hagenia abyssinica		
Albizia gummifera		
Cassipourea malosana		
Ficus ovata		
Apodytes dimidiata		
Juniperus procera		
Polyscias fulva		
Pouteria adolfi-friederici		

Regeneration status: Species composition and density

A total of 35 species were represented in the seedlings class, representing 30 genera belonging to 23 families. This accounted for about 53.8% of the floristic composition of the matured forest species. The total seedling density was 3537.9 per ha. However, the mean density was 101.1 per ha.

The sapling class was composed of more than 30 species representing 26 genera which belonged to 19 families. This equaled to 46.2% of the floristic composition of the matured forest species. The total sapling density was 2606.1 per ha and mean density was 86.8 per ha.

Myrsine melanophloëos, Calpurnia aurea, Acokanthera schimperi, Podocarpus falcatus and Celtis africana were the five abundant species in the natural regeneration. Although Demel Teketay (1996) suggested the seedling bank as the major regeneration route of most woody plants in dry Afromontane forests of Ethiopia, some species of economic and ecological importance were absent in the regeneration strata (seedling and sapling). These species included *Hagenia abyssinica, Prunus africana, Croton macrostachyus, Ficus sur, Schefflera volkensii, Polyscias fulva, Apodytes dimidiata, Ilex mitis, Juniperus procera, Pouteria adolfi-friederici, Nuxia congesta, Phoenix reclinata, Maytenus addat, Cordia africana, Chionanthus mildbraedii, Ficus sycomorus, Ficus vallis-choudae, Ficus ovata,* and *Albizia gummifera*. This may suggest that these species were either under threat of local extinction or may prefer coppices or sprouts as the strategy of survival. For instance, *Hagenia abyssinica* and *Prunus africana* regenerate mainly through vegetative sprouts (Getachew Tesfaye, 2001). Some species such as *Syzygium guineense*, *Olea europaea* subsp. *cuspidata* and *Dovyalis abyssinica* appeared only in the regeneration phase.

Gemedo Dalle (1999) reported that the regeneration of *Podocarpus falcatus* in the forest appeared to be from the suppressed seedlings and saplings under shade while that of *Croton macrostachyus* was from seed bank in the treefall gaps. Besides, *Myrsine melanophloëos, Maytenus addat, Bersama abyssinica, Dovyalis abyssinica*, and *Teclea nobilis* might have regenerated from seed bank.

CONCLUSION AND RECOMMENDATIONS

Shashemenne-Munessa is a diversified forest with more than 90 woody species. The total density (446 per ha) of tree and shrub species is low as compared to normal density of 600 per ha, which probably implied external pressure. *Podocarpus falcatus* is the principal commercially and ecologically important species in the forest. *Podocarpus falcatus* was the most preferred species for logging as it is the most commonly used timber tree. In connection with timber production, local farmers and daily laborers of sawmill exploit valuable trees, primarily *Podocarpus falcatus.* Therefore, this unwise exploitation should be monitored before these species run out of our eyes. In addition to unwise utilization of valuable timber resources, an on-going agricultural encroachment is also taking place in the forest. Each year some areas of forestlands have been converted into cultivation land. The on-going destruction consequently leads to loss of indigenous species and associated biodiversity. It has also negative effects on soil fertility and water cycle.

Some important species had bad population structures that showed abnormal patterns with no or few individuals at lower size or middle classes, or well-represented at larger size classes, which meant old-aged population. There is, therefore, a need to develop and implement effective forest management activities in the area to facilitate healthy regeneration and eventually ensured the sustainable use of these species.

Podocarpus falcatus, Ficus sycomorus, Maytenus senegalensis, Celtis africana, Ficus sur, Maytenus addat, Cordia africana, Schefflera volkensii, Mimusops kummel, Maesa lanceolata, Myrsine melanophloëos, Arundinaria alpina, Acokanthera schimperi, Erythrococca trichogyne and Calpurnia aurea were important species that need conservation measures.

Economically as well as ecologically important species such as Hagenia abyssinica, Prunus africana, Croton macrostachyus, Pouteria adolfi-friederici, Albizia gummifera, Apodytes dimidiata, Polyscias fulva, Ficus sur, Schefflera volkensii, Juniperus procera, Cordia africana and Ilex mitis were absent in the regeneration assessment. This may suggest that these species are either under threat of local extinction or may prefer coppices or sprouts as the strategy of survival. Therefore, further investigation is strongly recommended to find out the actual causes for such species loss.

