STRUCTURE AND POTENTIAL REGENERATION OF DEGRADED SECONDARY STANDS IN MUNESSA-SHASHEMENE FOREST, ETHIOPIA

A Girma* & R Mosandl

Technische Universität München, Center of Life and Food Sciences Weihenstephan, Institute of Silviculture, Hans-Carl-von-Carlowitz-Platz 2, 85354 Freising, Germany

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GIRMA A & MOSANDL R. 2012. Structure and potential regeneration of degraded secondary stands in Munessa-Shashemene forest, Ethiopia. The dry afromontane forests in the Ethiopian highlands are being threatened by deforestation and forest degradation. A study was conducted in a dry afromontane forest of Munessa-Shashemene to evaluate the density and diversity of the forest. Due to harvesting of valuable trees many gaps are now present. The species composition and structure of the remaining secondary forest as well as the regeneration were analysed. A total of 25 forest stands in the neighbourhood of 25 gaps in an enrichment planting experiment were assessed. A plot of dimension 30 × 30 m was established in each stand. Diameter at breast height (dbh) and height of all trees with dbh > 2 cm were measured. Regeneration of woody plants was assessed in four subplots in each stand. Thirty-six woody species were recorded in the mature stand, representing 35 genera and 30 families. Density of woody species was 734 stems ha^{-1} and the total basal area was 9.5 m^2 ha^{-1}. Regeneration of trees and shrubs was 1,000 saplings and 31,600 seedlings ha^{-1}. Enrichment of valuable tree species with supplement plantings may be required to keep the valuable species as part of these forests.

Keywords: Dry afromontane forest, highlands, species composition and structure, sustainable management

GIRMA A & MOSANDL R. 2012. Struktur dan potensi pemulihan dirian sekunder yang ternyah gred di hutan Munessa-Shashemene, Ethiopia. Hutan afrogunung yang kering di tanah tinggi Ethiopia diancam oleh pembasmian hutan dan pendegradan hutan. Kajian dijalankan di hutan afrogunung kering Munessa-Shashemene untuk menilai kepadatan dan kepelbagaian hutan. Penebangan pokok bernilai mengakibatkan terbentuknya banyak ruang di dalam hutan. Komposisi spesies, struktur hutan dan pemulihan dianalisis di hutan sekunder yang masih ada. Sejumlah 25 dirian hutan di sekitar 25 ruang dalam eksperimen tanaman mengaya dinilai. Plot berdimensi 30 m × 30 m diasaskan dalam setiap dirian. Diameter aras dada (dbh) dan ketinggian kesemua pokok dengan dbh > 2 cm disukat. Pemulihan tumbuhan berkayu dinilai di empat subplot dalam setiap dirian. Sebanyak 36 spesies tumbuhan berkayu daripada 35 genus dan 30 famili dicerap dalam dirian matang. Kepadatan spesies tumbuhan berkayu ialah 734 batang ha^{-1} dan jumlah luas pangkal ialah 9.5 m^2 ha^{-1}. Pemulihan bagi pokok dan pokok renek ialah 1,000 anak pokok sehektar dan 31,600 anak benih sehektar. Penanaman spesies pokok bernilai mungkin diperlukan bagi memastikan spesies bernilai kekal di dalam hutan.

INTRODUCTION

World deforestation is primarily due to the conversion of tropical forest to agricultural land, which is at a high rate in many countries (FAO 2010). The forest cover in Ethiopian highlands has reduced substantially due to overexploitation for fuelwood, construction and agricultural purposes (Yirdaw 2002).

