Structure and Regeneration Status of Menagesha Amba Mariam Forest (Egdu Forest) in Central Highlands of Shewa, Ethiopia

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Abstract
This study was conducted in Menagesha Amba Mariam Forest (Egdu), a dry evergreen afromontane forest in central highlands of Ethiopia. The aim of the study was to determine vegetation structure, community types and regeneration status of the forest. Sixty- nine sample plots (20 m x 20 m) were laid following altitudinal gradient and each releve has a 125 m altitudinal drop. Herbaceous species were collected from five (1 m x 1 m) sub-plots laid at four corners each and one at the centre of the large releve. All plant species found in each plot were recorded, collected, pressed and identified following Flora of Ethiopia and Eritrea. Diameter at Breast Height (DBH) and height were measured for trees and shrubs having DBH > 2.5 cm. The analysis of vegetation revealed that the forest possesses the highest number of DBH, height and density of species at the lower classes. Vertical stratification revealed that most of the species in the Menagesha Amba Mariam Forest were found in the lower storey. The total density of tree stems per hectare and basal area of trees with DBH >2.5 cm were 4,362.08 and 84.17 m^2 ha^{-1} respectively. The total density of tree species greater than 2 cm and 10 cm DBH were found to be 860.56 which is greater than those with DBH >20 cm (197.46). Thus the regeneration prevalence of small individuals (seedlings and saplings) was at good condition. Menagesha Amba Mariam Forest which is one of the remnant dry evergreen afromontane forests in central Ethiopia was selected to provide baseline information of the forest and degree of anthropogenic impact.
Keywords: Altitudinal gradient, dry evergreen montane forest, Menagesha Amba Mariam Forest, regeneration

INTRODUCTION

Ethiopia is extremely heterogeneous ecologically. The great geographical diversity, vegetation types, soil types and diverse climatic conditions led to the emergence of habitats that are suitable for the evolution and survival of various plant and animal species. As a result, Ethiopia has diverse flora and fauna in tropical Africa (Tewolde B.G. Egziabher, 1991). The vegetation of the country is very heterogeneous and has a rich endemic element. Biological diversity is a very complex and multifaceted term (Groombridge, 1999). UNEP (1995) defines biodiversity as the variability among living organisms of all sources. It encompasses: ecosystems, species, genes and cultural diversity. The complexity arises from the great variation in altitude employing equally great spatial difference in moisture regime as well as temperature (Zerihun Woldu, 1999). Forests are one of the great inherited resources of the earth and are nature's generous and abundant renewable resource, providing a wide range of economic, social, environmental and cultural benefits and services. The demand for versatile functions and outputs of forests are increasing with exponential population growth, whereas forest resources are shrinking as a result of over-harvesting, deforestation and permanent conversion to other forms of land use in tropical countries in which forest represents unique situation in terms of global environmental issues (Birhanu Mengesha, 1997).

In Ethiopia, forest cover has been declining rapidly. Most of the remaining forests of the country are confined to south and south- western parts of the country (Tesfaye Bekele, 2002). Loss of forest cover and biodiversity owing to human-induced activities is a growing concern in many parts of the world including our country (Sebesebe Demissew, 1980). Deforestation is one of the main causes of the prevailing land degradation in Ethiopia. Some parts of northern Ethiopia that currently are bare and experience severe land degradation once had a good vegetation cover. The reduction of forests in the tropics impairs important atmospheric functions as carbon sinks and the combustion of forest biomass releases the atmospheric CO_2, contributing to the buildup of greenhouse gases and global warming. The current rate of deforestation and loss of fertile topsoil results in massive environmental degradation (Tamrat Bekele, 1993). The climate of Ethiopia has been changing due to global and local effects of vegetation degradation. Frequent drought, crop failure and famine are becoming common events in the highlands, which are the indicators of desertification (Demel Teketay, 2001). The vertical stratification of trees in the study area was examined using classification scheme (Lamprecht, 1989). Even though Ethiopia is rich in biodiversity with high endemism and most of the forests provide socio-economic benefits and ecological function for longtime (Abate Zewdie, 2007), most of its biodiversity is being now threatened, endangered and some are also locally extinct. This is due to habitat destruction and fragmentation, over exploitation of wildlife and their habitat beyond the limit of regeneration (Million Bekele, 1998). Forests also have indispensable role in day to day life functions, but they have been given least considerations. Human pressure and unwise utilization of forest resources are among the existing threats which lead to habitat loss.

Menagesha Amba Mariam (MAM) Forest is also one of these exposed forests, and there was no research carried out in the forest previously. Therefore, in order to implement appropriate forest management measures that could minimize forest losses, adequate information on factors affecting natural forest and the rate at which they cause depletion have to be obtained. The research assessed degree of exploitation, rate of regeneration, structure and distribution of plant species in a given area. The question is the magnitude of the impact and changes occurred on the distribution in general and structure in particular as a result of the combined effect of anthropogenic activities. Hence, the present situation of such fragile ecosystem grabs the attention and interest of researchers. Therefore, the present study is broadening its scope to assess the structural distribution together with regeneration status of the forest. Hence, this study was initiated to be conducted on the forest with the major objective of investigating structure and regeneration status of Menagesha Amba Mariam (Egdu) Forest in central highlands of Shewa, Ethiopia.

MATERIALS AND METHODS

Study Area Description

Geographical location

The present study was conducted in Welmera Wereda, Oromia National Regional State, central high lands of Ethiopia (Fig. 1). The study forest is located at about 30 km west of Addis Ababa, and has total area around 84.354 hectare. The forest is known to have gradient of altitude and consequently, it contains variety of wildlife including mammals, birds, natural and planted plant species, algae, fungi, etc. Menagesha Amba Mariam Forest (MAMF) is situated approximately between $9^0 01'$- $09^0 03'$ N and $38^0 35'$ - $38^0 36'$ E. The altitudinal range of the study area varies from 2574 - 2948 m above sea level.

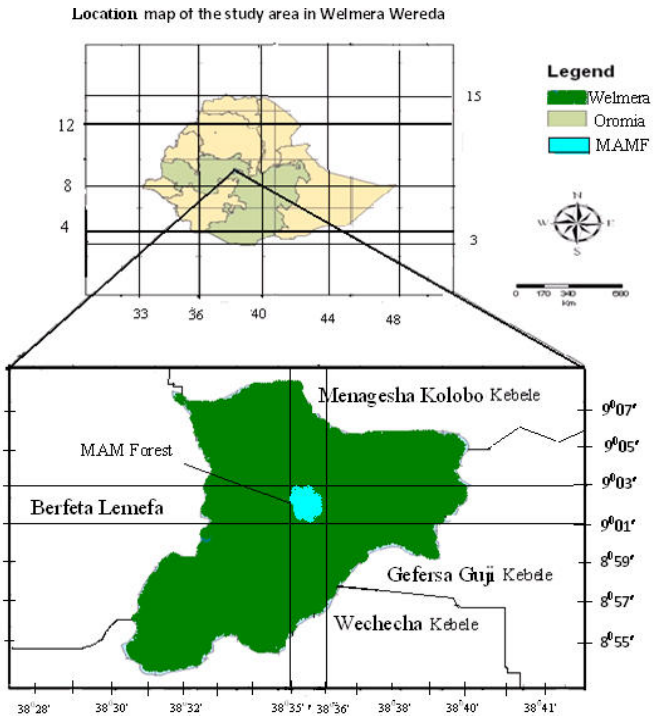


Figure 1. Location map of the study forest

Natural vegetation

The forest is dominated by *Juniperus procera*, *Olea europea* subsp *cuspidata, Olinia rochetiana* and *Rhus vulgaris. Hagenia abyssinica* trees are found scattered in some inaccessible parts of the forest. At higher altitudes, smaller trees of *Juniperus procera* are mixed with *Erica arborea*, *Rosa abyssinica,* planted *Acacia mearnsii,* and the endemic *Jasminum stans* are the dominant species. *Carissa spinarum* and *Smilax anceps* are among the most dominant shrub and woody climber respectively. *Arundinaria alpina* is found only at the top in one corner of the forest.

RESULTS AND DISCUSSION

Analysis of Vegetation Structure

Density of tree species

Analysis on density distributions by diameter classes for tree species showed different patterns. Such patterns of species population structure can indicate variation in population dynamics. To observe regeneration of species in the study area, 32 plant species were selected based on their mean cover abundance value (Table 2). The total density of mature species with DBH > 2.5 cm in the forest was 1058.02 stems ha^{-1}. This was classified into seven density classes: 1) ≤ 1, 2) 1.01- 5, 3) 5.01-10, 4) 10.01-20, 5) 20.01-35, 6) 35.01-50 and 7) > 50 stems ha^{-1}. The density of each species was calculated and compared as the number of individuals per hectare with DBH greater than 2 cm, 10 cm and 20 cm (Table 6). The density of trees with DBH greater than 2 cm is 705.1 individuals / ha. The density shows irregular distribution which increases from the first to the second classes and then decrease in the third class and then increase in the fourth; it also decreases in the fifth class and absent in the sixth class (Fig. 4a). The density of species with DBH greater than 10 cm is 155.46 individuals per hectare. This class shows significant values in the first three classes and very small values in the fifth and seventh classes and totally absent in the fourth and sixth classes (Fig.4b). The density of woody species at DBH greater than 20 cm is 197.46 individuals per hectare. The first two classes contain maximum values of this class while the fourth and seventh classes show very small values and classes: three, five and six have no representatives (Fig. 4c). The overall density distribution of the forest shows high value in the first two classes and small values in the rest classes except class six which has no representatives in all the density classes (Fig. 4d). As Table 7 shows, the largest proportion of the species density at DBH > 2 cm is contributed by *Olea europaea* (17.7%) followed by *Juniperus procera* (15.8%) *Olinia rochetiana* (11.3%) and *Erica arborea* (9.73%) which constitute the 1st, 2nd, 3rd and 4th largest proportions. The density of species (Table 7) at the DBH class > 10 cm alone is 155.46 individuals per hectare. At this DBH class, the largest proportion of species density is contributed by *Juniperus procera* (34.00 %), *Olea europaea* subsp. *cuspidata* (20.5%) *and Myrica salicifolia* (5.1%). Tree species with DBH class > 20 cm has 197.46 individuals ha^{-1}. Among the tree species *Juniperus procera, Olea europaea* subsp. *cuspidata* and *Scolopea theifolia* covers 50.8 %, 25.5 %, and 9 % of the species density respectively.

