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Structure, Species Composition and Status of Naturally Regenerated Woody Species in *Eucalyptus globulus* Labill. (Myrtaceae) Plantation at Entoto Mountain, Ethiopia

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Abstract
This study was carried out at Entoto Mountain *Eucalyptus* plantation; about 10 km north of the center of Addis Ababa, to assess the composition, structure and the status of naturally regenerated woody species in *Eucalyptus globulus* Labill. plantation. Sixty plots of 400 m ^{2} (20 m X 20 m) size were established along a transect lines at every 300 m distance between them. Transects were laid in north–south directions at 500 m distance from each other. Seedlings were colleted from five sub-plots (4 m ^{2}) within each major plot. A total of 41 naturally regenerated woody species (NRWS) were recorded in Entoto *E. globulus* plantation. They represented 33 genera and 25 families. Density of NRWS greater than 2.5 cm DBH was 932.1ha^{-1}. With increase in diameter class, the number of NRWS decreased in the *E. globulus* plantation. About 87% of the individuals had DBH of first DBH class (2.6-7.5 cm). Density ratio of individuals >10 cm DBH to that of individuals >20 cm DBH showed the predominance of small-sized individuals; this is the result of the recent regeneration. The ratio of stems per species is very high in the lower storey (63.9) also showed the predominance of shorter high individuals. *J. procera* (98.3%) was the most frequent NRWS and had an overriding dominance in terms of basal area (95.16%) and IVI values (81.8%). This result may indicate that *J. procera* is eco-friendly and competent with *E. globulus.* Therefore, *E. globulus* may not have a negative effect on *J. procera*. Thus, in degraded high rainfall areas, *E. globulus* plantations may play a role in fostering the regeneration of woody species such as *J. procera.* Species were prioritized for conservation using important value index, population structure and regeneration status as criteria.
Keywords: Entoto, *Eucalyptus globulus*, naturally regenerated woody species, Plantation

INTORDUCTION

Ethiopia is an important regional centre of biological diversity, and the flora and fauna have a rich endemic element (Sayer *et al*., 1992; WCMC, 1992). The country has the fifth largest flora in tropical Africa. The flora of Ethiopia is very heterogeneous and estimated to include about 6000 species of higher plants, and about 10% of these are endemic (Vivero *et al*., 2005). The natural forests of the country particularly the *J. procera*, *Olea europea* subsp. *cuspidata*, and *Podocarpus falcautus* forest around the capital city were depleted at faster rate for fuel and construction material. As a result, the development of the capital city, Addis Ababa was threatened by a fuel wood scarcity. In 1895, King Menilek II introduced fifteen *Eucalyptus* species for a trial in and around the capital city to solve fuel wood shortage (Breitenbach, 1961; Davidson, 1995). The introduction of *Eucalyptus* species was a great success and the planting of *Eucalyptus* species for fuel, particularly, *Eucalyptus globulus* and *Eucalyptus camaldulensis* was expanding in the vicinity of Addis and other small towns in the country. *E. globulus* was the most successful of the introduced *Eucalyptus* species and was quickly adopted by farmers. The reason for the widespread early popularity and success of the blue gum can be attributed to its fast growth, coppicing ability, the unpalatability of its leaves, and its adaptability to a wide range of site conditions (FAO, 1981). Although plantations have such, and many other benefits, they are widely viewed in a negative light in relation to biological diversity conservation, especially when intensive monocultures of exotic species are involved (Carnus *et al*., 2003). Some of the criticisms associated with *Eucalyptus* species plantations are: *Eucalyptus* species are alleged to impede the establishment of other plants in their understory by out-competing them for the available soil moisture and nutrients, as well as by direct inhibition through phytotoxic exudates of its leaves and litter (Shiva and Bandyopadhyay, 1983; Poore and Fries, 1985; Florence, 1986). In contrast to this view, the *E. globulus* understory has been found to have a high herbaceous species richness and biomass in the Ethiopian highlands and, moreover, naturally regenerated woody species have also been found in these plantations (Holgen and Svensson, 1990; Pohjonen and Pukkala, 1990; Michelsen *et al.*, 1996). Plantations can have also a catalytic effect on the regeneration of some species and can be used as a management tool for restoration of degraded lands (Lugo, 1997; Yitebtu Moges, 1998; Engelmark, 2001; Eshetu Yirdaw, 2002; Feyera Senbeta *et al*., 2002; Mulugeta Lemenih and Demel Teketay, 2004; Mulugeta Lemenih *et al*., 2004). Recent research on tropical forest plantations indicates that plantations may enhance the recruitment, establishment and succession of native woody species by functioning as foster ecosystems (Parrotta, 1992 & 1995; Lugo *et al*., 1993; Geldenhuys, 1997; Otsamo, 2000). Thus, controversy over the impacts of *E. globulus* plantation on the regeneration of woody species is considered a serious barrier to take any feasible biodiversity conservation measures in the study area. Its current management system, however, deserves a close scrutiny. In view of this, the present study was carried out with the objective to assess the composition, structure and the status of naturally regenerated woody species (NRWS) in *E. globulus* plantations and prioritize NRWS for conservation.