Forest stand structure and regeneration assessment have been done in the tropics and temperate regions (Geldenhuys & Pieterse 1993). It has also been reported that different species require different regeneration niches (Grubb 1977). Understanding the pattern of forest structure and composition has important implication on population dynamics (Clark 1991). Different regeneration studies have been conducted including assessment of regeneration of selected trees in the tropics (Pande & Bischt

*E-mail: girma12000@yahoo.com

1988, Kumar & Pandey 1993, Poorter et al. 1996), performance and pattern of the overall forest (Bekele 1993, Smale & Kimberly 1993, Lieberman et al. 1996, Teketay 1996, Derero 1998, Derero et al. 2003, Tesfaye 2007) and disturbance regimes or gaps and the respective regeneration responses (Veblen et al. 1992, Midgley et al. 1995). In Munessa-Shahemene forest, a study on regeneration was conducted by Tesfaye 2007 (see also Tesfaye et al. 2010). However, the use of this information for management decision has been limited and the effects of silvicultural management on status, composition and structure of regeneration of these forests are few.

The investigation on Munessa-Shashemene forest was conducted to evaluate species composition and structure of woody vegetation, regeneration potential and to recommend silvicultural management pratices.

MATERIALS AND METHODS

Study area

The study area was located at the Degaga block in Munessa-Shashemene forest, 38° 53' E and 7° 27' N. It covers 10,761 ha and the range of altitude extends from approximately 2090 to 2700 m (Figure 1) (Silvanova 1996). It is situated in the warm subhumid and cold humid agro-ecological zones of Ethiopia with mean annual rainfall and temperature of 1343 mm and 15 °C respectively (Friis 1986, Cheffey 1978). Soils from the middle (2300 m asl) to the upper (2700 m asl) slope position were derived from weathered volcanic rock, mainly, reddish or brown in colour, draining freely and of medium to heavy texture. The pH ($CaCl_2$) and CEC ranged from 5.5 to 7 and 30 to100 mmol kg^{-1} respectively (Lundgren 1971, Fritzsche et al. 2006).

Assessments of mature stand and regeneration

The study was conducted to characterise the mature stand in the neighbourhood of the gaps and to analyse the regeneration status of the forest. A total of 25 plots of dimension 30 × 30 m each were systematically placed. Inventory of the woody vegetation and regeneration were conducted.

Density calculation was made for the three categories, namely, trees, saplings and seedlings. In each main plot, diameter and height of all woody species with diameter at breast height (dbh) greater than 2 cm were measured. Diameter was measured using diameter tape. Height was measured using Vertex Laser VL400 height measuring instrument. In addition, the height of saplings (height > 1 m and dbh < 2 cm) was measured using metre rule.

Seedlings (with two normal leaves above cotyledons and with height less than 1 m) were counted in four 2 × 1 m plots (four plots at the four corners in each main plot). Altitude and slope in each quadrat were recorded using

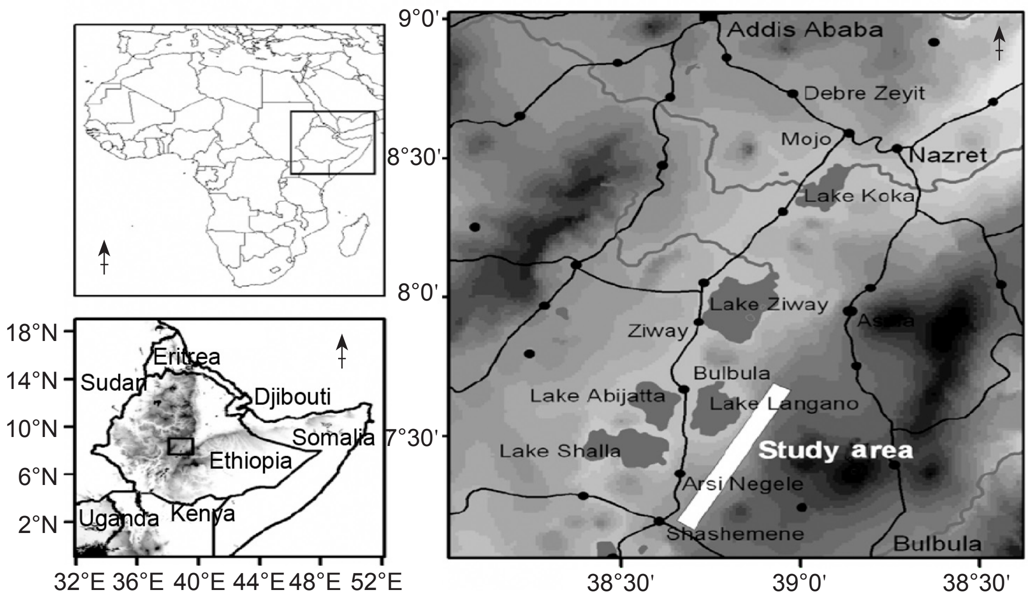


Figure 1 The study area

altimeter and clinometer respectively. Plants were identified to the species level.