Finally, it was concluded that there is need to use multiple criteria in identifying threatened species and/or species that need conservation priority.

The recommendations are:-

- Carry out further investigation on the patterns of ecosystem functioning, the soil seed banks, germination characteristics and establishment of seedlings.

- Conduct studies on the role of gap dynamics since tree fall gaps are necessary for the establishment of seedlings and saplings of forest tree species. The knowledge of natural gap dynamics is also important where forest management objectives include maintaining biological diversity.
- Raise public awareness on the value of forest genetic resources and the problems related to loss of genetic information and devise a mechanism by which human impacts can be minimized through discussion and consultation with the local people.
- Establish *in situ* and *ex situ* conservation sites to conserve priority species.
- Conduct research on storage behavior (seed physiology) and reproduction biology of woody species that focus on threatened and economically important species.

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Annex 1. Floristic composition of Shashemenne-Munessa Natural Forest.

No	Species			Family	Hab.	Vern. Name (Oromo)
1	*Acacia*	*sp*		Fabaceae	T	Ajo
2	*Acacia*	*abyssinica**	*Hochst. Ex Benth.*	Fabaceae	T	Lafto
3	*Acacia*	*sp**		Fabaceae	T	Gerbi
4	*Acokanthera*	*schimperi*	*(A. DC.) Schwein*	Apocynaceae	T/S	Qararu
5	*Albizia*	*gummifera*	*(Gmel.) C. A. Sm.*	Fabaceae	T	Qerch'eche
6	*Aleyo*					*Aleyo*
7	*Allophylus*	*abyssinicus**	*(Hochst.) Radlkofer*	Sapindaceae	T	Hirqemo
8	*Apodytes*	*dimidiata*	*E. Mey. ex Arn.*	Icacinaceae	T	Arebdotessa
9	*Arundinaria*	*alpina*	*K. Schum.*	Poaceae	T/S	Lemen
10	*Bersama*	*abyssinica*	*Fresen.*	Melianthaceae	T	Foreqa
11	*Brucea*	*antidysenterica*	*J. F. Mill.*	Simarubaceae	T/S	Ch'ironta
12	*Buddleja*	*polystachya**	*Fresen.*	Loganiaceae	S	Bulchara
13	*Calpurnia*	*aurea*	*(Ait.) Benth.*	Fabaceae	T/S	Chekata
14	*Canthium*	*oligocarpum**	*Hiern*	Rubiaceae	S	Wontefulasa
15	*Capparis*	*tomentosa**	*Lam.*	Capparidaceae	S	Obo meda
16	*Carissa*	*edulis*	*Vahl*	Apocynaceae	S	Agamssa
17	Cassipourea	malosana	*(Baker)Alston*	Rhizophoraceae	T	Tilo
18	*Celtis*	*africana*	*Burm f.*	Ulmaceae	T	Amalaqa
19	*Chionanthus*	*mildbraedii*	*(Gilg & Schellenb.) Stearn*	Oleaceae	T	Sigeda
20	*Combretum*	*collinum**	*Fresen.*	Combretaceae	T	Rukessa
21	*Cordia*	*sp*		Boraginaceae	T	Mandhera
22	*Cordia*	*africana*	*Lam.*	Boraginaceae	T	Wedesa
23	*Crotalaria*	*sp**		Fabaceae	S	
24	*Croton*	*dichogamus*	*Pax*	Euphorbiaceae	T	Uleefooni
25	*Croton*	*macrostachyus*	*Del.*	Euphorbiaceae	T	Mekanisa
26	*Diospyros*	*abyssinica**	*(Hiern.)F. White*	Ebenaceae	T	Tilo-dima
27	*Discopodium*	*penninervium*	*Hochst.*	Solanaceae	S	Meraru
28	*Dombeya*	*torrida**	*(J.F. Gmel.) Bamps*	Sterculiaceae	T	Danisa
29	*Dovyalis*	*verrucosa*	*(A. Rich.)*	Flacourtiaceae	T/S	Dengogo