MATERIALS AND METHODS

The Study Area

The study was conducted in Entoto-mountain range about 10 km north of the center of Addis Ababa between latitudes 9º04' to 9º05' N and longitudes 38º43' to 38º47' E. The altitude range in the study area is between 2596 and 2956 m a.s.l. The typical catena in the mountain of Entoto is characterized by Nitisols at higher altitude. Further down the hills Cambisols have been formed from deposits of erosion material from the higher altitude Nitisols. Furthest down the mountain, and in depressions, Vertisols have been formed from the finest erosion material. All these soils are considered fertile. The color is blackish brown due to a high content of basalt, a rock type that generally has a considerable weathering potential (Tobias, 2004). Analysis of the meteorological data result showed that the mean annual temperature of the study area is about 13.1^{0}C, ranging from a mean minimum of 8.2^{0}C to mean maximum of 18^{0}C. The hottest month is May (mean maximum 20.1^{0}C) while the coldest month is December (mean minimum 7.0 ^{0}C). The mean annual rainfall of the area is 1233.1 mm year $^{-1}$. Generally, the study area has a bimodal type of rainy seasons. The short rainy season extends from March to May, and the long rainy season ranges from July to September. Most of the rain comes in July and August. The large area of Entoto, where the study area is located belongs to the Afromontane forest belt in the central highlands of Ethiopia. Similar to other parts of Ethiopia, the natural *Juniperus procera*, *Olea europea* subsp. *cuspidata*, and *Podocarpus falcautus* forest which was once abundant on the Entoto Mountain rapidly vanished due to an over exploitation of the indigenous trees (Pohjonen, 1989). Currently, the most dominating species in the area is *E. globulus*.

Vegetation Sampling

In this study, a systematic sampling design was used to collect data on vegetation. A total of 60 relevés of size 20 m x 20 m (400 m^2) were systematically laid in north–south directions using Compass and the distance between consecutive plots along the transect line was 300 m. Thirteen transects were laid at 500 m distance from each other. For the collection of seedlings, subplots of 2 m x 2 m (4 m^2) at the four corners and the center of the large relevé were laid. Diameter was measured for every individual tree and shrub species having DBH (diameter at breast height) greater than 2.5 cm using a measuring diameter tape. If a tree branched at breast height or below, the diameter was measured separately for the branches and averaged. In case where tree/shrub boles buttressed, diameter measurements were taken from the point just above the buttresses. Height was measured for every individual tree and shrub with DBH greater than 2.5 cm using a Suunto Clinometer. Where slope, topography and/or crown structure made it difficult to use the Clinometer, height of trees and shrubs were visually estimated. To determine the regeneration status of woody species, seedling individuals with DBH less than 2.5 cm and height less than 1.5 m and saplings (individual with height greater than 1.5 m and DBH less than 2.5 cm) were counted. Plant specimens were collected, pressed, dried, checked and identified at the National Herbarium (ETH), Biology Department of the Addis Ababa University. In each major plot, altitude and geographical positions in degrees and UTM were taken using GPS (Global Position System).

Data Analysis

Vegetation data entry form was developed using Microsoft Access application and subsequent analyses of the data were performed using the same application. Graphs were drawn using Excel spread sheets.

Diameter at Breast Height (DBH): DBH measurement was taken at about 1.3 m from the ground using a measuring diameter tape. Basal area is computed for naturally regenerated woody species with DBH > 2.5 cm.

Basal area (BA) = $\pi d^2/4$; Where $\pi = 3.14$; d = diameter at breast height
Density: it is defined as the number of plants of a certain species per unit area.
Frequency: The number of quadrats in which a species recorded/ total number of quadrats.

Importance Value Index (IVI): Relative density + Relative dominance + Relative frequency. All NRWS were grouped into three IVI classes based on their IVI values as follows: 1. > 30; 2. 1-30; 3. <1.

RESULTS AND DISCUSSION

Species Composition

A total of 41 NRWS were recorded in Entoto *E. globulus* plantation. They represented 33 genera and 25 families. However, the number of NRWS recorded under *E. globulus* plantation in this study was relatively higher than the number of species recorded under some of the exotic plantation species in Ethiopia. For example, Feyera Senbeta and Demel Teketay (2001) recorded 37 species under *E. globulus, E. saligna, Pinus patula* and *Cupressus lusitanica* on the central highlands of Ethiopia. The number of woody species recorded in the *Eucalyptus* plantations at Chancho and Menagesha were 20 and 22 respectively (Eshetu Yirdaw, 2001). The total number of regenerated woody species at the present study site (41 species) is very close to previous reports from Jirren forest, South-Western Ethiopia (40 species) (Getachew Tesfaye and Abyot Berhanu, 2006), but lower than the one recorded in Munessa-Shashemene (55 species) (Feyera Senbeta *et al*., 2002).

Vegetation structure

Density and Diameter at Breast-Height (DBH)

The first highest density of NRWS was contributed by *Juniperus procera* Endl. (867.1 individuals ha^{-1}). The least dense species in the *E. globulus* plantation was for example *Podocarpus falcatus* (Thunb) Mirb., contributing only 0.4 individuals ha^{-1}. Generally, the total density of NRWS was 932.1 individuals ha^{-1}. In the *Eucalyptus* plantation, lower diameter class (DBH = 2.6-17.5 cm) was the dominant. The study showed that the relative density of trees and shrubs of ≤ 7.5 cm diameter constituted 72.2%. The DBH structure of species can reveal the population dynamics. With increase in diameter class, the number of trees and shrubs decreased in the *E. globulus* plantation. Based on diameter class distribution and density, the effects of plantation on the recruitment of different species can be inferred. Less density of tree and shrub species in different diameter classes means the *E. globulus* plantation has high impact on the undergrowth of the species, and vise versa. In the lower diameter class (2.6-7.5 cm) 14 species were recorded in *E. globulus* plantation. As the diameter classes increase, the number of species decreases considerably. Trees in the higher diameter class (>42.5 cm) were few (*Juniperus procera and Acacia abyssinica*) in the *E. globulus* plantations. The ratio of density of individuals with DBH >10 cm to density >20 cm DBH showed the distribution of size classes (Grubb *et al*., 1963). The densities of naturally regenerated woody species in *E. globulus* plantation with DBH >10 cm and DBH >20 cm were 103.3 (11.1%) and 17.9(1.9%) individuals ha^{-1}, respectively, and the ratio of the former to the latter was 5.77 (Table 1). About 87% of the individuals had DBH of first DBH class (2.6-7.5 cm). Density ratio of individuals >10 cm DBH to that of individuals >20 cm DBH showed preponderance of small-sized individuals for some species whereas comparable distribution for others in the plantation. The predominance of small-sized individuals in the Entoto *Eucalyptus* plantation was largely due to the high density of *J. procera.* Generally, the very high a/b ratio in the Entoto plantation indicates the predominance of small-sized individuals; this is the result of the recent regeneration.