Data analysis

Density, basal area and height of the forest were based on stems greater than 2 cm dbh. Importance value indices (IVI) (Curtis & McIntosh 1951) were calculated for woody species found in the main plots.

IVI = Relative basal area (dominance) + relative abundance + relative frequency

where

Relative basal area = basal area of a species/total basal area of all species × 100
Relative abundance = the number of all individual trees of a species/the total number of all individual trees × 100
Relative frequency = the number of main plots where a species occurs/the total number of all main plots (equals 25) × 100

Densities of seedlings and saplings were computed for all woody species (except vines). Statistical analyses were done using SAS for Windows, version 9.1 (Littell et al. 1991).

RESULTS

Forest structure: density, frequency and importance value index

Tree and shrub species found in the study plots represented 30 families, 35 genera and 36 species (Table 1). Tree density was 734 stems ha^{-1} and the total basal area was 9.5 m^2 ha^{-1}. The tree species with the highest basal areas were *Croton macrostachyus* and *Podocarpus falcatus*. About 70.1% of the stems had dbh ≤ 10 cm, 19.8% between 10 and 40 cm and 5.1% ≥ 40 cm (Figure 2). The largest diameter recorded for *P. falcatus* was 322 cm. Trees with heights ≤ 10 m made up 76.7% of the total height class. Individuals between 10 and 20 m height made up 11.6% whereas individuals greater than 20 m, 11.7%.

Importance value index showed that *C. macrostachyus* (Euphorbiaceae), *P. falcatus* (Podocarpaceae),*Canthium crassum* (Rubiaceae), *Maytenus ovatus* (Celasteraceae) and *Bersama abyssinica* (Melianthaceae) were the top five IVI species in the study (Table 1). These five IVI values combined contributed to 56.3% of the total IVI of all species.

Size class representation

Size of trees and IVI showed distinct inverted J-shaped curves that were indicative of good regeneration (Figures 2 and 3). Population structure of the selected tree species revealed variable structural patterns (Figure 4): an inverted J curve type, an interrupted inverted J curve type, Gauss type curve, interrupted Gauss type curve and an irregularly interrupted curve.

The inverted J curve type species structure included *Celtis africana,* whereas *Milletia ferruginea* and *Fagaropsis angolensis* showed an interrupted inverted J curve type. *Allophylus abyssinicus* and *Spiniluma oxyacantha* revealed a Gauss type of curve, whereas *Nuxia congesta* showed an interrupted Gauss type curve. An irregularly interrupted curve was represented by *Ficus vista.*

Regeneration status: composition and density of saplings and seedlings

A total of 17 species were found in the main plots (Table 2). High numbers of seedling (31,600/ha) and sapling (1000/ha) were recorded. Three species, namely, *C. crassum, B. abyssinica* and *C. macrostachyus* represented 63.3% of the saplings. Economically or ecologically important species (*Prunus africana* and *P. falcatus*) were less represented (Table 2).

Only 15 seedling species were represented from the 36 tree species found in the overstorey (Table 2). Seedlings of eight species (*B. abyssinica, M. ovatus, P. africana, Cassipourea malosana, C. macrostachyus*, *C. africana, Syzygium guineense* and *C. crassum*) made up 88% of the total seedlings counted. The remaining contributed to 12% of the total seedling density (*Allophylus abyssinicus, Brucea antidysentenica, Myrica salicifolia, Teclea nobilis, Fagaropsis angolensis, Galinieria coffeoides* and *P. falcatus*).