No	Species			Family	Hab.	Vern. Name (Oromo)
			Warburg			
30	*Ehretia*	*abyssinica*	*R. Br. ex Fresen.*	Boraginaceae	S	
31	*Ekebergia*	*capensis*	*Sparrm.*	Meliaceae	T	Ononu
32	*Embelia*	*schimperi**	*Vatk.*	Loganiaceae	L	Qanqu
33	*Erythrococca*	*trichogyne*	*(Muell.Arg) Prain*	Euphorbiaceae	S	Orjefuga
34	*Euclea*	*racemosa*		Ebenaceae	S	Measa
35	*Euphorbia*	*sp*		Euphorbiaceae	T	
36	*Ficus*	*ovata*	*Vahl*	Moraceae	T	Qilit'u
37	*Ficus*	*sur*	*Forsssk.*	Moraceae	T	
38	*Ficus*	*sycomorus*	*L.*	Moraceae	T	
39	*Ficus*	*thoninngi**	*Blume*	Moraceae	T	Dembi
40	*Ficus*	*vallis-choudae*	*Del.*	Moraceae	T	
41	*Ficus*	*vasta**	*Vahl.*	Moraceae	T	Qilt'u
42	*Flacourtia*	*indica**	*(Burm.f.)Merrill*	Flacourtiaceae	S	Hudha
43	*Galiniera*	*saxifraga*	*(Hochst.) Bridson*	Rubiaceae	T	Korala
44	*Galmiyo**					
45	Geto				T	
46	Grewia	bicolor*	*Juss.*	Tiliaceae	S	Haroressa dima
47	*Hagenia*	*abyssinica*	*(Bruce) G.F. Gmel.*	Rosaceae	T	Heet'o
48	*Hypericum*	*revolutum*	*Vahl*	Hypericaceae	T	Geramba
49	*Ilex*	*mitis*	*(L.) Radlk.*	Aquifoliaceae	T	Amshiqa
50	*Jasminum*	*abyssinicum**	*Hochst. ex DC.*	Oleaceae	L	Diki
51	*Juniperus*	*procera*	*Endl.*	Cupressaceae	T	Hindhesa
52	*Justecia*	*schimperiana**	*T. Anders*	Acanthaceae	S	T'umuga
53	Kembecha				T	
54	*Landolphia*	*buchananii*	*(Hall. f.) Stapf*	Apocynaceae	L	T'it'it'a
55	*Lobelia*	*giberroa*	*Hemsl.*	Lobeliaceae/Campanulaceae	T/S	Terura
56	*Maesa*	*lanceolata*	*Forssk.*	Myrsinaceae	T/S	Abeyi
57	*Maytenus*	*gracilipes**	*(Welw. Ex Oliv.) Exell*	Celastraceae	S	Kombolcha
58	*Maytenus*	*senegalensis*	*(Lam.) Exell*	Celastraceae	T/S	Kombolcha