Table 1: Density of NRWS individuals in Entoto *E. globulus* plantation.

DBH (cm)	Density (stem/ha)	Percentage %
> 10 < 20 (a)	103.3	11.1
≥ 20 (b)	17.9	1.9
≤ 10	810.9	87
Ratio of a to b = 5.77		

Height distribution of trees and shrubs

The vertical structure of the NRWS under *E. globulus* plantation at Entoto Mountain was described following the International Union for Forestry Research Organization (IUFRO) classification scheme (Lamprecht, 1989). Three vertical structures were distinguished: upper storey (> 2/3 of top height), middle storey (between 1/3 and 2/3 of top height) and lower storey (< 1/3 of top height). In this study, the highest naturally regenerated tree species in *E. globulus* plantation was *J. procera*, which was 22 m. This species was used to determine the different storeys. Therefore, the lower storey includes all individuals of species that are less than 7 m high, the middle storey includes all individuals that fall between 7 and 15 m, and the upper storey includes all individuals taller than 15m. A total of 2237 individuals of NRWS have DBH >2.5 cm under *E. globulus* plantations. The majority of naturally regenerated woody species individuals are confined to the lower canopy (89.2%), about 10.6% individuals contribute to the middle canopy while very few individuals contribute to the highest canopy (0.2%). The ratio of stems per species is very high in the lower storey (63.9) showing the predominance of shorter high individuals of naturally regenerated woody species in the *E. globulus* plantations. In general, the densities of naturally regenerated woody species in lower, middle and upper story was found to be 831, 99 and 2.1 individuals ha^{-1} respectively (Table 2). More than 90% individuals of NRWS had height up to 10 m.

Table 2: Stem number ha^{-1}, species number and ratio of stem/ha to species number by storey.

Storey	Stem/ha	%	Specie No.	%	Ratio
Upper	2.1	0.2	1	5.3	2.1
Middle	99	10.6	5	26.3	19.8
Lower	831	89.2	13	68.4	63.9
Total	932.1	100			

Frequency

The frequency gives an approximate indication of the homogeneity and heterogeneity of a stand. Lamprecht (1989) pointed out that high value in higher frequency and low value in lower frequency classes indicate constant or similar species composition whereas high value in lower frequency classes and low values in higher frequency classes indicate high degree of floristic heterogeneity. According to their total frequency expressed as percentage, species were grouped into the following five frequency classes: A = 81 – 100, B = 61 – 80, C = 41 – 60, D = 21 – 40, E = 0 – 20 %. Only *J. procera* belongs to the frequency class A. No other species belong to frequency class B, C and D. On the other hand, the lower frequency class (E) comprised all the remaining species. The most frequent naturally regenerated woody species in *E. globulus* plantation was *J. procera* (98.3%).

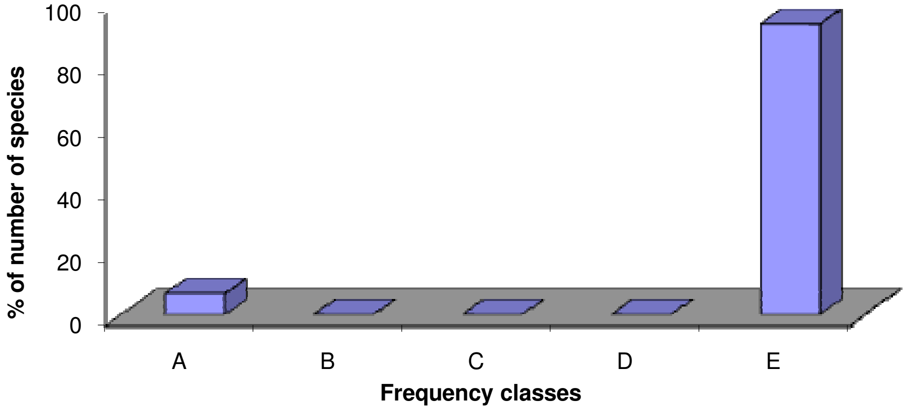

Figure 1: Frequency distribution of woody species in Entoto *E. globulus* plantation.

In the present study high values (high number of species) were obtained in lower frequency classes whereas low values (low number of species) were obtained in higher frequency classes (Figure 1). Therefore, according to the above interpretation it is possible to conclude that there exists floristic heterogeneity in the Entoto *E. globulus* plantation. The species that appear in the lower frequency classes have irregular occurrence whereas those appearing in higher classes have regular horizontal distribution.