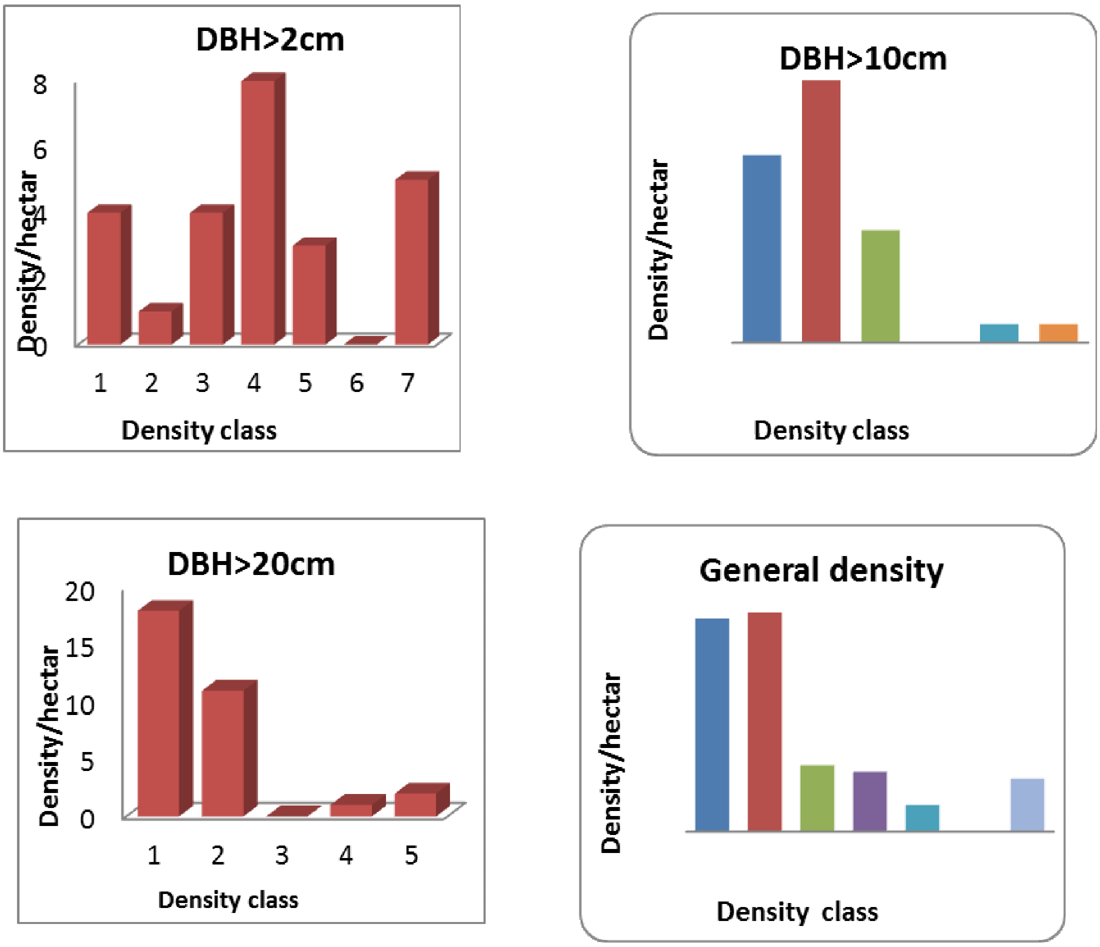


Figure 2. Population structure of plant species with DBH >2 cm, >10 cm, >20 cm and their general density.

Table 1. Distribution of trees in different DBH classes

DBH (cm)	Density ha^{-1}	Percentage
< 10	705.1	66.60
>10 (a)	155.46	14.70
>20 (b)	197.46	18.70
Ratio of a to b	0.8	

The ratio of the density of individuals greater than 10 cm to those greater than 20 cm is taken as a measure of the distribution of the size classes (Grub *et al*., 1963). This ratio is 0.8 for the Menagesha Amba Mariam Forest, indicating only slight variability between the proportion of small-sized and large-sized individuals. According to Grubb *et al*. (1963), the ratio of 'density at DBH class >10 cm' to 'density at DBH class >20 cm' can be used as a measure of the distribution of the different size classes. The dominance of small sized (DBH>2-9.9 cm) individuals in the forest is largely due to the high density of *Olea europaea* subsp. *cuspidata* (124.28 stems/ha), *Juniperus procera* (111.23 stem/ha), *Olinia rochetiana* (79.71 stems ha^{-1}) and *Erica arborea* (68.5 stems/ha) (Table 7). The density of species include not only species with DBH value greater than 2.5 cm but also those trees and shrubs with DBH <2.5 cm by considering as seedling and sapling. The seedling, sapling and trees density of selected 32 species were 451.77, 1166.13 and 2744.18 individuals/ha respectively. The highest seedling density ha^{-1} (Fig. 12c & Table 15) was observed for *Olinia rochetiana (*17.7%), *Erica arborea* (15.2%)*, Scolopea theifolia* (8%) and *Olea europaea* subsp. *cuspidata* (7%). Density of sapling (1025.7 individuals/ha) of species was also investigated and the highest number of sapling density ha^{-1} was exhibited by *Olea europaea* subsp. *cuspidata* (14.3%) *Olinia rochetiana* (12.9%), *Erica arborea* (11.4%), *Juniperus procera* (7.9%*)* and *Sideroxylon oxyacanthum* (6.3%) respectively. The bold value in Table 9 shows species with higher contribution for the large value of density.

Table 2. Density of trees from MAM Forest with different DBH classes

No	Species	>2cm Ind/ha	%	>10cm Ind/ha	%	> 20cm Ind/ha	%	Total Density
1	*Acacia abyssinica*	14.90	2.11	6.88	4.43	4.35	2.20	26.13
2	*Apodytes dimidiata*	2.17	0.31	0.00	0.00	1.45	0.73	3.62
3	*Aruninaria alpina*	2.17	0.31	0.36	0.23	0.00	0.00	2.53
4	*Bersama abyssinica*	16.30	2.32	1.10	0.70	0.00	0.00	17.40
5	*Buddleja polystachya*	9.10	1.29	5.07	3.26	0.72	0.37	14.89
6	*Carissa spinarum*	14.41	1.91	0.36	0.23	0.00	0.00	14.77
7	*Croton macrostachyus*	0.72	0.10	1.45	0.93	2.54	1.28	4.71
8	*Scolopia theifolia*	5.10	0.72	1.81	1.17	**17.75**	9.00	24.66
9	*Dombeya torrida*	4.71	0.67	0.72	0.47	0.00	0.00	5.43
10	*Dovyalis abyssinica*	13.04	1.85	1.45	0.94	0.36	0.18	14.85
11	*Ekebergia capensis*	2.90	0.41	0.72	0.47	0.00	0.00	3.62
12	*Erica arborea*	**68.50**	9.73	5.79	3.73	1.45	0.73	75.74
13	*Ficus sur*	0.00	0.00	0.36	0.23	0.72	0.37	1.08
14	*Hagenia abyssinica*	7.61	1.08	3.99	2.56	2.17	1.10	13.77
15	*Hypericum revolutum*	2.17	0.31	0.36	0.23	0.72	0.37	3.25
16	*Juniperus procera*	**111.23**	15.80	**52.90**	34.03	**100.36**	50.83	**264.49**
17	*Maesa lanceolata*	0.72	0.10	0.00	0.00	0.00	0.00	0.72
18	*Maytenus arbutifolia*	12.68	1.81	1.10	0.70	0.00	0.00	13.78
19	*Maytenus obscura*	3.62	0.51	2.17	1.40	1.45	0.73	7.24
20	*Millettia ferruginea*	0.00	0.00	1.10	0.70	1.10	0.55	2.20
21	*Myrica salicifolia*	8.70	1.24	**7.97**	5.14	1.81	0.93	18.48
22	*Nuxia congesta*	28.26	4.01	3.99	2.57	0.36	0.18	32.61
23	*Olea europaea* subsp. *cuspidata*	**124.28**	17.65	**31.88**	20.50	**50.36**	25.50	**206.52**
24	*Olinia rochetiana*	**79.71**	11.32	4.71	3.03	0.00	0.00	**84.42**
25	*Osyris quadripartita*	30.43	4.32	3.26	2.10	0.36	0.18	34.05
26	*Pittosporum viridiflorum*	11.60	1.65	1.45	0.93	0.00	0.00	13.05
27	*Podocarpus falcatus*	13.04	1.85	5.43	3.50	3.99	2.01	22.46
28	*Prunus africana*	13.77	1.96	1.45	0.93	2.90	1.47	18.12
29	*Rhamnus staddo*	3.99	0.56	0.00	0.00	0.00	0.00	3.99
30	*Rhus glutinosa*	1.45	0.21	0.36	0.23	0.00	0.00	1.81
31	*Rhus vulgaris*	30.07	4.27	5.10	3.26	2.54	1.29	37.71
32	*Sidroxylon oxyacanthum*	**67.75**	9.62	2.17	1.40	0.00	0.00	69.92
	Total	705.10	100.00	155.46	100.00	197.46	100.00	1058.02

Diameter at Breast Height (DBH)

The distribution of trees in different DBH classes is given in Figure 6. The number of stems in DBH class less than 10 cm (classes 1 and 2) is 708.7/ha (67.18%), 188.04/ha (17.8%) in 10-25 cm, 89.13/ha (8.42%) in 25-40 cm and 69.93/ha (6.6%) in >40 cm. The overall density distribution of individuals in the various size classes showed decline towards the higher DBH classes (i.e., as DBH size classes increase the number of individuals decrease). The highest densities of species were recorded in the lowest DBH size classes. The distribution of trees in DBH class from lower to higher showed a decreasing trend, but the percentage DBH of trees in DBH class >140 cm was contributed by *Juniperus procera*, *Olea europaea* subsp. *cuspidata* and few individuals of *Hagenia abyssinica*. The total DBH of trees in lower classes is much higher when compared to the DBH of the intermediate and higher classes. Distribution of all individuals in different size classes showed relatively an inverted J-shape distribution for both DBH and height classes (Fig. 4). This pattern indicates that the majority of the species had the highest number of individuals in lower DBH and height classes. This pattern implies that the forest vegetation has good reproduction and recruitment potential.