No	Species			Family	Hab.	Vern. Name (Oromo)
59	*Maytenus*	*addat*	*(Loes.) Sebsebe*	Celastraceae	T	
60	*Maytenus*	*obscura*	*(A. Rich.) Cuf.*	Celastraceae	T/S	Wantafulasa
61	*Mimusops*	*kummel*	*A. DC.*	Sapotaceae	T	Olati
62	*Myrsine*	*africana**	*L.*	Myrsinaceae	S	Qech'amo
63	*Myrsine*	*melanophloeos*	*(L) R.Br.*	Myrsinaceae	T/S	Tula
64	*Nuxia*	*congesta*	*Fresen.*	Loganiaceae	T	Bitena
65	*Olea*	*capensis sp. macrocarpa**		Oleaceae	T	Sigeda
66	*Olea*	*europaea ssp. cuspidata**		Oleaceae	T	Ejersa
67	*Olinia*	*rochetiana**		Oliniaceae	T	Guna
68	*Oncinotis*	*tenuiloba**		Asclepediaceae	L	Hadhemene
69	*Pavetta*	*abyssinica*	*Fresen.*	Rubiaceae	S	Galo
70	*Phoenix*	*reclinata*	*Jacq.*	Palmae	T	Mit'I
71	*Phytolacca*	*dodecandera**	*L'Herit*	Phytolaccaceae	L/S	Handode
72	*Pittosporum*	*viridiflorum*	*Sims*	Pittosporaceae	T	Ara
73	*Podocarpus*	*falcatus*	*(Thunb.) Mirb*	Podocarpaceae	T	Birbirsa
74	Polyscias	fulva	*(Hiern)Harms*	Araliaceae	T	Harfatu
75	Pouteria	adolfi-friederici	*(Engl.)Baehni*	Sapotaceae	T	Suduba
76	*Prunus*	*africana*	*(Hook. f.) Kalkm*	Rosaceae	T	Suke
77	*Psydrax*	*schimperiana**	*(A.Rich.)Bridson*	Rubiaceae	S	Galo buno
78	*Pterolobium*	*stellatum*	*(Forssk.) Brenan*	Fabaceae	L	Gort'a
79	Qechachilo				T	Qechachilo
80	*Rhus*	*natalensis*	*Krauss*	Anacardiaceae	S	T'at'essa
81	*Rhus*	*ruspolii*	*Engl.*	Anacardiaceae	T	Qamo
82	Rosa	abyssinica*		Rosaceae	S/L	Harengama
83	*Rubus*	*apetalus*	*Poir.*	Rosaceae	L	Gora
84	*Schefflera*	*volkensii*	*(Engl.) Harms*	Araliaceae	T	Ansha
85	*Solanecio*	*mannii**	*(Hook.f.)C. Jeffrey*	Asteraceae	S	Worqiye
86	*Solanum*	*gurae**	*Friis*	Solanaceae	S	Oromo Halala
87	*Strychnos*	*henningsii*	*Gilg*	Loganiaceae	T	Galo
88	*Syzygium*	*gueneense**	*(Willd.) DC*	Myrtaceae	T	Bedesa
89	*Teclea*	*simplicifolia*	*(Engl.) Verdoorn*	Rutaceae	T	Hadhessa
90	*Toddalia*	*asiatica*	*(L.) Lam*	Rutaceae	L	Go'o

No	Species			Family	Hab.	Vern. Name (Oromo)
91	*Trichilia*	*emetica**	*Vahl.*	Meliaceae	T	Kokolfa
92	*Urera*	*hypselodendron*	*(A.Rich.) Wedd.*	Urticaceae	L	Halilu
93	*Vepris*	*dainellii*	*(Pich.-Serm.) Kokwaro*	Rutaceae	T	Hadhessa
94	*Vernonia*	*amygdalina**	*Del.*	Asteraceae	T/S	Ebicha
95	*Vernonia*	*auriculifera*	*Hiern*	Asteraceae	S	Reji
96	*Wontafulesa-Dima**			Celastraceae		*Wontafulesa-Dima**
97	Worqicha				T/S	Worqicha

Annex 2. Important Value Index (IVI) of species in Munessa-Shashemene Natural Forest (in descending order).

No.	Species		RD	RelDom	RF	IVI	%age	Rank
1	*Podocarpus*	*falcatus*	7.0	19.5	9.4	35.9	12.7	1
2	*Maytenus*	*senegalensis*	15.4	8.1	4.1	27.6	9.7	2
3	*Myrsine*	*melanophloeos*	12.8	2.1	4.5	19.4	6.8	3
4	*Ficus*	*sycomorus*	0.8	14.4	1.1	16.3	5.8	4
5	*Arundinaria*	*alpina*	12.3	0.3	2.3	14.9	5.2	5
6	*Celtis*	*africana*	4.1	5.7	4.1	14.0	4.9	6
7	*Acokanthera*	*schimperi*	7.1	1.5	2.6	11.3	4.0	7
8	*Maesa*	*lanceolata*	3.8	3.0	3.4	10.2	3.6	8
9	*Erythrococca*	*trichogyne*	5.9	0.4	3.4	9.6	3.4	9
10	*Calpurnia*	*aurea*	4.3	2.3	3.0	9.6	3.4	9
11	*Bersama*	*abyssinica*	2.1	0.1	6.4	8.7	3.1	11
12	*Maytenus*	*obscura*	1.8	3.4	3.4	8.6	3.0	12
13	*Croton*	*macrostachyus*	1.4	2.9	3.8	8.1	2.8	13
14	*Cordia*	*africana*	0.9	3.5	3.4	7.8	3.0	14
15	*Ficus*	*sur*	0.4	5.7	0.8	6.9	2.4	15
16	*Mimusops*	*kummel*	0.9	2.7	2.6	6.3	2.2	16
17	*Maytenus*	*addat*	0.3	4.8	0.8	5.8	2.0	17
18	*Galiniera*	*saxifraga*	2.5	1.1	1.9	5.6	2.0	17
19	*Prunus*	*africana*	0.7	2.7	1.9	5.3	1.9	19
20	*Schefflera*	*volkensii*	0.3	3.5	0.8	4.6	1.6	20
21	*Ficus*	*vallis-choudae*	0.2	2.9	1.1	4.3	1.5	21
22	*Hagenia*	*abyssinica*	0.2	2.8	1.1	4.2	1.5	21
23	*Nuxia*	*congesta*	1.1	0.3	2.3	3.7	1.3	23
24	*Brucea*	*antidysenterica*	1.7	0.1	1.9	3.6	1.3	23
25	*Ilex*	*mitis*	0.6	1.8	1.1	3.5	1.2	25
26	*Carissa*	*spinarum*	1.0	0.0	1.9	2.9	1.0	26
27	*Vernonia*	*auriculifera*	0.9	0.0	1.9	2.8	1.0	26
28	*Ficus*	*ovata*	0.1	1.7	0.8	2.6	0.9	28
29	*Dovyalis*	*verrucosa*	0.5	0.0	1.9	2.4	0.8	29
30	*Ekebergia*	*capensis*	0.4	0.3	1.5	2.2	0.8	29
31	*Albizia*	*gummifera*	0.2	0.7	0.8	1.7	0.6	31
32	*Lobelia*	*giberroa*	0.7	0.1	0.8	1.5	0.5	32