Basal area

The basal area of all NRWS in Entoto *E. globulus* plantation as calculated from DBH data is found to be 4.9 m^2/ha. Most of the naturally regenerated woody species are small sized as shown by the peak in basal area in the lowest DBH classes. Individuals that belong to higher DBH classes are few in number, but their contribution to the total basal area is significant. The normal basal area value for virgin tropical forests in Africa is 23 – 37 m^2/ha (Dawkins, 1959; cited in Lamprecht, 1989). This comparison may indicate that Entoto *E. globulus* plantation is composed of relatively very smaller sized NRWS.

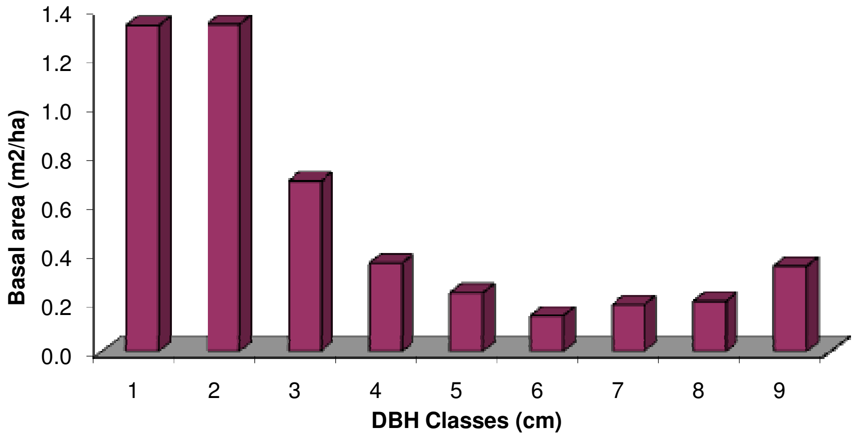

Figure 2: Basal area distribution of NRWS by DBH classes in Entoto *E. globulus* plantation.

The basal area and density distribution of five species, selected based on the basis of a high Importance Value Index (IVI) is shown in Table 3. *J. procera* took the biggest share in the percentage contribution of basal area (95.16%) and they were occupied most area of the sample plots. *J. procera* had an overriding dominance in terms of basal area and IVI. This result may indicate that *J. procera* is eco-friendly and competent with *E. globulus.* Some species with low density, low IVI and low frequency ranked among the top in case of basal area. An example is *Acacia abyssinica*, which could be attributed to the few but very large trees. Species with the highest basal area do not necessarily have the highest density, indicating size difference between species. *Acacia abyssinica* represented by few individuals but with high contribution to the overall basal area of the forest. *Carissa spinarum*, *Maesa lanceolata* and *Maytenus arbutifolia* were more dense than *Acacia abyssinica* but with low contribution to basal area (Table 3).

Table 3: Basal area, density, IVI and frequency values for five most dominant species other than *E. globulus*.

Species	BA/ha	Relative BA	Density	IVI	Frequency
J. procera	4.634	95.16	867.1	245.2	98.33
A. abyssinica	0.128	2.63	2.5	7	6.67
C. spinarum	0.019	0.39	17.9	8.1	10.00
M. lanceolata	0.019	0.39	4.6	4.8	6.67
M. arbutifolia	0.018	0.38	13.8	9.6	13.33

High density and high frequency coupled with high basal area indicate the overall dominant species of the forest (Lamprecht, 1989). Accordingly, *J. procera* was the primary dominant species in Entoto *E. globulus* plantation. On the other hand, high density and high frequency indicate regular horizontal distribution. *J. procera* was one of the species with such type of distribution. Generally, these result indicated that there is a good natural regeneration of *J. procera* within the *E. globulus* plantation.

Importance Value Index (IVI)

Ecologists consider IVI as the most realistic aspect in vegetation study (Curtis and McIntosh, 1951). They stated that species with the greatest importance value are the leading dominants of the forest. It is also useful to compare the ecological significance of species (Lamprecht, 1989). The reason why *J. procera* produced the highest IVI value is that it has the highest relative density, relative frequency and relative dominance. These results may suggest that *E. globulus* plantation may not have a negative effect on *J. procera*. High IVI value indicates that the species sociological structure in the community is high.

Table 4: The importance value index of tree and shrub species in Entoto *E. globulus* plantation.

NO	Species	Relative Density %	Relative Dominance %	Relative Frequency %	IVI
1	*Juniperus procera* Endl.	93.02	94.9	57.3	245.2
2	*Maytenus arbutifolia* (A. Rich.)Wilczek	1.48	0.3	7.8	9.6
3	*Carissa spinarum* L.	1.92	0.4	5.8	8.1
4	*Olinia rochetiana* A. Juss.	1.12	0.5	5.8	7.4
5	*Acacia abyssinica* Hochst. ex Benth	0.27	2.8	3.9	7.0
6	*Rosa abyssinica* Lindley	0.89	0.2	5.8	6.9
7	*Maesa lanceolata* Forssk.	0.49	0.4	3.9	4.8
8	*Prunus africana* (Hook. F.) Kalkm.	0.31	0.3	1.9	2.5
9	*Premna schimperi* Engl.	0.13	0.1	1.9	2.1
10	*Bersama abyssinica* Fresen.	0.09	0.1	1.9	2.1
11	*Ekebergia capensis* Sparrm.	0.13	0	1	1.1
12	Dovyalis abyssinica (A. Rich.) Warb	0.04	0	1	1.0
13	*Podocarpus falcatus* (Thunb) Mirb.	0.04	0	1	1.0
14	*Maytenus gracilipes* (Welw. ex Oliv.) Exell	0.04	0	1	1.0

The IVI classes for the fourteen common NRWS and the list of species under each IVI conservation priority classes are presented in Tables 5 and 6 respectively. The classification of the fourteen common species under conservation priority classes revealed that 1 species and 13 species belong to class 1 and 2, respectively. None of the common species belongs to class 3 for both classification criteria.