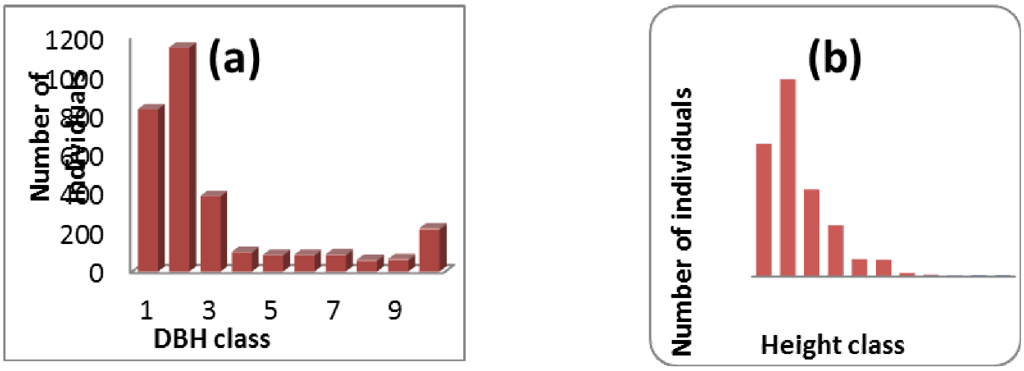
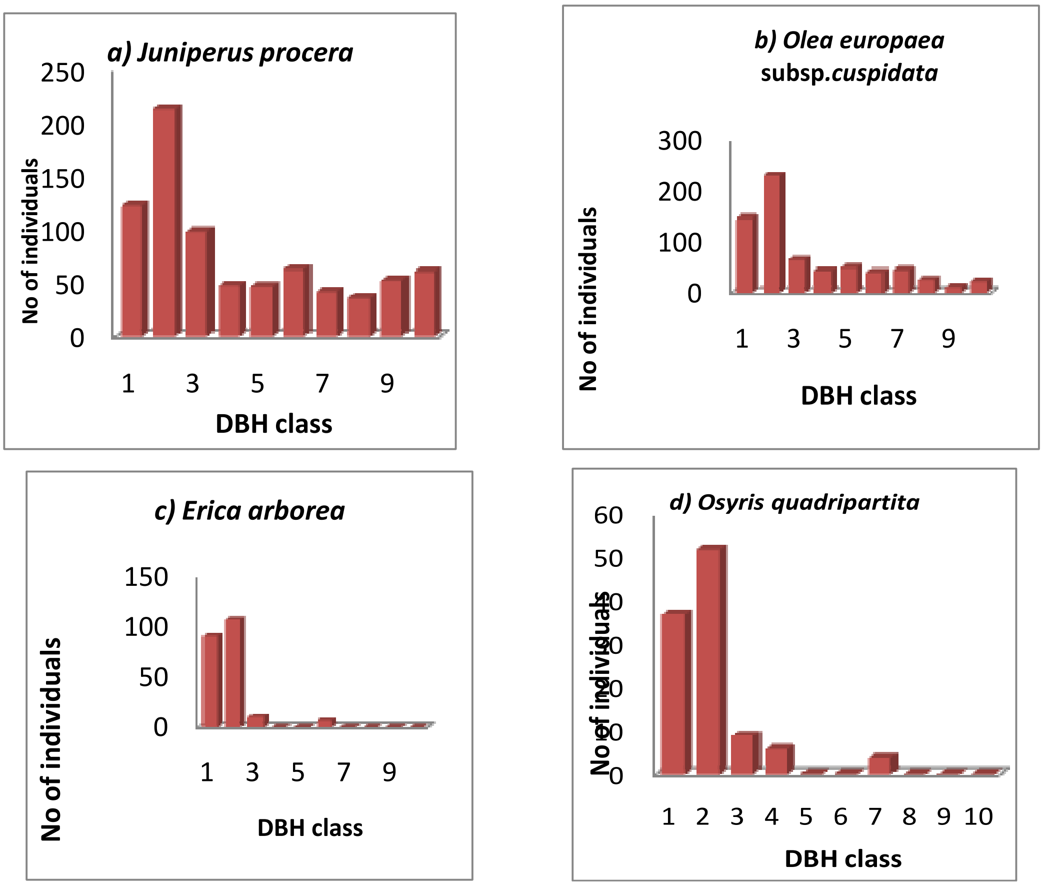


Figure 3. General DBH and Height class versus number of individuals in MAM Forest



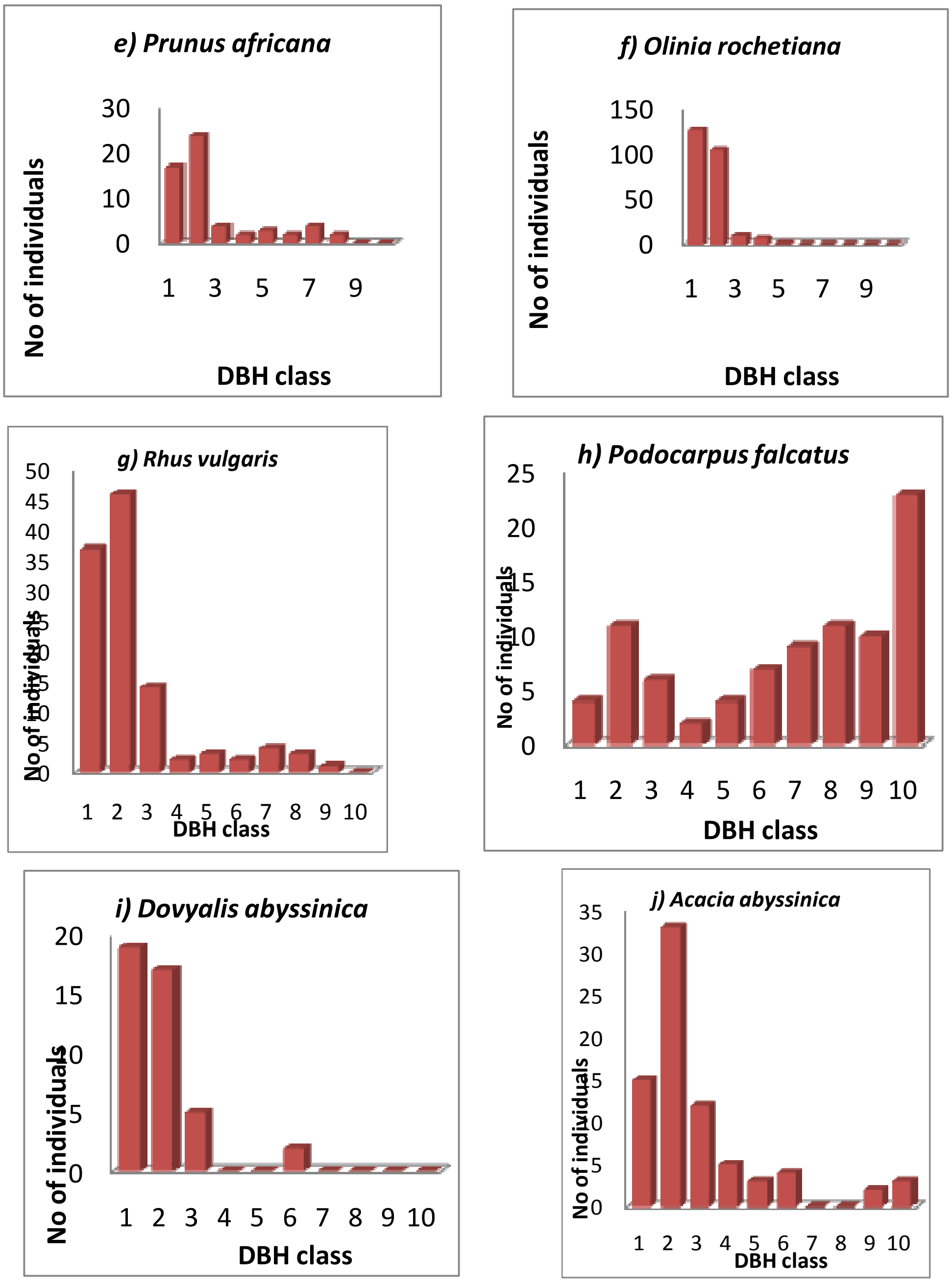


Figure 4 (a-j). Ten top dominant tree species population structure of the Forest

Analysis of density distribution by diameter classes of woody species resulted in different patterns (Figure 4a-j). The first pattern shows high value in the 5.1-10cm diameter class and almost uniformly represented in the rest classes. This pattern is detected for *Juniperus procera* (Fig.4a). Figure 4c, d, and g also showed strong peaks up to 10 cm and followed by abrupt decline from 10.1-20 cm and then totally absent in the higher classes (>20 cm). This pattern was represented by *Erica arborea, Osyris quadripartita,* and *Rhus vulgaris.* Population patterns (Figure 4e & j) indicating selective removal of higher class individuals which shows good reproduction but, discontinuous recruitment. Representative species for this pattern are *Prunus africana* and *Acacia abyssinica*. Figure 4b shows high value up to 10 cm (class1 & 2) and uniformly decline up to the ninth class and also increases in the tenth class. This pattern relatively shows an inverted J-shape and exemplified by *Olea europaea* subsp. *cuspidata.* The other recognizable pattern (Figure 4h) shows high value in the higher DBH classes and small value in DBH classes<5 cm, and 15-25 cm and then highest value in the last class (>45 cm). This pattern revealed selective cutting and removal of medium sized individuals have taken place. In this case the juveniles are not well represented and show poor regeneration. The representative example is *Podocarpus falcatus.*

Tree height

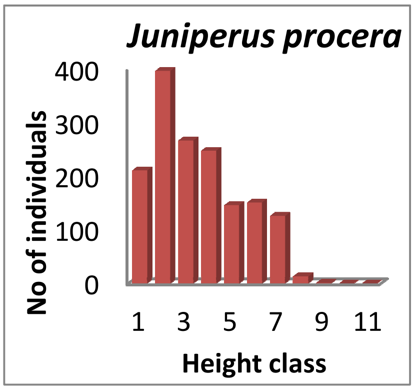
The trees in the study area could be conveniently divided into eleven height classes. The overall height class distribution of individuals in Menagesha Amba Mariam Forest showed higher number of individuals in the lower size and a gradual decrease towards the middle and upper size trees indicating continuous representation of individuals in all height classes. Trees in height class I and II, together make 65.5%/ha. Trees in the height classes III and IV together are found to be 24.5%. The old trees are found in the height class VII and VIII and their percentage distribution is 9.52%/ha. Height classes I and II are represented by *Olea europaea* subsp. *cuspidata,Juniperus procera, Erica arborea, Sideroxylon oxyacanthum* with 15.78%, 15, 6%, 9.91% and 8.8% respectively while height class VIII is dominated by *Juniperus procera* (72..7%) and *Apodytes dimidiata* (27.27%). The upper canopy is dominated by these five tree species in the area. *Olea europaea* subsp. *cuspidata, Juniperus procera,* and *Prunus africana are* the emergent trees and grow above all the canopy trees except *Podocarpus falcatus* and *Hagenia abyssinica* at some inaccessible and well protected parts of the forest. The analysis based on relative density, diameter and height classes carried out for tree species of the forest resulted in different patterns. Generally, four patterns of population structure were analyzed. Each structural pattern reveals different population dynamics (Fig. 5).