No.	Species		RD	RelDom	RF	IVI	%age	Rank
33	*Chionanthus*	*mildbraedii*	0.4	0.6	0.4	1.4	0.5	32
34	*Teclea*	*simplicifolia*	0.6	0.0	0.8	1.4	0.5	32
35	*Croton*	*dichogamus*	0.5	0.0	0.8	1.2	0.4	35
36	*Euclea*	*racemosa*	0.2	0.1	0.8	1.0	0.4	35
37	*Pittosporum*	*viridiflorum*	0.1	0.4	0.4	0.8	0.3	37
38	*Pavetta*	*abyssinica*	0.3	0.0	0.4	0.7	0.3	37
39	*Discopodium*	*penninervium*	0.3	0.0	0.4	0.7	0.2	39
40	*Rhus*	*natalensis*	0.2	0.0	0.4	0.6	0.2	39
41	*Hypericum*	*revolutum*	0.1	0.0	0.4	0.5	0.2	39
42	*Acacia*	*sp*	0.1	0.1	0.4	0.5	0.2	39
43	*Ehretia*	*abyssinica*	0.1	0.0	0.4	0.5	0.2	39
44	*Rhus*	*ruspolii*	0.1	0.0	0.4	0.5	0.2	39
45	*Apodytes*	*dimidiata*	0.1	0.0	0.4	0.5	0.2	39
46	*Juniperus*	*procera*	0.1	0.0	0.4	0.4	0.2	39
47	*Strychnos*	*henningsii*	0.1	0.0	0.4	0.4	0.2	39
48	*Vepris*	*dainellii*	0.1	0.0	0.4	0.4	0.2	39
49	*Phoenix*	*reclinata*	0.1	0.0	0.4	0.4	0.2	39
	Total					283.7	100.0	

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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.

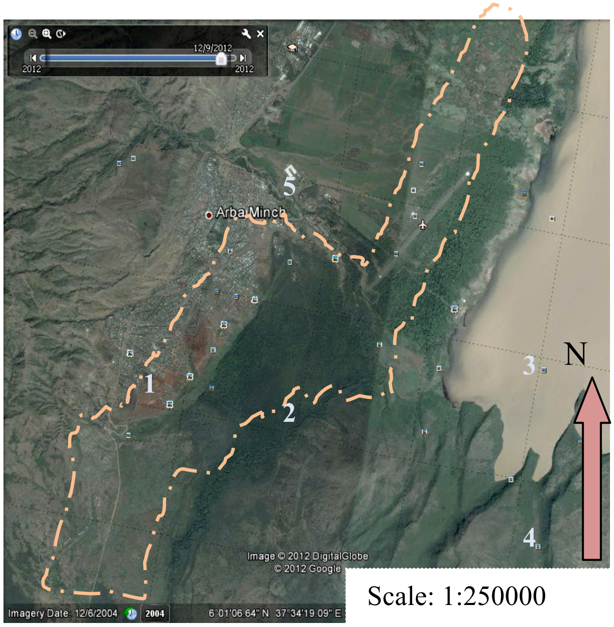
There is, therefore, a need to study the country's riverine forests in terms of their species diversity, structural elements and identification of ecologically important and threatened species, which are in need of high attention for conservation. The present study aims at investigating the floristic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



Scale: 1:250000

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.