Table 5: IVI classes and the number of species belonged to each class.

IVI class and value	No. of Species	Sum of IVI	Percentage
3 (<1)	0	0	0
2 (1-30)	13	54.6	18
1 (>30)	1	245.2	82

About 82% of the IVI is contributed by *J. procera*. This species is abundant, frequent and dominant in the *E. globulus* plantation. The criteria for classifying species under conservation priority placed the majority of the NRWS under priority class 2; this means that, although they appeared to be common species, their IVI showed highly insufficient stock in this *E. globulus* plantation compared to *J. procera*. According to this classification, those individual species falling in IVI priority class two have insufficient stocks and are recommended for conservation priority.

Table 6: List of species under each IVI priority class

Priority class		
3	2	1
Nil	*Acacia abyssinica* *Bersama abyssinica* *Carissa spinarum* *Dovyalis abyssinica* *Ekebergia capensis* *Maesa lanceolata* *Maytenus arbutifolia* *Maytenus gracilipes* *Olinia rochetiana* *Podocarpus falcatus* *Premna schimperi* *Prunus africana* *Rosa abyssinica*	*Juniperus procera*

Species population structure

The density distribution of individuals in the various size classes was not equal in Entoto *E. globulus* plantations, but showed more or less uniform trend of decline (Figure 3). The number of individuals decreased as DBH classes increased up to the last DBH class (9th). This relatively regular distribution of individuals indicated that the population structure was a reversed J-shape. However, some forests of Ethiopia have shown variation in their population structure; for example, some with little or no recruitment at middle or larger DBH classes implying hampered regeneration as a result of disturbance i.e. deviated from normal reversed J-shape distribution. About 96.9% of the density was distributed in the diameter classes between 1 (2.6 cm) and 3 (17 cm), indicating the predominance of small-sized individuals in the *E. globulus* plantation. This could be attributed to high rate of regeneration but poor recruitment in the *E. globulus* plantation, which might have been caused by over exploitation of large-sized individuals. The presence of small-sized individuals in *E. globulus* plantation acts as a reserve for replacing the losses of larger-sized individuals. Population structures of trees and shrubs have significant implications to their management, sustainable use, and conservation.

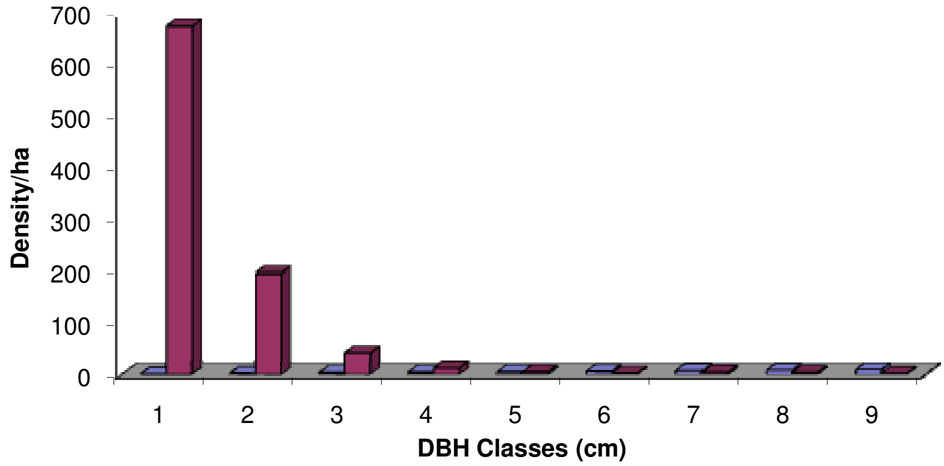

Figure 3: Tree/shrub density distribution by DBH classes in Entoto *E. globulus* plantation; where (1) = 2.6-7.5, (2) = 7.6-12.5, (3) = 12.6-17.5, (4) = 17.6-22.5, (5) = 22.6- 27.5, (6) = 27.6-32.5, (7) = 32.6-37.5, (8) = 37.6-42.5 and (9) = > 42.5 cm.

Similar to the density distribution of DBH classes, the density distribution of height classes of trees and shrubs in Entoto *E. globulus* plantation was not uniform (Figure 4). The number of individuals decreased as height classes increased.

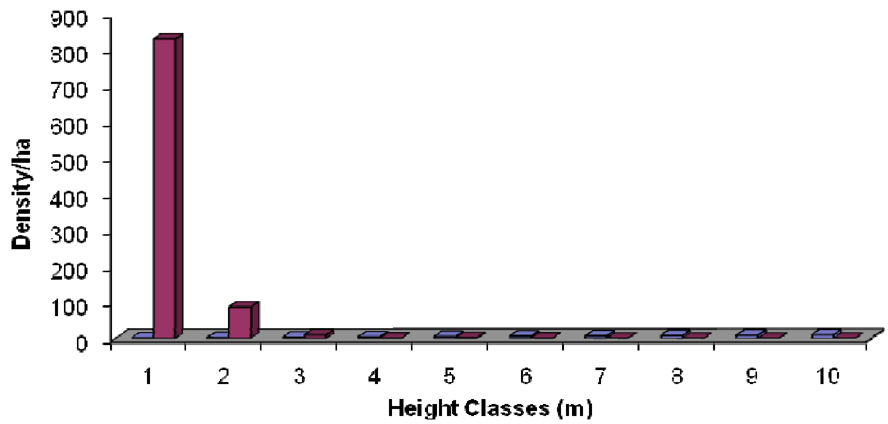

Figure 4: Tree/shrub density distribution by height classes in Entoto *E. globulus* plantation Where: (1) = 1.5-6, (2) = 6.1-9, (3) = 9.1-12, (4) = 12.1-15, (5) = 15.1-18, (6) = 18.1-21, (7) = 21.1-24, (8) = 24.1-27, (9) = 27.1-30 and (10) = > 30 m.