The first pattern was formed by species with highest density in the second class, medium value in the first, third and fourth classes, small values in classes five six and seven and no value in the rest classes. This pattern shows better reproduction but a bad recruitment potential in the forest. This pattern was observed height class of *Olea europaea* subsp. *cuspidata* and *Juniperus procera* (Fig. 5a & b).

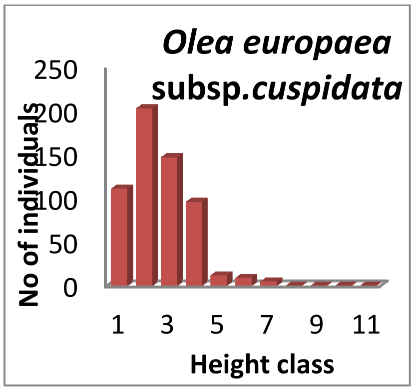
The second pattern (Fig. 5c, f, g & i) was indicated by species well represented in the lower height classes and absent in the higher classes which are species with no reproduction and only very few large and old individuals. This pattern was frequent in most shrubs and some trees. This indicates that there is an indiscriminate exploitation of large individuals of this species. Species with such a pattern could become endangered in the future, because individuals are being harvested before reaching reproductive ages, and this could result in the future decline of the species population because these reflect good reproduction but, bad recruitment. The height class of *Erica arborea, Olinia rochetiana, Prunus africana* and *Rhus vulgaris* shows this type of pattern.

The third pattern (Fig. 5k) indicates a normal distribution of species with reversed J-shape. Maximum values occurred in the first class and then reduce gradually up to the fourth class. This pattern represents good reproduction status and regeneration potential. *Osyris quadripartita* is the representative of this pattern.

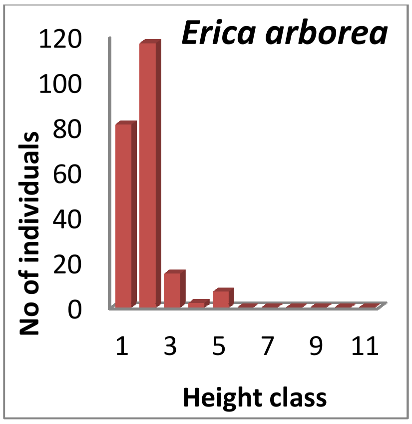
The fourth pattern was indicated by low density in the lower height classes and high density in the higher height classes and no value in the last class. The species under this pattern have big individuals that are less competent to reproduce and hence represent poor reproduction, regeneration and thus a declining population. The pattern shows relatively J-shape curve and represented by height class of *Podocarpus falcatus* (Fig. 5h). Variations in the population structure of plant species may be attributed to environmental factors that can interrupt in regeneration, differences in the regeneration behavior of the species, human intervention, and change in climate, natural and artificial disturbances.


Juniperus procera
No of individuals
400
300
200
100
0
1 3 5 7 9 11
Height class

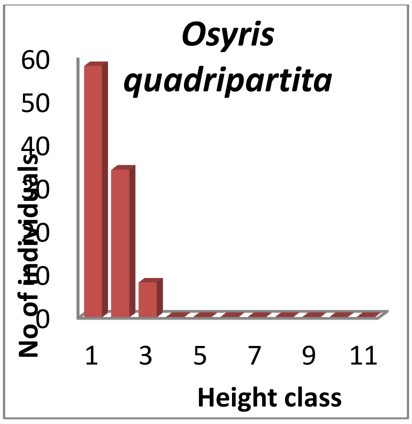
(a)


Olea europaea subsp.cuspidata
No of individuals
250
0
1 3 5 7 9 11
Height class

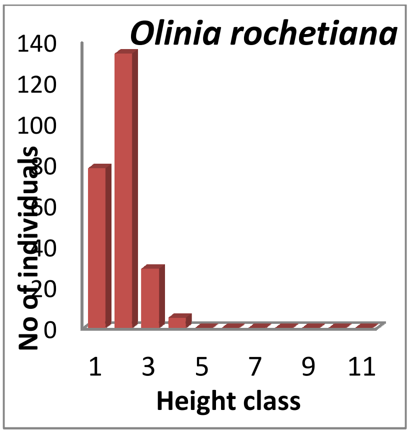
(b)


Erica arborea
No of individuals
120
100
80
60
40
20
0
1 3 5 7 9 11
Height class

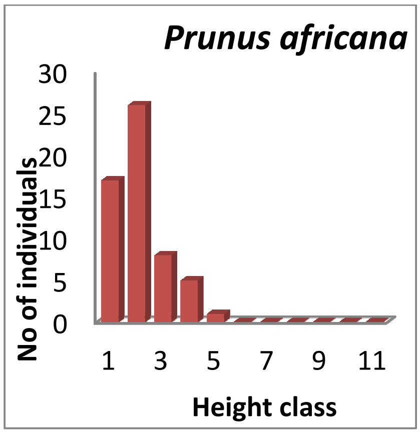
(c)


Osyris quadripartita
No of individuals
60
50
1 3 5 7 9 11
Height class

(d)


Olinia rochetiana
No of individuals
140
120
100
0
1 3 5 7 9 11
Height class

(f)


Prunus africana
No of individuals
30
25
20
15
10
5
0
1 3 5 7 9 11
Height class

(g)