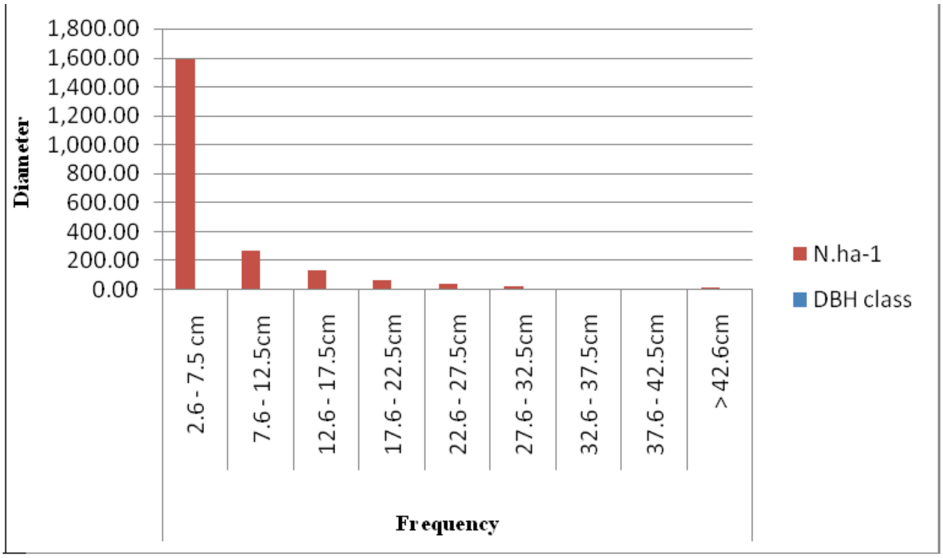


Fig. 2. Diameter-frequency distribution.

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.

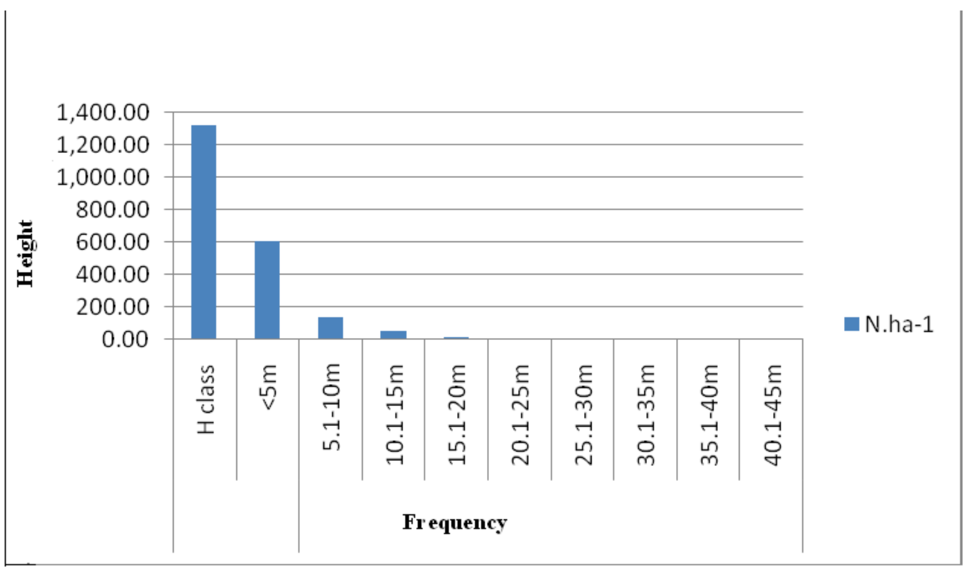


Fig. 3. Height-frequency distribution.