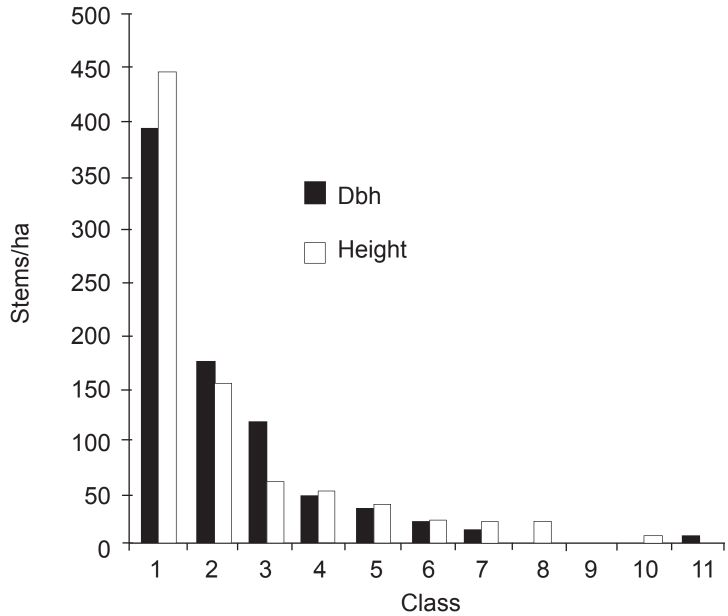
DISCUSSION

The abundance of small diameter trees seemed to indicate that the forest was disturbed recently. Many authors reported fewer stems of lesser dbh and height in afromontane forests (Bekele 1993, Teketay 1996, Derero et al. 2003, Tesfaye 2007).

Table 1 Abundance, basal area, frequency and importance value index of woody species

Species	Family	Ab/ha	Ab%	Ba/ha	Ba%	Fr/25 plots	Fr%	IVI
Croton macrostachyus	Euphorbiaceae	155	21.06	2.393	25.19	25	7.02	53.27
Podocarpus falcatus	Podocarpaceae	39	5.29	2.202	23.18	25	7.02	35.49
Canthium crassum	Rubiaceae	177	24.05	0.134	1.41	25	7.02	32.48
Maytenus ovatus	Celasteraceae	91	12.36	0.605	6.37	23	6.46	25.19
Bersama abyssinica	Melianthaceae	89	12.09	0.276	2.91	25	7.02	22.02
Teclea nobilis	Rutaceae	50	6.79	0.206	2.15	23	6.46	15.40
Allophylus abyssinicus	Sapindaceae	17	2.31	0.576	6.06	25	7.02	15.39
Prunus africana	Rosaceae	9	1.22	0.751	7.90	16	4.49	13.61
Celtis africana	Ulmaceae	13	1.77	0.511	5.38	21	5.90	13.05
Aningeria adolfi-friederici	Sapotaceae	4	0.54	0.582	6.12	13	3.65	10.31
Cassipourea malosana	Rhizophoraceae	7	0.95	0.255	2.68	16	4.49	8.12
Brucea antidysentenica	Simaroubaceae	19	2.58	0.024	0.27	16	4.49	7.34
Galinieria coffeoides	Rubiaceae	15	2.04	0.102	1.07	14	3.93	7.04
Fagaropsis angolensis	Rutaceae	4	0.54	0.028	0.30	12	3.37	4.21
Syzygium guineense	Myrtaceae	4	0.54	0.018	0.19	11	3.09	3.82
Milletia ferruginea	Papilionaceae	4	0.54	0.160	1.69	5	1.41	3.64
Calpurnia aurea	Papilionaceae	6	0.82	0.021	0.22	9	2.53	3.57
Olea hochstetteri	Oleaceae	2	0.27	0.194	2.04	4	1.12	3.43
Ficus vista	Moraceae	2	0.27	0.131	1.37	4	1.12	2.76
Nuxia congesta	Loganiaceae	2	0.27	0.041	0.43	6	1.69	2.39
Flacourtia indica	Flacourtiaceae	4	0.54	0.005	0.05	6	1.69	2.28
Apodytes dimidiata var. *acutifolia*	Icacinaceae	3	0.41	0.041	0.43	5	1.41	2.25
Olinia usambarensis	Oliniaceae	4	0.54	0.062	0.65	3	0.84	2.03
Ekebergia capensis	Meliaceae	1	0.14	0.0001	0.001	5	1.41	1.55
Myrica salicifolia	Myricaceae	2	0.27	0.008	0.08	4	1.12	1.47
Spiniluma oxyacantha	Sapotaceae	1	0.14	0.065	0.69	1	0.28	1.11
Vernonia auriculifera	Asteraceae	1	0.14	0.0003	0.003	3	0.84	0.98
Polyscias fulva	Araliaceae	1	0.14	0.0426	0.45	1	0.28	0.87
Dombeya goetzenii	Sterculiaceae	1	0.14	0.0032	0.03	2	0.56	0.73
Schefflera volkensii	Araliaceae	1	0.14	0.0283	0.30	1	0.28	0.72
Vernonia amygdalina	Asteraceae	1	0.14	0.00002	0.0002	2	0.56	0.70
Scelerocarya birea	Anacardiaceae	1	0.14	0.0008	0.008	1	0.28	0.43
Pittosporum viridiflorum	Pittosporaceae	1	0.14	0.0003	0.003	1	0.28	0.42
Dovyalis abyssinica	Flacourtiaceae	1	0.14	0.0001	0.001	1	0.28	0.42
Albizia gummifera	Mimosaceae	1	0.14	0.00001	0.0001	1	0.28	0.42
Euclea racemosa subsp. *schimperi*	Ebenaceae	1	0.14	0.00001	0.0001	1	0.28	0.42
Total		734	100	9.5	100	356	100	299.34