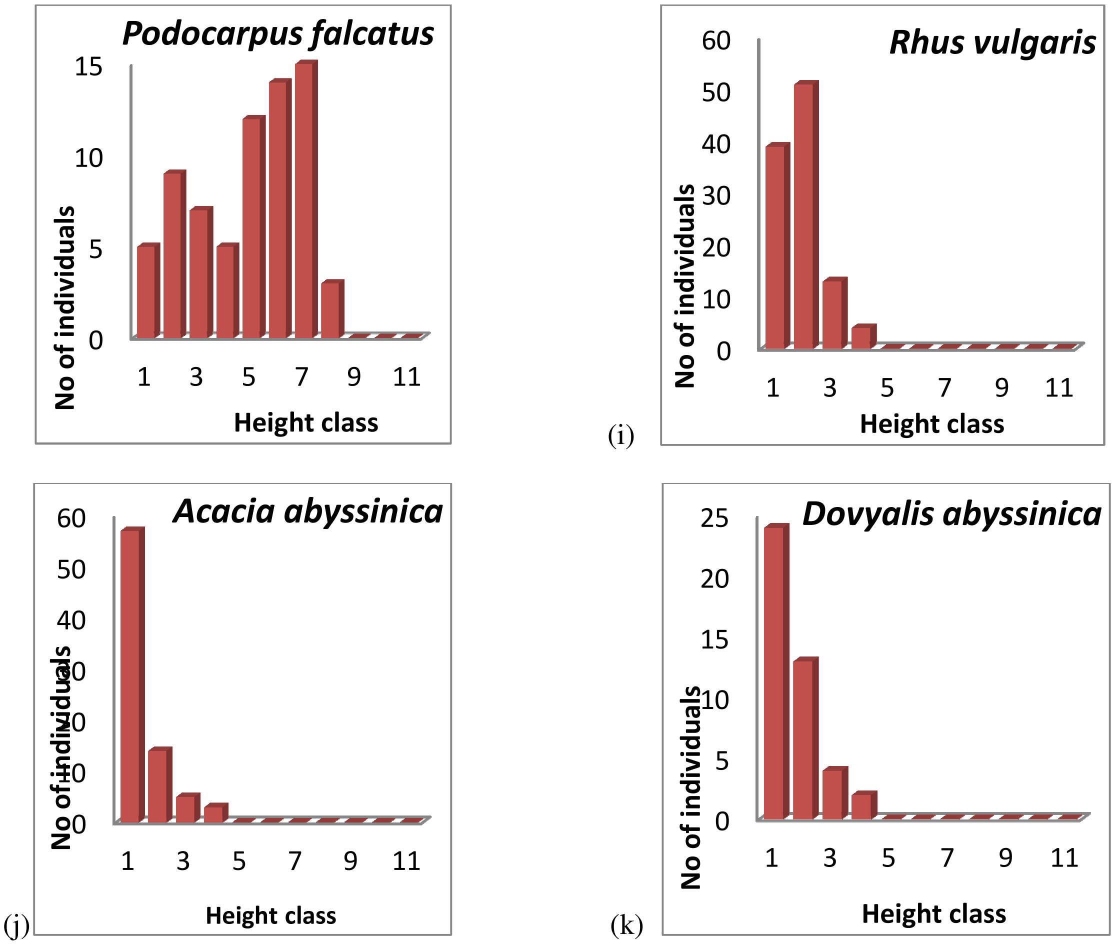


Figure 5. Ten top dominant tree species population structure of MAM Forest

Vertical structure

The vertical stratification of trees in the study area was examined using classification scheme (Lamprecht, 1989). According to this scheme, three simplified vertical structures are distinguished in tropical forests. These are: upper, middle and lower storeys. Based on the above scheme the forest vegetation was classified into three strata. The upper includes where individual tree height exceeds 2/3 of the top height while the middle storey includes species having height between 1/3 and 2/3 of the top height and the lower stratum (storey) is less than 1/3 of the top height. Based on the result obtained from the study the top height is 30 m which indicates that the upper storey is greater than 20 m, the middle storey is between 10 & 20 m and the lower storey is less than10 m. The result obtained from this forest study indicated that the highest species density, 192 species (86.9%) was found in the lower storey. Most of the apparent gaps were filled up with under storey species canopy. The lower storey is mainly covered with herbs, shrubs and small trees. Twenty five species of plants (11.4 %) reach to the middle storey. Species like *Erica arborea, Olinia rochetiana, Croton macrostachyus, Hagenia abyssinica, Buddleja polystachya, Bersama abyssinica, Nuxia congesta, Osyris quadripartita, Ficus sur, Acacia abyssinica, Maytenus arbutifolia, Maytenus obscura, Dovyalis abyssinica, Pittosporum viridiflorum, Prunus africana, Rhus vulgaris, Rhus glutinosa, Sideroxylon oxyacanthum, Myrica salicifolia, Acacia mearnsii, Dombeya torrida, Arundinaria alpina, Scolopia theifolia, Pinus patula,* and *Eucalyptus globulus* have representatives in the middle storey. The Upper storey also contains Only 5 emergent tree species (2.3%) of the total individuals in the forest that include *Podocarpus falcatus, Juniperus procera, Olea europaea* subsp. *cuspidata, Apodytes dimidiata* and *Millettia ferruginea.* There are many species which couldn't attain the upper and the middle storey by their nature. All species that have representative in the upper also appeared in the middle and lower storey. Most of these trees have started dying-back from their tips and degenerating and some of them are completely absent.

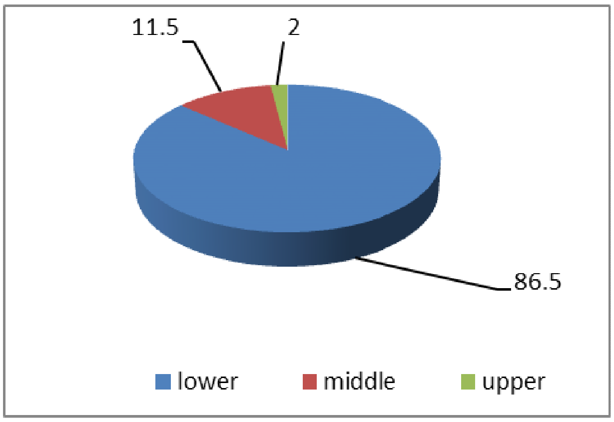


Figure 6. Percentage density of trees in lower, middle and upper storey

Basal area (BA)

The basal area of Menagesha Amba Mariam Forest was 84.17m^2/ha. The highest (44.38%) and the lowest (0.01%) BA ha^{-1} was contributed by *Juniperus procera* and *Maesa lanceolata* respectively **(Table3).** The contribution of each species to the BA ha^{-1} is given in Table 10. It is important to note here that species with the highest basal area do not necessarily have the highest density, indicating size difference between species (Tamrat Bekele, 1994; Simon Shibru and Girma Balcha, 2004; Dereje Denu, 2007). It was reported that BA provides a better measure of the relative importance of the species than simple stem count (Cain and Castro, 1959; cited in Tamrat Bekele, 1994). Thus, species with the largest contribution to BA can be considered as the most important species in the forest. Consequently, the most important tree species in Menagesha Amba Mariam Forest are *Acacia abyssinica, Hagenia abyssinica, Olea europaea* subsp. *cuspidata, Juniperus procera, Podocarpus falcatus* and *Rhus vulgaris.*

Table 3. BA m^2 ha^{-1}, R.BA and % BA of tree species in MAM Forest

	Botanical name	**BA/ha**	**% BA**	**R.BA**
1	*Acacia abyssinica*	1.49	1.74	1.77
2	*Apodytes dimidiata*	0.93	1.1	1.10
3	*Arundinaria alpina*	0.04	0.05	0.05
4	*Bersama abyssinica*	0.14	0.13	0.17
5	*Buddleja polystachya*	0.42	0.5	0.5
6	*Carissa spinarum*	0.08	0.1	0.1
7	*Croton macrostachyus*	0.64	0.76	0.76
8	*Podocarpus falcatus*	10.43	12.4	12.4
9	*Dombeya torrida*	0.07	0.07	0.08
10	*Dovyalis abyssinica*	0.19	0.23	0.23
11	*Ekebergia capensis*	0.06	0.07	0.07
12	*Erica arborea*	0.91	1.05	1.08
13	*Ficus sur*	0.19	0.23	0.23
14	*Hagenia abyssinica*	1.63	1.92	1.94
15	*Hypericum revolutum*	0.43	0.51	0.51
16	*Juniperus procera*	44.38	52.70	52.73
17	*Maesa lanceolata*	0.01	0.01	0.01
18	*Maytenus arbutifolia*	0.10	0.12	0.12
19	*Maytenus obscura*	0.32	0.35	0.38
20	*Millettia ferruginea*	0.24	0.24	0.29
21	*Myrica salicifolia*	0.61	0.72	0.73
22	*Nuxia congesta*	0.46	0.55	0.55
23	*Olea europaea* subsp. *cuspidata*	15.28	18.43	18.15
24	*Olinia rochetiana*	0.69	0.82	0.82
25	*Osyris quadripartita*	0.35	0.42	0.42
25	*Pittosporum viridiflorum*	0.15	0.18	0.17
27	*Scolopia theifolia*	0.99	1.16	1.18
28	*Prunus africana*	0.71	0.82	0.84
29	*Rhamnus staddo*	0.02	0.02	0.01

	Botanical name	BA/ha	% BA	R.BA
30	*Rhus glutinosa*	0.02	0.02	0.01
31	*Rhus vulgaris*	1.71	2.02	2.03
32	*Sideroxylon oxyacanthum*	0.48	0.56	0.57
	Total	84.17	100	100

Frequency

Frequency is the indication of homogeneity and heterogeneity of given vegetation in which the higher number of species in higher frequency classes and low percentage of number of species in lower frequency classes shows similar species composition while large number of species in lower frequency classes and small number of species in higher frequency classes indicate higher heterogeneity Lambrecht1989).

The species that appear in the lower frequency classes have irregular occurrence whereas those appearin g in higher classes have regular horizontal distribution. Frequency is the number of relevés in which a given species occurred in the study area. The trees and shrubs were classified into five frequency classes on the bases of their percentage frequency values: 1= 0-20, 2= 21-40, 3= 41-60, 4= 61-80 and 5= > 81. The frequency and % frequency values of species were given in Table 4. Two tree species (Olea *europaea* subsp. *cuspidata, Juniperus procera*) are most frequently occurred (in 68 and 66 quadrats out of 69) respectively (Table 4). The species with more than 50% distribution were *Carissa spinarum, Dovyalis abyssinica, Erica arborea, Nuxia congesta, Rhus vulgaris, Olinia rochetiana, Osyris quadripartita* and *Pittosporum viridiflorum.* The species with the least occurrence are *Aruninaria alpina*, *Apodytes dimidiata, Ekebergia capensis, Millettia ferruginea, Rhamnus staddo*, *Hagenia abyssinica* and *Ficus sur.* This study revealed that there is high frequency in the lower frequency classes and low frequency in the higher frequency classes. This indicates that the vegetation has high heterogeneity and low homogeneity.

Table 4. The five most frequently occurring tree species in the forest

Species	Frequency (F)	Percentage frequency % FR	Relative frequency (RFR)	Priority class
Juniperus procera	68	98.5	8.6	1
Olea europaea subsp. *cuspidata,*	66	95.7	8.4	1
Olinia rochetiana, and *Rhus vulgaris*	58	84.1	7.3	2
Osyris quadripartita	56	81.2	7.1	2
Dovyalis abyssinica	52	75	6.5	2

Importance value index (IVI)

Importance Value Index combines data from three parameters which include RF, RD and RDO (Kent and Coker, 1992). IVI is useful to compare the ecological significance of species (Lamprecht, 1989). It was also stated that species with the greatest importance value are the leading dominant species of specified vegetation (Simon Shibru and Girma Balcha, 2004). Percentages of species in the IVI classes were 32.5%, 9.8%, 28.6%, 27.6% and 1.5% for classes 1, 2, 3, 4, and 5 respectively (Table 5). The highest IVI value (88.7%) was in classes 1, 3 and 4, while the remaining (11.3%) at classes 2 and 5. The five most dominant tree species of Menagesha Amba Mariam Forest occupied 54.5% of the total important value index (Table 5). The dominant species were *Erica arborea, Olinia rochetiana, Podocarpus falcatus, Olea europaea* subsp. *cuspidata* and *Juniperus procera.* This figure shows that much of IVI was attributed by a few species. These tree individuals were tolerant species that resist high pressure of disturbance, natural and environmental factors, and the effect of local communities. In terms of abundance, distribution and basal area, the contribution of *Olea europaea* subsp. *cuspidata* and *Juniperus procera* were the highest of all tree species and accounted for 32.53%. These two species were the most frequent (16.9%) and they had the highest BA (59.7 m^2 ha^{-1}) out of the total BA (84.17 m^2 ha^{-1}). *Millettia ferruginea* and *Ekebergia capensis* had the lowest relative IVI values and were found to be the least dominant species among the species in the study site. *Juniperus procera* was 150 times more important than *Millettia ferruginea.* Similarly, *Olea europaea* subsp. *cuspidata* was 75 times more important than *Ekebergia capensis* in Forest. Priority for conservation of these species must be given based on their IVI values (i.e. the first priority for species with highest IVI value and the last priority of conservation for species with least IVI values) (Table 5). The result (Table 6) shows three species (*Juniperus procera, Olea europaea* subsp. *cuspidata* and *Podocarpus falcatus* are grouped in priority class one that require immediate conservation and protection while species like *Millettia ferruginea, Ekebergia. capensis, Rhamnus staddo, Apodytes dimidiata* , *Maeasa lanceolata* and *Arundinaria alpina* in the last priority class and they need the last priority of conservation (Table 6). The rest species are in the intermediate priority classes (2, 3 and 4), indicating that they need intermediate conservation programme.