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.*

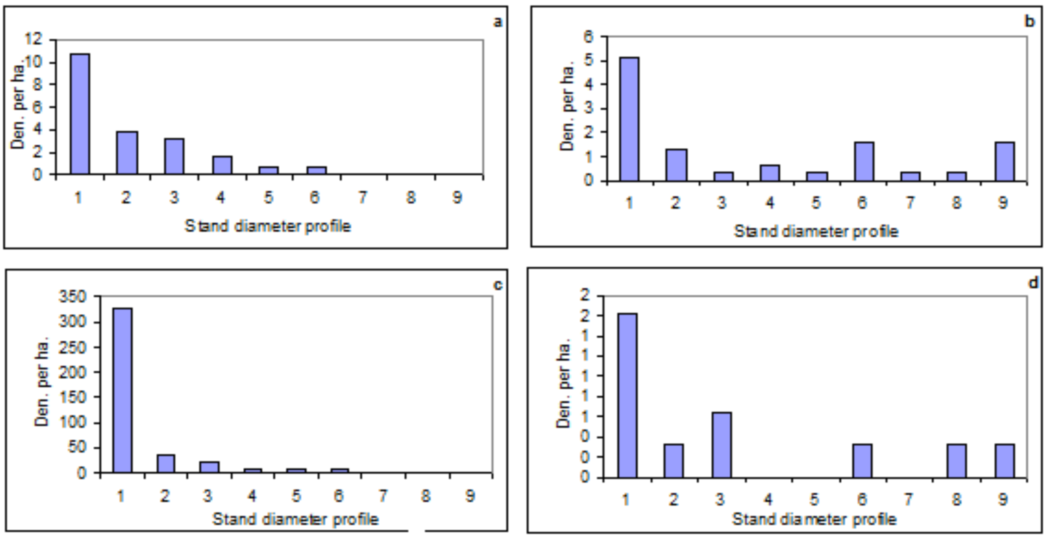


Fig.4. Four representative patterns of population structure of species: a = *C. Africana;* b = *T. emetic*; c = *L. fraxinifolius*; and d = *C. africana*

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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ETHIOPIAN JOURNAL OF BIODIVERSITY

GUIDELINES FOR CONTRIBUTORS

1. GENERAL

a) The Ethiopian Journal of Biodiversity (*EJB.*) publishes scholarly standard (full length) articles in the various basic and applied biological disciplines.

b) It also publishes feature articles, short communications, review articles, book reviews and dissertation abstracts.

2. STYLE AND FORMAT

2.1 Title page

2.1.1 The following shall appear on the title page:

- A full title of the manuscript.
- The name/s of the author/s and address(es) including institution(s) in which the research was carried out, affiliation(s) of the author(s) referred to at the bottom of the page with the use of an asterisk if it is a single author or numerical superscripts if more than one. The author to whom all correspondence should be addressed should also be mentioned.
- An abstract not more than 250 words.
- Key words (up to five, and in alphabetical order) should be given next to the abstract in a separate line.

2.2 Nature of the manuscript

2.2.1 Manuscripts should be written in English.

2.2.2 Manuscripts should not exceed 30 pages, including the abstract.

2.2.3 Original manuscript plus three copies, printed double-spaced throughout and with wide margins (minimum 30 mm) on a good quality paper should be submitted.

2.2.4 Statement of authorship should be submitted with the manuscript. This should state that:

a) All the authors have agreed to its submission and are responsible for its contents. This statement should preferably be signed by all authors.

b) The paper, other than an abstract or an oral presentation, has not been or will not be submitted elsewhere.

2.3 Standard ('full-length') papers

2.3.1 Standard papers should be divided into the following sections: Abstract, Introduction (including objectives and literature survey), Materials and Methods, Results, Discussion, Acknowledgements and References. Repetition of content between sections must be avoided. A combined Results and Discussion section is permitted.

2.3.2 Citations and references

a) Each reference should have the following form in the text:

- Skole and Tucker (2003), or if more than two authors, Ensermu Kelbessa *et al.* (2000).
- Put dates of publication chronologically when references are large (Evans *et al*., 1992; Richard, 1995; Claudia, 1998; Abebe Belay *et al.*, 2001).
- Ethiopian names should be in direct order, i.e., the full first name followed by the father's name; e.g. (Aramde Fetene, 2012*)* and not (Fetene, 2012) or Fetene, A. (2012).
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- Claudia, J.C. (1998). Patterns of vegetation along the Omo River in Southwest Ethiopia. *Plant Ecology* **135**: 135-163.
- Greig-Smith, P. (1983). **Quantitative plant ecology.** 3rd ed. Butterworths, London.