Generally, four patterns of population structure of woody species occurring in Entoto *E. globulus* plantations were analyzed. The analysis was expressed in density of individuals against the already established DBH classes. The emerging population structure of the various species could be interpreted as an indication of variation in population dynamics in the given forest (Popma *et al*., 1988). The first pattern (Figure 5a) was formed by species with positively skewed distribution (inverted J- curve). These species had the highest density in the lower DBH classes with decrease in density towards the bigger classes, which suggests good reproduction and recruitment potential in the forest. *J. procera* had such type of pattern. The second pattern (Figure 5b) was exhibited by species with individuals represented only in the first DBH class (2.6 cm -7.5 cm). These species exhibited good reproduction but very bad recruitment. One of the possible reasons for the discontinuity in this type of structure could be the local disturbance (natural as well as human). This is particularly true for *Ekebergia capensis* Sparrm. and *Podocarpus falcatus* (Thunb) Mirb. Therefore, the low stocking level of mature trees and shrubs confirmed that the forest has been affected by collection of fuel wood, for household consumption, for sale and felling trees for construction poles. The third pattern (Figure 5c) was exhibited by species with individuals well represented in the first, second and in some of them in the third DBH classes. These species exhibited very good reproduction but very poor recruitment. This pattern is exemplified by species like *Maesa lanceolata* Forssk. and *Prunus africana* (Hook. F.) Kalkm. The fourth pattern (Figure 5d) is a pattern where few individuals are represented in the first, second and the last DBH classes, while being absent in the other classes. It might be possible to assume that such patterns are characterized by good reproduction, selective cutting of the medium sized individuals and poor recruitment. Only one species, *Acacia abyssinica,* belongs to this type.

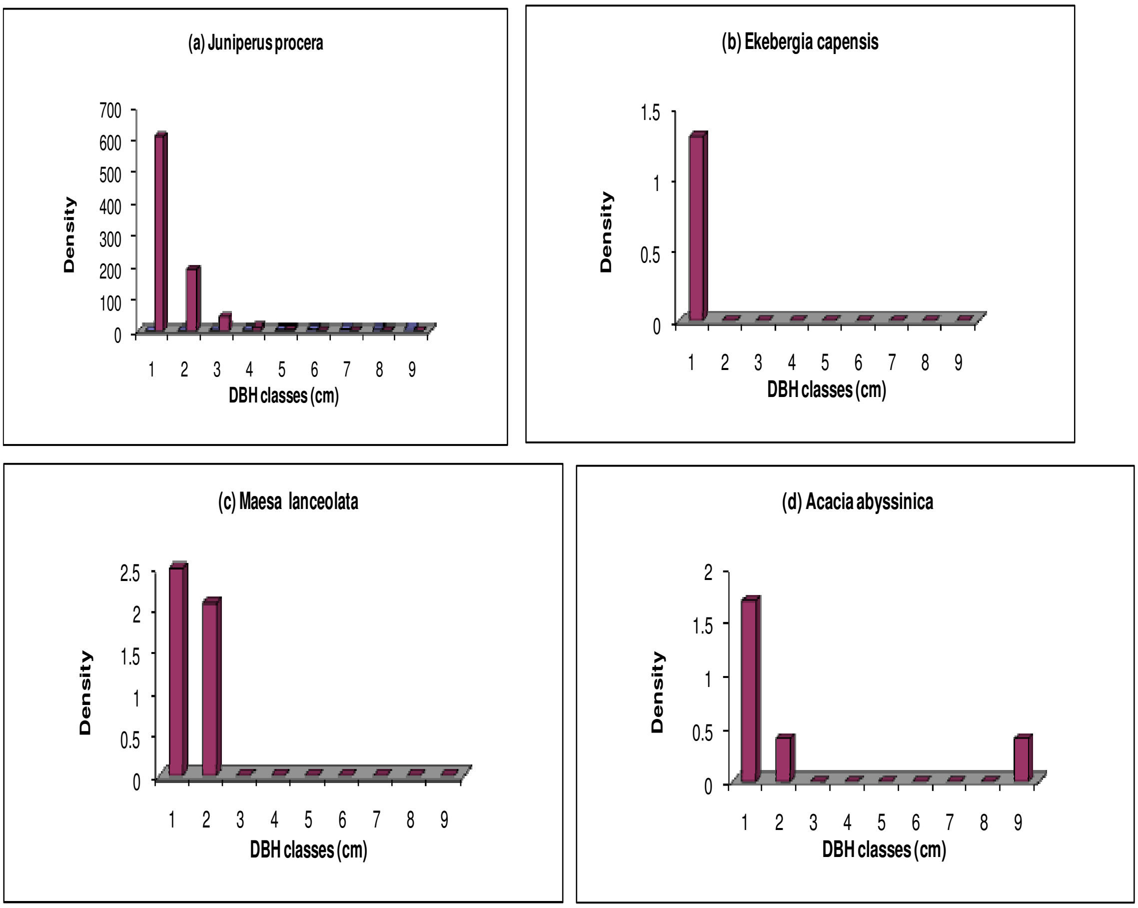

Figure 5: Representative Patterns of species population structures in Entoto *E. globulus* plantation; where (1) = 2.6-7.5, (2) = 7.6-12.5, (3) = 12.6-17.5, (4)= 17.6-22.5, (5) = 22.6-27.5, (6) = 27.6-32.5, (7) = 32.6-37.5, (8) = 37.6-42.5 and (9) = > 42.5 cm.