Table 5. IVI classes, Values, sum of species belonging to each class and their percentage value

IVI class &value	No of species	Sum of IVI	Percentage (%)
5(<1)	6	4.22	1.5
4(1-10)	17	82.93	27.6
3(10.1-20)	6	85.73	28.6
2(20.1-30)	1	29.52	9.8
1(>30)	2	97.6	32.5

Table 6. List of species under each IVI priority class

Class 5	Class 4	Class 3	Class 2	Class 1
M. ferruginia	*Ficus sur*	*B. abyssinica*	*O. rochetiana,*	*Olea europaea*
E. capensis	*C. macrostachyus*	*O. quadripartita*	*D. abyssinica*	*J. procera*
R. staddo	*M. obscura*	*Prunus africana*	*Carissa spinarum*	*P. falcatus*
A. dimidiata	*D. torrida*	*Nuxia congesta*	*Rhus vulgaris*	
M. lanceolata	*B. polystachya*	*S. oxyacanthum*	*Erica. arborea*	
A. alpina	*H. abyssinica*	*Acacia abyssinica*		
	Myrica salicifolia	*P. viridiflorum*		
	Maytenus arbutifolia			
	Rhus glutinosa			
	Hypericum revolutum			

Where *M. Ferruginea=Millettia, B.abyssinica=Bersama, O.rochetiana=Olinia, E.capensis=Ekebergia, R.staddo=Rhamnus, A.dimidiata=Apodytes dimidiata,A.alpina=Arundinaria alpina,D.torrida=Dombeya, M.obscura=Maytenus, P.falcatus=Podocarpus,S.oxyacanthum=Sideroxylon* and *J.procera=Juniperus*

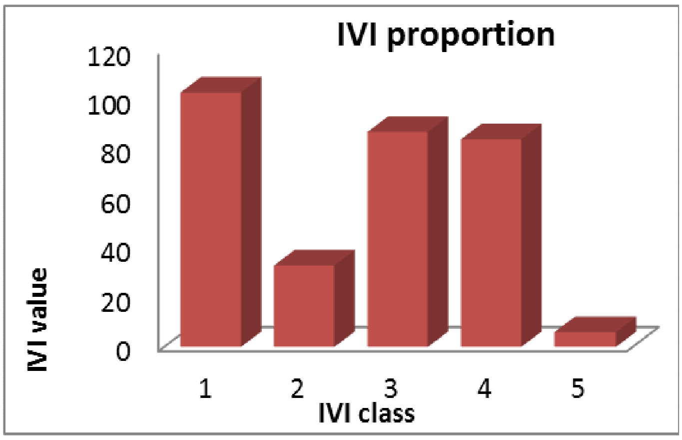


Figure 7. The IVI proportions of most frequent and dominant trees and shrubs in the study area, **IVI class:** 1=>30, 2=20.1-30, 3=10.1-20, 4=1-10, 5=<1

Regeneration status of some woody species

The density and composition of seedlings and saplings indicate the status of regeneration. The density classes of seedlings, saplings and tree species were described in Table 7. The total density of seedling, sapling and trees were 451.77 ha^{-1}, 1166.13 ha^{-1} and 2744.18 ha^{-1} (Table 7). The ratio of seedlings to saplings is 0.4 and saplings to trees (0.43) and seedlings to mature trees is 0.17. The above ratio indicates that the distribution of seedling populations less than that of sapling and that of saplings is less than mature individuals (i.e. density of seedling<saplings<mature trees). The distribution of seedlings, saplings and mature trees shows three distinct

patterns. First distribution pattern contains least density of seedlings, intermediate in saplings and highest in the tree levels. This pattern was exhibited by *Hagenia abyssinica, Olea europaea* subsp. *cuspidata*, *Juniperus procera, Osyris quadripartita, Pittosporum viridiflorum, Scolopia theifolia, Prunus africana, Dovyalis abyssinica, Ekebergia capensis, Rhus glutinosa, Rhus vulgaris* and *Sideroxylon oxyacanthum* (Table 5 & Fig. 4a, h &c).

The second distribution pattern represents the highest population in sapling stages and medium in seedlings and trees. The pattern is represented by *Olinia rochetiana, Rhus vulgaris* and *Erica arborea* (Fig.4e, f & g). Few seedlings per species may be due to disturbances like seed predators, grazers, canopy cover for seedling recruitment, nature of seeds dormancy breakage in relation to environmental factors, physical factors, pathogens, and others those affecting the nature of propagation and reproduction. Pattern three shows complete absence of seedlings and saplings. This includes *Apodytes dimidiata* and *Milletia ferruginea* and has very rare mature individuals in the forest (Fig. 4b & d). The result from regeneration analysis of species revealed the complete absence or small amount distribution of seedlings and saplings shows insufficient recruitment hampered regeneration for the majority of species. This may be due to sensitiveness of seedlings and saplings to the disturbance such as seed predators, grazers and browsers, lack of safe site for seedling recruitment, litter accumulation, pathogens and environmental variables. To set priority for regeneration analysis species in the study site, the species were classified in to three groups. Group 1, those species that were totally absent in regeneration category, Group 2, species whose density was greater than zero and less than 50 individuals ha^{-1} and Group 3, species having individuals greater than 50 individuals ha^{-1} (Table 8). Species classified as Group 1 and Group 2 is recommended to be given the highest priority for conservation purpose. The result shows certain gaps between floristic composition and structure of matured stands and the regeneration. Some of the matured trees lacked seedlings and /or saplings. This suggests that their regeneration from seedling and sapling is reduced and these species may disappear in the future. Abundance of seedlings and saplings are indicators of the establishment of young individuals. The regeneration potential of plant species could depend on factors like soil seed bank, physical factors and anthropogenic activities.

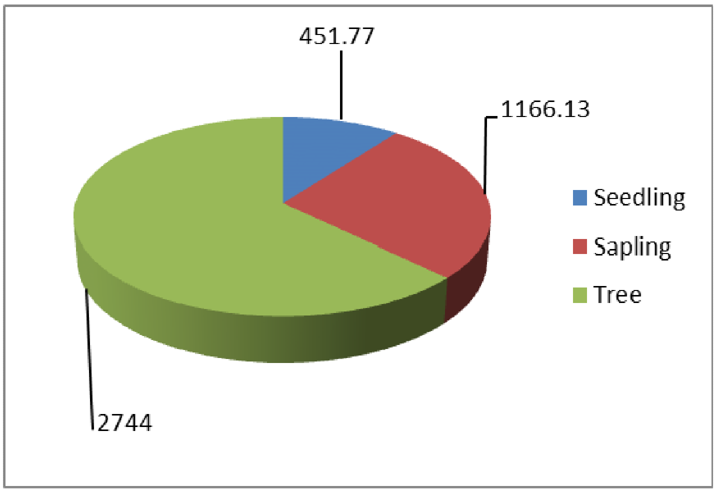
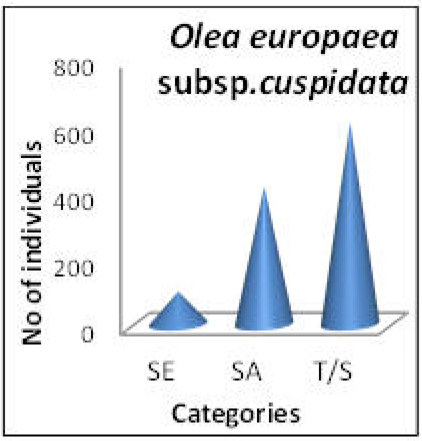


Figure 8. The proportion of seedling, sapling and tree species in which A=seedling, B=sapling and C= mature trees

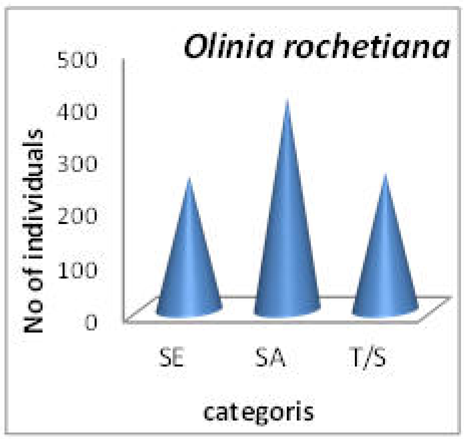
As figure 8 shows the proportion of seedlings is much smaller than both the saplings and tree species in the forest. Most species have large number of old age individuals this indicates that such species have poor regeneration, recruitment and reproduction. As a result the composition, species richness and diversity may decline unless possible solutions like conservation, restoration and protection taken place.

Table 1. Density ha^{-1} of seedling, sapling and mature tree species in Menagesha Amba Mariam Forest, T-Tree, S-Shrub

No	Botanical name	Habit	Seedling Density ha^{-1}	Sapling Density ha^{-1}	Tree D ha^{-1}	Sum of densities
1	*Acacia abyssinica*	T	14.13	27.9	68.12	110.15
2	*Apodytes dimidiata*	T	0	0	3.62	3.62
3	*Arundinaria alpina*	S	1.5	11.23	15.22	27.95
4	*Bersama abyssinica*	T	30.1	19.6	65.94	115.64
5	*Buddleja polystachya*	T	5.44	0.72	20.65	26.81
6	*Carissa spinarum*	S	22.5	8	189.86	220.36
7	*Croton macrostachyus*	T	1.1	2.54	7.97	11.61
8	*Podocarpus falcatus*	T	36.23	32.25	92.39	160.87
9	*Dombeya torrida*	T	6.9	14.5	26.45	47.85
10	*Dovyalis abyssinica*	T	15.6	23.2	78.62	117.42
11	*Ekebergia capensis*	T	0.36	4.4	8.33	13.09
12	*Erica arborea*	T	68.5	117	260.51	446.01
13	*Ficus sur*	T	0.36	145.1	6.52	151.98
14	*Hagenia abyssinica*	T	0.72	3.3	17.39	21.41
15	*Hypericum revolutum*	T	8.33	23.6	35.14	67.07
16	*Juniperus procera*	T	19.2	81.5	365.22	465.92
17	*Maesa lanceolata*	T	1.1	6.2	7.97	15.27
18	*Maytenus arbutifolia*	T	4.7	19.2	37.32	61.22
19	*Maytenus obscura*	T	3.62	2.17	12.68	18.47
20	*Millettia ferruginia*	T	0	1.1	2.17	3.27
21	*Myrica salicifolia*	T	8.7	8	34.06	50.76
22	*Nuxia congesta*	T	6.2	48.6	87.32	142.12
23	*Olea europaea* subsp. *cuspidata*	T	31.9	146.4	385.14	563.44
24	*Olinia rochetiana*	T	79.7	133.3	297.46	510.46
25	*Osyris quadripartita*	T	8.7	21.7	112.32	142.72
26	*Pittosporum viridiflorum*	T	11.6	56.9	81.16	149.66
27	*Scolopia theifolia*	T	5.44	18.5	46.01	69.95
28	*Prunus africanus*	T	13.8	40.6	72.1	126.5
29	*Rhamnus staddo*	T	1.8	0.72	6.52	9.04
30	*Rhus glutinosa*	T	5.44	22.1	29.35	56.89
31	*Rhus vulgaris*	T	30	60.9	128.26	219.16
32	*Sideroxylon oxyacanthum*	T	8.1	64.9	142.39	215.39
	Total		451.77	1166.13	2744.18	4362.08