Ab = abundance, Ab% = relative abundance, Ba = basal area, Ba% = relative basal area, Fr = frequency, Fr% = relative frequency, IVI = importance value index



Dbh classes (cm): 1 = 2.0–5.0, 2 = 5.1–10.0, 3 = 10.1–25.0, 4 = 25.1–40.0, 5 = 40.1–55.0, 6 = 55.1–70.0, 7 = 70.1–85.0, 8 = 85.1–100.0, 9 = 100.1–115.0, 10 = 115.1–130.0, 11 > 130.1; Height classes (m): 1 = 1.3–5.0, 2 = 5.1–10.0, 3 = 10.1–15.0, 4 = 15.1–20.0, 5 = 20.1–25.0, 6 = 25.1–30.0, 7 = 30.1–35.0, 8 = 35.1–40.0, 9 = 40.1–45.0, 10 > 45.1

Figure 2 Diameter and height structure of the forest

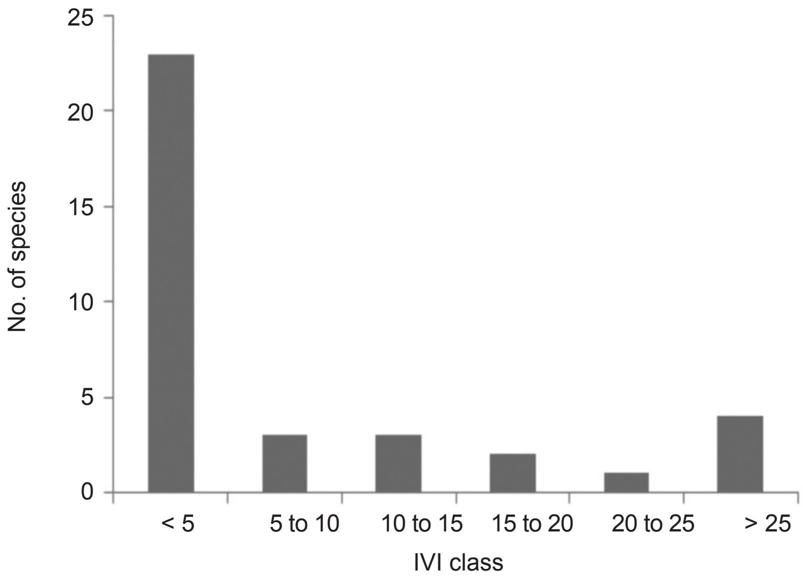


Figure 3 Distribution of IVI in the forest

Importance value shows structural dominance of trees (Curtis & McIntosh 1951). The five dominant species with higher IVI in the overstorey were *C. macrostachyus*, *P. falcatus*, *C. crassum*, *M. ovatus* and *B. abyssinica*. Few species have been reported to have high IVI in tropical and subtropical forests (Uhl & Murphy 1981, Derero et al. 2003). However, the high IVI is not always attributed to the same growth or structure parameter. The high IVI of *C. macrostachyus* was attributed to its high abundance and basal area in the forest. High IVI of *P. falcatus* was due to its high basal area (2.2 m^2 ha^{-1}), whereas the high IVI of *C. crassum* was attributed to its high abundance.

Most of the species in this study had shown differences in forest structure. This is not only attributed to environmental factors but also anthropogenic influences (Tesfaye 2007). Species represented by an inverted J curve had good regeneration and recruitment status (Derero et al. 2003). *Milletia ferruginea* and *T. nobilis* showed inverted J curve structure. Many tropical forests show this structure (Richards 1996) and regeneration will be successful for these species (Poorter et al. 1996).

Milletia ferruginea (Figure 4) and *T. nobilis* (not shown) revealed an interrupted inverted J curve population. This may be attributed to human disturbance (Lieberman et al. 1996, Derero et al. 2003, Tesfaye 2007, Tesfaye et al. 2010). The Gaussian type of size distribution—many large trees with few small trees—indicates poor recruitment and regeneration. The species in