To cite some pages in a publication prepared by one or more editors, an acceptable format is:

- Okigbo, N.B. (1990). Homegardens in tropical Africa. In: **Tropical homegardens**, pp. 21-40 (Landauer, K. and Brazil, M., eds.). United Nations University Press, Tokyo.

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a) Tables should bear Arabic numerals and be referred to in the text by their numbers. Each table must be typed on a separate sheet and should be placed at the end of the manuscript. The approximate position of each table should be indicated in the text. Footnotes in tables should be indicated by superscript letters beginning with 'a' in each table. Descriptive material not designated as a footnote may be placed under a table as a NOTE. Vertical lines should not be used to separate columns; instead extra space should be left between the columns.

b) All illustrations should be given separately, not stuck on pages and not folded. They should be numbered as figures in sequence with Arabic numerals. Each figure should have a descriptive legend and this should be given on a separate sheet after the manuscript. Clear, glossy black and white photographs (100 X 70 mm) can be submitted to the Journal; they should be clearly numbered on the back in pencil.

c) Only International System of Units (SI) are acceptable. Symbols and nomenclatures should conform to international recommendations with respect to specific fields of specialization.

3. OTHER COLUMNS

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These are aimed at giving an overview of a particular subject suitable for a wider audience that includes recent advances in an area in which an author has been actively engaged.

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A critical evaluation of recently published books in any discipline of biological sciences will be published under this column.

Short Communications

Short communications must report completed work, not preliminary findings. They are an alternative format for describing smaller pieces of work. They should not be more than six pages and should not contain more than two figures, tables or combinations.

Feature Articles

These are articles that may cover a range of topics in basic and applied botanical, zoological, microbial and agricultural sciences, biodiversity conservation education and contributions of basic and applied agricultural sciences to society and development.

4. SUBMISSION OF MANUSCRIPT

The original and three copies typed with double spacing (unfolded) should be sent to: The Editor-in-Chief, *Ethiopian Journal of Biodiversity,* PO Box 30726, E-mail: ejb@ibc.gov.et, Addis Ababa, Ethiopia. A complete mailing and telephone or e-mail address of the corresponding author is also necessary.

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THE ETHIOPIAN BIODIVERSITY INSTITUTE

OBJECTIVES

- ➘ Create awareness on Biodiversity conservation, sustainable utilization and access to genetic resources and fair and equitable sharing of benefits arising from their utilization;
- ➘ Promote any biodiversity-related research and encourage researchers to strive for advancement of high quality research;
- ➘ Contribute to the growth and development of biodiversity education and give technical support and encouragement particularly to appropriate stakeholders;
- ➘ Enable stakeholders to interact with their local as well as international counterparts through seminars, workshops, symposia, publications, etc.;
- ➘ Popularize biodiversity conservation and sustainable use through publications and the mass media;
- ➘ Provide consultancy services and conduct collaborative investigations on issues that require biodiversity expertise;
- ➘ Publish scientific journals and other documents as media for communication among its members and the general public.

ACTIVITIES

- ➘ Organize conferences, workshops, seminars, panel discussions and film shows;
- ➘ Support the existing biodiversity education school clubs and encourage the establishment of others;
- ➘ Publish background reading materials on biodiversity topics in English and the main local languages to improve the understanding of biodiversity issues for students, teachers, and the general public;
- ➘ Create networks with sister institutions at national and international levels on matters of common interest;
- ➘ Seek for funds to support the institute's activities.

ORGANIZATION

The Ethiopian Biodiversity Institute (EBI) consists of 5 key processes (Directorates), namely: (1) Genetic Resources Access and Benefit-Sharing Directorate, (2) Field Crop & Horticulture Biodiversity Directorate, (3) Forest and Rangeland Biodiversity Directorate, (4) Animal Biodiversity Directorate, (5) Microbial Biodiversity Directorate; and 4 support processes (Directorates), namely: (1) Public Relations and Communication Directorate, (2) Finance, Procurement and Property Administration Directorate, (3) Audit Directorate, Plan & Program Directorate, and (4) Human Resources Development and Administration Directorate.

All inquiries about the EBI can be addressed to the

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