(a)



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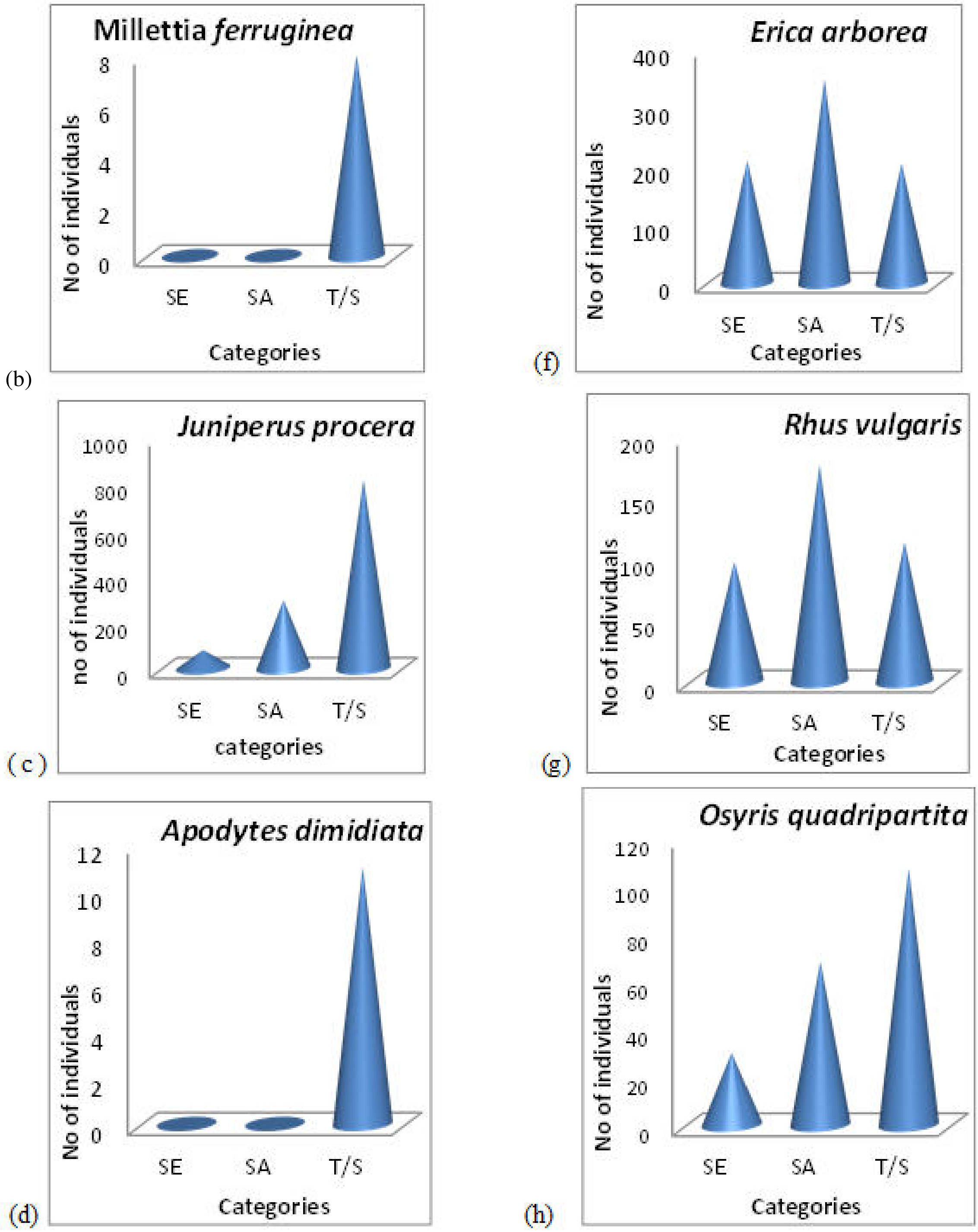

Figure 9. Seedlings, saplings and tree/shrub distribution of some selected species occurring in MAMForest

Table 8. List of species under regeneration status group

Regeneration status		
Group 1	**Group 2**	**Group 3**
Apodytes dimidiata	*Arundinaria alpina*	*Acacia abyssinica*
Millettia ferruginea	*Buddleja polystachya*	*Bersama abyssinica*
	Croton macrostachyus	*Carissa spinarum*
	Ekebergia capensis	*Podocarpus falcatus*
	Ficus sur	*Dombeya torrida*
	Hagenia abyssinica	*Dovyalis abyssinica*
	Maesa lanceolata	*Erica arborea*
	Maytenus obscura	*Hypericum revolutum*
	Myrica salicifolia	*Juniperus procera*
	Rhamnus staddo	*Maytenus arbutifolia*
		Nuxia congesta
		Olea europaea subsp. *cuspidata Olinia rochetiana*
		Osyris quadripartita
		Pittosporum viridiflorum
		Scolopia theifolia
		Prunus africana
		Rhus glutinosa
		Rhus vulgaris
		Sideroxylon oxyacanthum

Management and anthropogenic impacts on Menagesha Amba Mariam Forest

The complex nature of human activities has a tremendous impact in forests including grazing and selective tree cutting for wood based industries and clearing for cultivation and settlements (Alemu Abebe, 2007). Among these, the major disturbances are selective tree cutting and clearing for cultivation which seriously affects both the structure and species composition of forest. Eye witness, interview with local monks of the surrounding Churches and monastery and forest guards revealed that most of the people always experience clearing the vegetation for cultivable land expansion and to procure essential forest products.

Result from interviews of local people revealed that *Hagenia abyssinica* is mainly used by the local communities for medicinal purpose, i.e. why the species is found in some inaccessible parts of the forest. *Hagenia abyssinica, Juniperus procera, Olea europaea* subsp. *cuspidata, Olinia rochetiana,* and *Erica arborea* are *locally* threatened and require a serious remedy and priority for conservation. As indicated in Table 15, IVI values of *Juniperus procera* and *Olea europaea* subsp. *cuspidata* are the most dominant and important species in the forest but, Table 9 revealed that most new stumps left after tree harvesting were observed from these species. Most local farmers sell firewood and charcoal due to the proximity of the forest to urban centers like Addis Ababa, Menagesha and Holeta. The local women and men frequently take charcoal and fire wood to the urban centers using donkey, children and women mainly at night. Human disturbances are the most significant types of disturbance indicated by stumps left (Table 9), fences of surrounding farms, foot paths and charcoal kilns. The high dependency of the local people on natural resources and lack of proper alternatives, they are not able to change their present forest resource use patterns. The most important plant species of the forest (Juniperus *procera, Olea europaea* subsp. *cuspidata, Podocarpus falcatus, Olinia rochetiana and Erica arborea* have been exposed to anthropogenic impacts (Table 9). But, these species show large number of new stumps and dead standings. Generally, this study provide new insights on how to develop forest conservation strategy and the extent and status of forest in relation to anthropogenic, natural and environmental factors.

Table 9. The number of stumps in the study site

Species name	No of stumps	IVI value	Priority
Olinia rochetiana	150	19.61	2
Juniperus procera	149	58.66	1
Erica arborea	137	16.61	2
Olea europaea subsp.*cuspidata*	94	38.94	1
Acacia abyssinica	43	9.14	3
Osyris quadripartita	33	12.11	2
Myrica salicifolia	28	2.92	4
Rhus vulgaris	28	14.08	2
Podocarpus falcatus	16	29.52	1
Prunus africana	14	9.82	3
Dovyalis abyssinica	10	10.02	2
Pittosporum viridiflorum	8	8.3	3
Nuxia congesta	6	8.8	3
Sideroxylon oxyacanthum	5	8.9	3
Hagenia abyssinica	5	2.81	4
Hypericum revolutum	5	3.95	4

CONCLUSION

From population structure analysis, most tree species were in poor regeneration and recruitment level. The forest was grouped into five community types. The communities at the bottom and middle of the altitudinal gradient were found to be rich in species composition due to the presence of dense *Carissa spinarum, Rosa abyssinica* and *Myrsine africana* while the community at the top was poor in species composition. The total density of tree stems per hectare was 4362.08 indicating that the vegetation of the Forest has densely populated and dominant trees like *Juniperus procera, Olea europaea* subsp. *cuspidata, Olinia rochetiana* and *Rhus vulgaris.* The species population structure showed different dynamics. Most species have high population in the lower DBH and Height classes. Few species occur in all DBH and Height classes showing variation in population size. The forest is characterized by high density of trees in the lower class than in the higher. The total Basal area of trees whose DBH >2.5 cm was 84.17 m^2 ha^{-1}. This value is supposed to be high in basal area coverage in dry evergreen montane forest. IVI of 59.14% was attributed by *Juniperus procera, Olea europaea* subsp. *cuspidata, Podocarpus falcatus, Olinia rochetiana, Erica arborea* and *Rhus vulgaris.* These species were also important in ecological significance. The regeneration status of Menagesha Amba Mariam Forest was studied by selecting 32 most important tree and shrub species based on their IVI. Species classified as regeneration classes as Group 1 (with no regeneration like *Apodytes dimidiata* and Group 2 (>zero & <50) individuals ha^{-1} as *Millettia ferruginea, Hagenia abyssinica, Ficus sur, Ekebergia capensis, Maytenus obscura, Croton macrostachyus, Maesa lanceolata, Buddleja polystachya, Rhamnus staddo* and *Myrica salicifolia*) are recommended to be given high priority for conservation purpose.

