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Research Article

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A comparative study on indigenous and exotic woody vegetation of three different church forest ecosystems in Gondar, Ethiopia

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ABSTRACT

This study was confined to three Ethiopian Orthodox Tewahido Church (EOTC) forests in Gondar namely; Saint Michael (SMC), Queskum (QUC) and Debrebrhan Selassea (DSC). They are located in South west, West and North east directions from center of the city respectively. Information was gathered on woody vegetation characteristics from study plots with the objective of comparing indigenous and exotic woody species stand density (D_S), stand basal area (BA_S), importance value index (IVI) and species diversity (H'). A total of 35 woody species (seven IUCN red listed) belong to 23 families were recorded. Among the records, 25 were indigenous (one endemic) and 10 exotics. DSC contains 31 species (maximum) belonging to 19 families and overall highest D_S was recorded from same site followed by QUC which contains 24 species belonging to 18 families and lowest from SMC (22 species from 16 families). Higher H' was recorded from QUC and lower in SMC. The Jaccard's species similarity index (SJ) calculation shows maximum species similarity among overall and indigenous categories between QUC and DSC and it was highest for exotics between SMC and DSC. The stand characteristics followed different patterns of variations in D_S, BA_S, IVI, richness (S), H' and evenness (H'E). An analysis of variance showed that species and its density and basal area and IVI significantly differ between and within groups ($p < 0.001$). A significant difference was found ($p \leq 0.005$) between species category (indigenous and exotics) and basal area and it was insignificant between species category and density ($p \geq 0.05$).

Key words: *Basal area, Church forest ecosystems, Density, Diversity, Importance value index.*

INTRODUCTION

Conservation of natural resources has been an integral part of diverse cultures in different ways and the traditional worship practice shows the symbiotic relationship of human beings and nature[1]. Sacred forests across the world are conserved primarily for spiritual reasons, harming a forest is forbidden by tradition and it is typically believed that any alteration of the forest such as cutting wood, hunting animals or other forms of resource extraction will result in negative consequences to the person taking the resources[2].

The forests located around the churches in Ethiopia comprise local as well as global hotspots. In the northern highland Ethiopia, patchy remnants of old aged afromontane forests are found almost only around the EOTC[3&4].

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These forests are still sanctuaries of many plant and animal species that have almost disappeared in most parts of northern Ethiopia[5]. Forests in most other areas have been completely destroyed and converted into farming and grazing lands over centuries. As a result, church forests still pose a great heritage of diverse gene pool of many forest species.

Ecological theory states that patches of fragmented forest lose species and have low biodiversity, suggesting that such patches have limited value for biodiversity conservation[6]. However, a network of patches is known to support higher biodiversity than a single patch alone[7]. Furthermore, if the patches are connected by corridors, they can potentially support higher number of species[8].

The potential disadvantage of exotic plantation includes invasion and replacement of native flora[9] and invasion of habitats by exotics often associated with a decrease in abundance of native species, particularly trees[10]. In this context, the objective of the present study was to compare indigenous and exotic woody vegetation among three different church forests in Gondar, Ethiopia.

MATERIAL AND METHODS

Gondar is located in north western part of Ethiopia under Amhara Regional State on a mountainous land and at a distance of 727 km from the capital city Addis Ababa with an average elevation of 2210 m.a.s.l. The Saint Michael Church (SMC) is located at $12^0$37’21’’ North latitude and $37^0$25’55’’ East longitude in the south west direction of Gondar city, with an area of 13.8 hectares. The Queskum Church (QUC) is located in the southern part of the city and the area covers 14.2 hectares. The Debrebrhan Selassea Church (DSC) is located in the north east portion of the city and the size of the forest area is 14.5 hectares. In the past four years average monthly temperature of these areas was 21^0 C and the average annual rainfall was 1172 mm.

Methodology

A preliminary survey was carried out during July, 2012 to get familiar with the study area. However, this study was conducted from February 2013 to June, 2013. A total of seven transect lines were laid out according to the size and shape of the study areas (2 in SMC; 3 in QUC and 2 in DSC) in 100 m interval. The length of transects ranged between 250 m and 550 m. A total of 24 study plots (8 plots per site) of 25 m X 25 m were laid along these transects, maintaining a distance of 100 m between study plots. Information was gathered on the occurrence of tree species, the number of mature stands and their circumference at breast height (1.3 m from ground) within each plot. The circumference of the stands was obtained by using a standard tape and converted in to diameter for calculations. Stands with ≥ 5 cm DBH were only enumerated[11]. Species were identified by referring the technical manual ‘Useful Trees and Shrubs for Ethiopia’[12].