Analysis of the population structure of the tree and shrub species can be summarized into two groups (Table 7). The first group includes those species whose reproduction is good but recruitment is hampered. The second group includes those species whose reproduction as well as recruitment is good. Hence, all species in the first group should accord the top priority for conservation measures.

Table 7: List of species according to population structure grouping.

Group 1	Group 2
Acacia abyssinica	*Juniperus procera*
Bersama abyssinica	
Carissa spinarum	
Dovyalis abyssinica	
Ekebergia capensis	
Maesa lanceolata	
Maytenus arbutifolia	
Maytenus gracilipes	
Olinia rochetiana	
Podocarpus falcatus	
Premna schimperi	
Prunus africana	
Rosa abyssinica	

Regeneration Status of Woody species: Composition and Density of Seedlings and Saplings

Composition and density of seedlings and saplings would indicate the status of regeneration in the study area. A total of 39 species were represented in the seedling class, representing 32 genera and 24 families. The total seedling density of naturally regenerated woody species was 1172 individuals ha^{-1}. The sapling class was composed of 28 species representing 25 genera and 21 families. The total sapling density of naturally regenerated woody species was 1512 individuals ha^{-1}. A total of 14 woody species were represented in the mature tree/shrub class, representing 13 genera and 12 families. The total mature tree and shrub density was 932.1 individuals ha^{-1}. The ratio of woody species seedlings to mature tree/shrub (1.26:1) and seedlings to saplings (0.78:1) and saplings to mature tree/shrub (1.62:1) showed the distribution of more sapling population than that of seedling and mature tree/shrub. The less seedling population compared to that of sapling population implying the perishing of most seedlings before reaching sapling stage. Seedlings are more vulnerable to environmental hazards and biotic factors especially at the early stages of seedling establishment.

Potential causes of seedling mortality include abiotic stresses such as shade, drought and trampling, and biotic influences such as herbivory, disease or root competition (Demel Teketay, 1997). To use the regeneration analysis for priority setting, the species considered in the forest were classified into three groups based upon the seedling density ha^{-1} (Table 8). Accordingly, those species having seedlings density ha^{-1} between 0 and 5 were grouped under class 1; others whose seedlings density ha^{-1} greater than 5 but less than 50.1 were grouped under class 2, and those species having seedlings density ha^{-1} greater than or equal to 50.1 were grouped under class 3. For the sake of conservation endeavors, those species under class 1 and class 2 are recommended to be given the highest priority. The results showed gaps between the floristic composition of the mature stand and the regeneration. There were most seedlings and/or saplings that lacked mature woody species. This might suggest that there was over exploitations of mature individuals.

The composition, distribution and density of seedlings and saplings indicate the future status of the forest. Therefore, further studies and continuous monitoring of the natural regeneration in the Entoto *E. globulus* plantation is required, particularly the status of soil seed banks has to be investigated to know whether or not regeneration potential, other than seedlings and saplings, exist. Entoto *E. globulus* plantations have been and continue to be subjected to natural and human-induced disturbances, which resulted in their degradation or complete destruction. The loss of forest results in soil erosion, land degradation, loss of biodiversity and impoverishment of ecosystems. In most of the woody plants in dry Afromontane forests the lack of persistent soil seed banks affect the formation of populations of seedlings on the forest floor (Demel and Granstrom, 1995).

Table 8: List of species under regeneration status group

Regeneration Status		
Class 1	Class 2	Class 3
Acacia abyssinica	*Asparagus africanus*	*Carissa spinarum*
Clutia lanceolata	*Asparagus setaceus*	*Jasminum grandiflorum*
Dovyalis abyssinica	*Bersama abyssinica*	*Juniperus procera*
Dovyalis verrucosa	*Clerododendrum* sp	*Maytenus arbutifolia*
Erica arborea	*Ekebergia capensis*	*Maytenus senegalensis*
Jasminum abyssinicum	*Jasminum stans*	*Olea europaea* subsp. *cuspidata*
Lippia adoensis	*Laggera tomentosa*	*Rosa abyssinica*
Maytenus gracilipes	*Maesa lanceolata*	
Nuxia congesta	*Myrsine africana*	
Pentas lanceolata	*Olinia rochetiana*	
Pentas schimperiana	*Osyris quadripartita*	
Podocarpus falcatus	*Prunus africana*	
Premna schimperi	*Satureja punctata*	
Rhamnus staddo	*Sida tenuicarpa*	
Rhus vulgaris	*Vernonia filigera*	
Rubus apetalus		
Satureja imbricata		
Scolopia theiofolia		
Smilax aspera		