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APPENDICES

Appendix 1. Location of quadrats in relation to altitude, latitude, longitude, number of species and aspects

Transect	Quadrats	Altitude (m)	Latitude	Longitude	Number of species	Aspect
1	1	2678	$9^001´$	$38^035´$	29	
1	2	2684	$9^002´$	$38^035´$	30	
1	3	2680	$9^002´$	$38^035´$	36	
1	4	2694	$9^002´$	$38^035´$	45	
1	5	2742	$9^002´$	$38^035´$	44	
1	6	2750	$9^002´$	$38^035´$	41	
1	7	2761	$9^002´$	$38^035´$	38	S
1	8	2779	902´	$38^035´$	38	
1	9	2831	$9^002´$	$38^035´$	42	
2	10	2632	$9^002´$	$38^036´$	39	
2	11	2642	$9^002´$	$38^036´$	39	
2	12	2688	$9^002´$	$38^036´$	43	
2	13	2728	$9^002´$	$38^036´$	43	
2	14	2752	$9^002´$	$38^036´$	43	
2	15	2764	$9^001´$	$38^035´$	36	SE
2	16	2780	$9^001´$	$38^036´$	35	
2	17	2948	$9^002´$	$38^035´$	33	
3	18	2647	$9^002´$	$38^036´$	42	
3	19	2664	$9^002´$	$38^036´$	43	
3	20	2679	$9^002´$	$38^036´$	39	
3	21	2704	901´	$38^036´$	45	
3	22	2774	$9^002´$	$38^035´$	39	
3	23	2847	$9^002´$	$38^035´$	26	E
3	24	2872	$9^002´$	$38^035´$	24	
4	25	2647	$9^002´$	$38^036´$	37	
4	26	2701	$9^002´$	$38^036´$	33	
4	27	2725	$9^002´$	$38^036´$	29	
4	28	2767	$9^002´$	$38^036´$	39	
4	29	2780	$9^002´$	$38^036´$	21	NE
4	30	2822	$9^002´$	$38^035´$	37	
4	31	2844	$9^002´$	$38^035´$	31	
4	32	2870	$9^002´$	$38^035´$	31	
5	33	2624	$9^003´$	$38^035´$	45	
5	34	2652	$9^003´$	$38^035´$	45	
5	35	2680	$9^003´$	$38^035´$	42	
5	36	2701	$9^002´$	$38^035´$	42	
5	37	2725	$9^002´$	$38^035´$	52	
5	38	2780	$9^002´$	$38^035´$	49	
5	39	2848	$9^002´$	$38^035´$	31	
5	40	2894	$9^002´$	$38^035´$	22	N
6	41	2624	$9^003´$	$38^035´$	51	
6	42	2649	$9^003´$	$38^035´$	42	
6	43	2688	$9^002´$	$38^035´$	42	
6	44	2705	$9^002´$	$38^035´$	47	
6	45	2748	$9^002´$	$38^035´$	41	NW
6	46	2824	$9^002´$	$38^035´$	43	
6	47	2865	$9^002´$	$38^035´$	26	
6	48	2906	$9^002´$	$38^035´$	35	
7	49	2625	$9^002´$	$38^035´$	17	
7	50	2650	$9^002´$	$38^035´$	28	
7	51	2673	$9^002´$	$38^035´$	21	
7	52	2705	$9^002´$	$38^035´$	27	
7	53	2720	$9^002´$	$38^035´$	23	
7	54	2742	$9^002´$	$38^035´$	28	
7	55	2771	$9^002´$	$38^035´$	28	W

Transect	Quadrats	Altitude (m)	Latitude	Longitude	Number of species	Aspect
7	56	2796	$9^{0}02'$	$38^{0}35'$	33	
7	57	2838	$9^{0}02'$	$38^{0}35'$	21	
7	58	2887	$9^{0}02'$	$38^{0}35'$	33	
8	59	2574	$9^{0}02'$	$38^{0}35'$	41	
8	60	2608	$9^{0}02'$	$38^{0}35'$	41	
8	61	2643	$9^{0}02'$	$38^{0}35'$	37	
8	62	2665	$9^{0}02'$	$38^{0}35'$	25	
8	63	2687	$9^{0}02'$	$38^{0}35'$	30	
8	64	2715	$9^{0}02'$	$38^{0}35'$	30	
8	65	2735	$9^{0}02'$	$38^{0}35'$	46	
8	66	2764	$9^{0}02'$	$38^{0}35'$	36	SW
8	67	2791	$9^{0}02'$	$38^{0}35'$	39	
8	68	2823	$9^{0}02'$	$38^{0}35'$	33	
8	69	2876	$9^{0}02'$	$38^{0}35'$	42	

Appendix 2. DBH class distribution of tree species in MAM Forest

	DBH classes										
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Acacia abyssinica	15	31	11	5	3	4	0	0	1	2	72
Apodytes dimidiata	4	2	0	0	0	0	0	0	0	4	10
Arundinaria alpina	4	2	1	0	0	0	0	0	0	0	7
Bersama abyssinica	21	24	2	0	0	0	0	0	0	0	47
Buddleja polystachya	13	11	13	1	1	0	0	1	0	0	40
Carissa spinarum	23	13	1	0	0	0	0	0	0	0	37
Croton macrostachyus	0	1	1	3	1	2	2	1	1	0	12
Podocarpus falcatus	3	10	4	1	2	4	6	8	5	23	66
Dombeya torrida	2	10	1	1	0	0	0	0	0	0	14
Dovyalis abyssinica	18	17	4	0	0	1	0	0	0	0	40
Ekebergia capensis	6	2	0	2	0	0	0	0	0	0	10
Erica arborea	89	101	13	0	1	2	1	0	0	0	207
Ficus sur	0	1	0	0	0	0	1	1	0	0	3
Hagenia abyssinica	5	15	9	2	0	0	1	0	2	3	37
Hypericum revolutum	2	4	1	0	1	1	0	0	0	0	9
Juniperus procera	115	202	99	47	37	48	37	29	45	81	740
Maesa lanceolata	0	2	0	0	0	0	0	0	0	0	2
Maytenus arbutifolea	21	14	3	0	0	0	0	0	0	0	38
Maytenus obscura	0	9	4	2	3	1	0	0	0	0	19
Millettia ferruginia	0	0	1	2	1	1	1	0	0	0	6
Myrica salicifolia	4	19	17	5	5	0	0	0	0	0	50
Nuxia congesta.	23	54	8	3	1	0	0	0	0	0	89
Olea europaea subsp. *cuspidata*	132	217	64	27	34	27	32	15	6	17	571
Olinia rochetiana	124	97	8	4	0	0	0	0	0	0	233
Osyris quadripartita	37	48	7	2	0	0	1	0	0	0	95
Pittosporum viridiflorum	9	22	3	1	0	0	0	0	0	0	35
Scolopia theifolia	19	16	10	5	3	5	3	0	0	0	0
Prunus africana	17	21	3	1	2	1	3	1	0	2	51
Rhamnus staddo	7	4	0	0	0	0	0	0	0	0	11
Rhus glutinosa	2	2	1	0	0	0	0	0	0	0	5
Rhus vulgaris	38	45	13	1	1	1	2	2	1	0	104
Sideroxylon oxyacanthum	106	81	5	1	0	0	0	0	0	0	193
Total	859	1097	307	116	96	98	90	58	61	132	2853

Appendix 3. Height class distribution of tree species in MAM Forest

Species	**Height classes**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**No**
Acacia abyssinica	54	13	3	2	0	0	0	0	0	0	0	72
Apodytes dimidiata	4	0	0	3	0	1	1	1	0	0	0	10
Arundinaria alpina	0	3	3	1	0	0	0	0	0	0	0	7
Bersama abyssinica	21	24	2	0	0	0	0	0	0	0	0	47
Buddleja polystachya	18	16	2	3	1	0	0	0	0	0	0	40
Carissa spinarum	13	22	2	0	0	0	0	0	0	0	0	37
Croton macrostachyus	8	4	0	0	0	0	0	0	0	0	0	12
Podocarpus falcatus	5	8	7	5	11	14	14	2	0	0	0	66
Dombeya torrida	13	0	0	1	0	0	0	0	0	0	0	14
Dovyalis abyssinica	23	13	4	0	0	0	0	0	0	0	0	40
Ekebergia capensis	3	7	0	0	0	0	0	0	0	0	0	10
Erica arborea	80	109	15	2	1	0	0	0	0	0	0	207
Ficus sur	1	0	1	1	0	0	0	0	0	0	0	3
Hagenia abyssinica	30	3	1	2	1	0	0	0	0	0	0	37
Hypericum revolutum	6	3	0	0	0	0	0	0	0	0	0	9
Juniperus procera	103	195	131	112	68	71	52	8	0	0	0	740
Maesa lanceolata	1	1	0	0	0	0	0	0	0	0	0	2
Maytenus arbutifolia	18	18	2	0	0	0	0	0	0	0	0	38
Maytenus obscura	3	6	8	2	0	0	0	0	0	0	0	19
Millettia ferruginea	0	0	1	1	1	2	1	0	0	0	0	6
Myrica salicifolia	7	19	15	9	0	0	0	0	0	0	0	50
Nuxia congesta.	24	40	19	5	1	0	0	0	0	0	0	89
Olea europaea sub sp. *cuspidata*	105	196	142	87	20	13	8	0	0	0	0	571
Olinia rochetiana	73	131	26	3	0	0	0	0	0	0	0	233
Osyris quadripartita	56	32	7	0	0	0	0	0	0	0	0	95
Pittosporum viridiflorum	9	20	4	2	0	0	0	0	0	0	0	35
Scolopia theifolia	18	17	14	11	1	0	0	0	0	0	0	61
Prunus africana	16	25	6	4	0	0	0	0	0	0	0	51
Rhamnus staddo	6	5	0	0	0	0	0	0	0	0	0	11
Rhus glutinosa	1	2	2	0	0	0	0	0	0	0	0	5
Rhus vulgaris	38	50	11	5	0	0	0	0	0	0	0	104
Sideroxylon oxyacanthum	61	107	19	4	2	0	0	0	0	0	0	193
Total	818	1089	447	265	107	101	76	11	0	0	0	2914