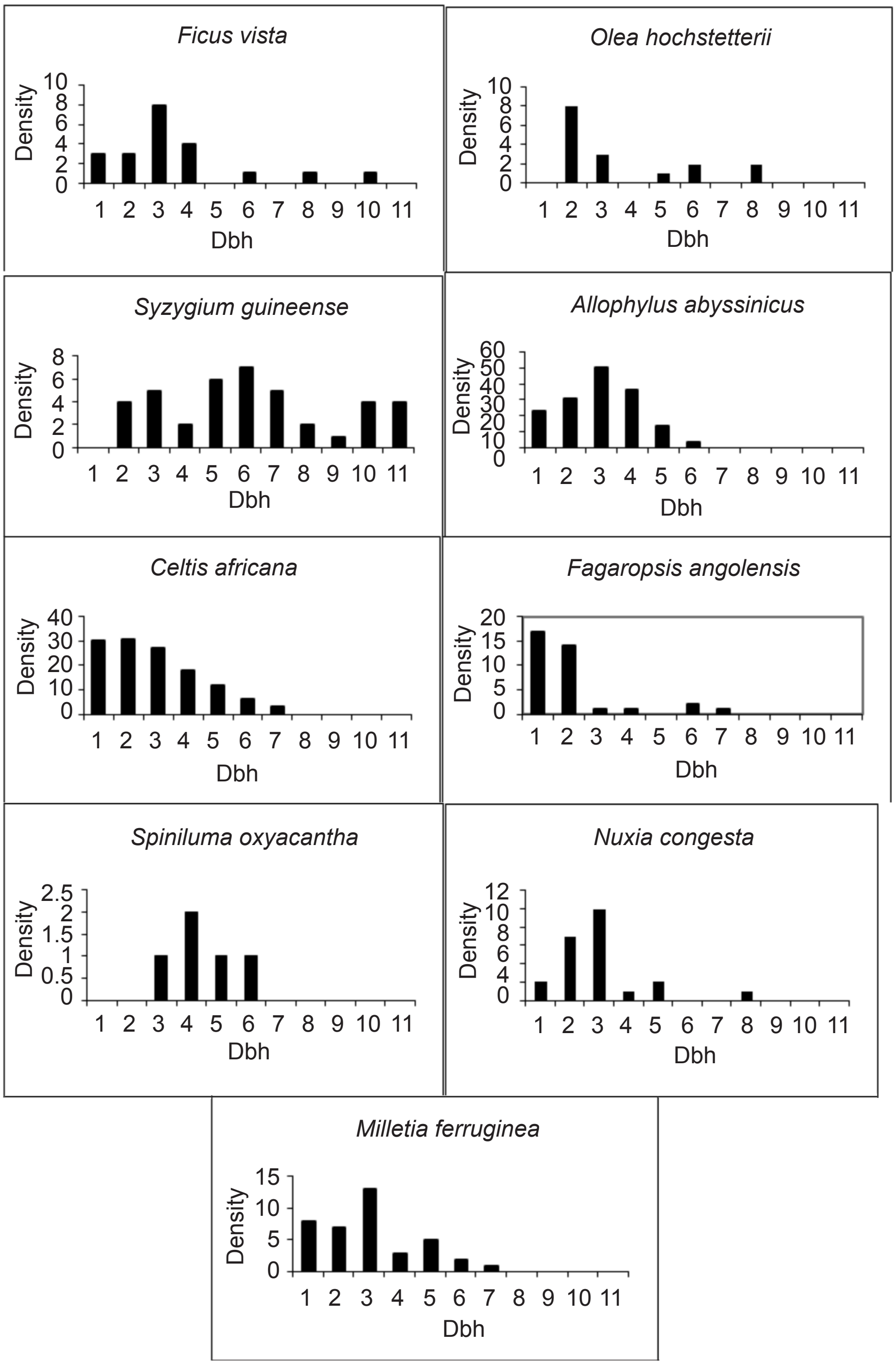


Figure 4 Population structure of some tree species in dbh classes (cm): 1 ≤ 5.0, 2 = 5.1–10.0, 3 = 10.1–25.0, 4 = 25.1–40, 5 = 40.1–55.0, 6 = 55.1–70.0, 7 = 70.1–85, 8 = 85.1–100, 9 = 100.1–115, 10 = 115.1–130, 11 > 130; density = stems/ha

Table 2 Density of saplings and seedlings

Species	Sapling density/ha	Sapling (%)	Seedling density/ha	Seedling (%)
Myrica salicifolia	10	1.0	700	2.22
Celtis africana	31	3.1	2900	9.18
Podocarpus falcatus	20	2.0	600	2.00
Calpurnia aurea	42	4.2	0	0.00
Brucea antidysentenica	63	6.3	700	2.22
Scelerocarya birea	21	2.1	0	0.00
Bersama abyssinica	166	16.6	1800	6.00
Canthium crassum	361	36.1	6700	21.20
Teclea nobilis	70	7.0	600	2.00
Allophylus abyssinicus	1	0.1	1000	3.16
Maytenus ovatus	77	7.7	2200	6.96
Croton macrostachyus	106	10.6	2800	8.86
Fagaropsis angolensis	5	0.5	100	0.32
Cassipourea malosana	27	2.7	2500	7.91
Galinieria coffeoides	0	0.0	100	0.32
Syzygium guineense	0	0.0	6500	20.57
Prunus africana	0	0.0	2400	7.59
Total	1000	100	31,600	100.00

this study which demonstrated Gaussian patterns were *A. abyssinicus* and *S. oxyacantha* (Figure 4).

The interrupted Gaussian curve indicates poor regeneration, poor recruitment and few stems in the higher dbh classes. The species representing the Gaussian curve was *N. congesta* (Figure 4). Derero et al. (2003) noted the same response in a southern Ethiopian forest. The irregularly interrupted dbh distributions of *F. vista* (Figure 4) and *Olea hochstetteri* indicate poor regeneration and recruitment. Similar response has been noted by Tesfaye (2007).

CONCLUSIONS

Height and diameter distributions as well as IVI of the woody vegetation indicated harvesting potential of some species. Regeneration of less valuable species, *C. macrostachyus* and *B. abyssinica,* was greater than the more valuable species. Two management recommendations could be made, i.e. economically valuable mature trees could be harvested before they decay and planting these tree species could be done to assist their natural regeneration.

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