CONCLUSION AND RECOMMENDATIONS

Conclusion

The results of this study indicated that *Juniperus procera* is the most NRWS in *E. globulus* plantation at Entoto Mountain, Addis Ababa, Ethiopia. *J. procera* was the most frequent (98.3%) NRWS and it took the biggest share in the percentage contribution of basal area (95.16%) and IVI values (81.8%). This result may indicate that it is eco-friendly and competent with *E. globulus.* The study on vegetation and population structure showed that the density of NRWS was high at the lower DBH class levels and at the lower canopy, indicating the predominance of small-sized individuals in the *E. globulus* plantation. This could be attributed to high rate of regeneration but poor recruitment in the *E. globulus* plantation, which might have been caused by over exploitation of large-sized individuals. The presence of small-sized individuals in *E. globulus* plantation acts as a reserve for replacing the losses of larger-sized individuals. Therefore, most seedlings and/or saplings were lacked mature woody species. Based on species population structure, IVI values and regeneration status, NRWS could be prioritized. Concerning the species population structure those species categorized under group 1 is given the highest priority for conservation. In the case of IVI, those species categorized under group 2 are recommended for conservation. Similarly, for regeneration status, those species under class 1 and class 2 are recommended to be given the highest priority for conservation. Entoto *E. globulus* plantations have been and continue to be subjected to natural and human-induced disturbances. Therefore, there was the intensive removal of litter falls from the plantations and the whole tree removal system may enhance soil erosion and land degradation at large. This might be results in soil erosion, land degradation, loss of biodiversity and impoverishment of ecosystems. Generally, in degraded high rainfall areas, *E. globulus* plantations may play a role in fostering the regeneration of woody species such as *Juniperus procera.* Conservation of this plantation site is not only restoring woody species but also rehabilitating the degraded land and allowing germination and successful growth of seedlings to mature individuals.

Recommendations

This research result gives a clue for further investigation to have a full picture on the interaction between *E. globulus* and naturally regenerated woody species. Therefore, to conserve NRWS in *E. globulus* plantations appropriate management strategy is vital. For example, Silvicultural practices such as thinning in densely *E. globulus* plantations should be practiced to allow light to reach the ground and to encourage natural regeneration of woody species.

Conservation and management activities should be immediately implemented to protect the most threatened and the most economically important species like, *Podocarpus falcutus,* from its local extinction. Land rehabilitation measures should be immediately taken to conserve the degraded parts of the study areas and maintaining soil seed bank taken away by soil erosion. It would be advisable to initiate further research related to the allelopathic effects over soil seed bank of NRWS. The status of soil seed bank has to be investigated to know whether regeneration potential, other than seedlings and saplings, exist.

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Appendix 1: List of woody species, families and habit recorded from Entoto Mountain.

No.	Botanical Name	Family	Habit
1	*Acacia abyssinica* Hochst. ex Benth	Fabaceae	Tree
2	*Asparagus africanus* Lam.	Asparagaceae	Shrub
3	*Asparagus setaceus* (Kunth) Jessop	Asparagaceae	Shrub
4	*Bersama abyssinica* Fresen.	Melianthaceae	T/S
5	*Carissa spinarum* L.	Apocynaceae	Shrub
6	*Clerododendrum* sp	Verbenaceae	Shrub
7	*Clutia lanceolata* Forssk	Euphorbiaceae	Shrub
8	*Dovyalis abyssinica* (A. Rich.) Warb	Flacourtiaceae	Shrub
9	*Dovyalis verrucosa* (Hochst.) Warb.	Flacourtiaceae	Shrub
10	*Ekebergia capensis* Sparrm.	Meliaceae	Tree
11	*Erica arborea* L.	Ericaceae	Shrub
12	*Jasminum abyssinicum* Hochest. ex Dc.	Oleaceae	Liana
13	*Jasminum grandiflorum* L. subsp.*floribundum* (R. Br. ex Fresen.) P. S. Green	Oleaceae	Liana
14	*Jasminum stans* Pax	Oleaceae	Shrub
15	*Juniperus procera* Endl.	Cupressaceae	Tree
16	*Laggera tomentosa* (Sch. Bip. ex A. Rich.) Oliv. & Hiern	Asteraceae	Shrub
17	*Lippia adoensis* Hochst. ex Walp.	Verbenaceae	Shrub
18	*Maesa lanceolata* Forssk.	Myrsinaceae	T/S
19	*Maytenus arbutifolia* (A. Rich.) Wilczek	Celastraceae	T/S
20	*Maytenus gracilipes* (Welw. ex Oliv.) Exell	Celastraceae	Shrub
21	*Maytenus senegalensis* (Lam.) Exell	Celastraceae	Shrub
22	*Myrsine africana* L.	Myrsinaceae	Shrub
23	*Nuxia congesta* R. Br. ex Fresen	Loganiaceae	T/S
24	*Olea europaea* L. subsp. *cuspidata* (Wall. ex G. Don) Cif., L'Olivicoltore	Oleaceae	Tree
25	*Olinia rochetiana* A. Juss.	Oliniaceae	T/S
26	*Osyris quadripartita* Decn.	Santalaceae	T/S
27	*Pentas lanceolata* (Forssk) Defl.	Rubiaceae	Shrub
28	*Pentas schimperiana* (A. Rich.) Vatke	Rubiaceae	Shrub
29	*Podocarpus falcatus* (Thunb) Mirb.	Podocarpaceae	Tree
30	*Premna schimperi* Engl.	Lamiaceae	Shrub
31	*Prunus africana* (Hook. f.) Kalkm.	Rosaceae	Tree
32	*Rhamnus staddo* A. Rich.	Rhamnaceae	Shrub
33	*Rhus vulgaris* Meikle	Anacardiaceae	Shrub
34	*Rosa abyssinica* Lindley	Rosaceae	Shrub
35	*Rubus apetalus* Poir.	Rosaceae	Shrub
36	*Satureja imbricata* (Forssk.) Briq. Check	Lamiaceae	Shrub
37	*Satureja punctata* (Benth.) Briq.	Lamiaceae	Shrub
38	*Scolopia theiofolia* Gilg	Flacourtiaceae	Tree
39	*Sida tenuicarpa* Vollesen	Malvaceae	Shrub
40	*Smilax aspera* L.	Smilacaceae	Liana
41	*Vernonia filigera* Oliv. & Hiern	Asteraceae	Shrub

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