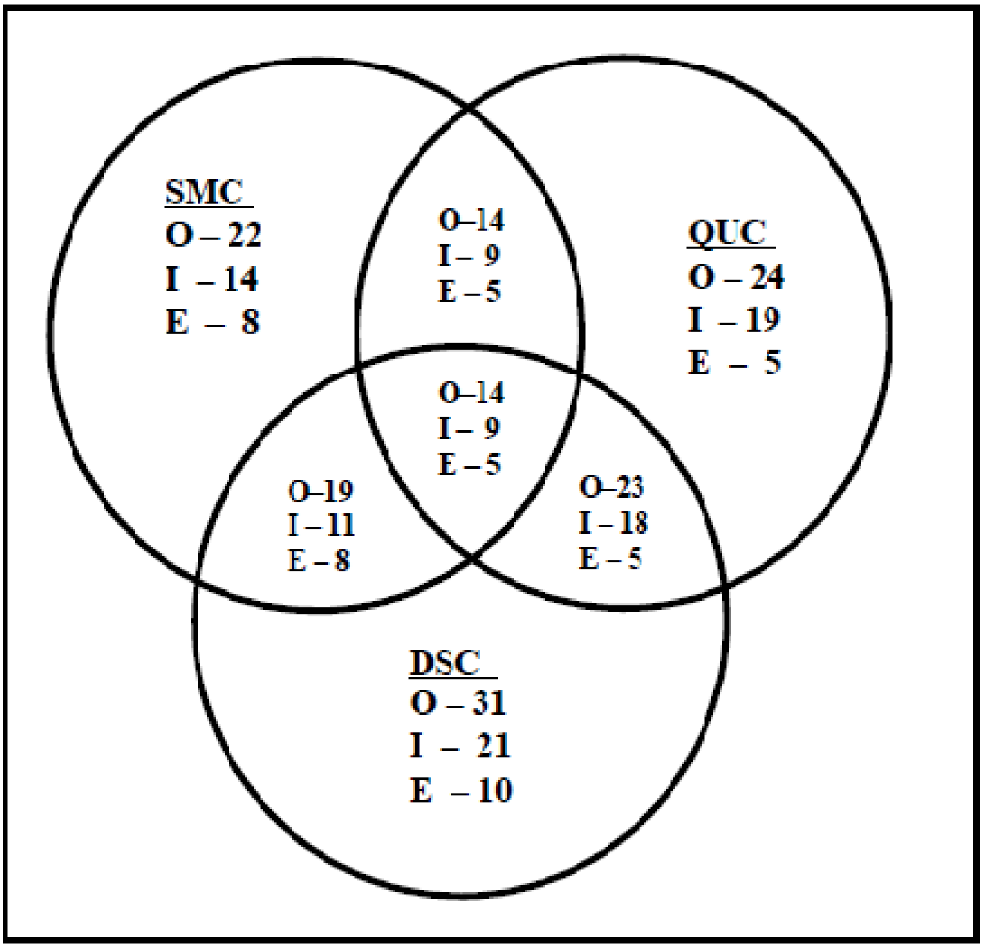
Data analysis

The species stand density (D_S), an expression of the numerical strength of a species in a given area at a particular time was calculated for each site. The basal area (BA_S) of each species was calculated in m^2ha^{-1} to know the occupancy of a species. Importance Value Index (IVI) was prepared to understand the importance of a particular species and the Shannon’s index (H') was chosen for diversity calculation. This diversity index was selected because it provides an account for both, abundance and evenness[13]. It also does not disproportionately favour some species over others, as it counts all species according to their frequencies[14] and the index ranges typically from 1.5 to 3.5 and reaches 4.5 rarely[15]. Other parameters such as species’ richness (S) and species’ evenness (H’E) were derived. In addition, the Jaccard’s index[16] was used for species’ similarity. Analysis of variance using one way ANOVA by SPSS version16 for windows was applied to separate the means.

RESULTS AND DISCUSSION

A total of 35 woody species, belonging to 23 families, were recorded from three sites. Twenty five of them were indigenous species (one endemic species to Ethiopia, included in indigenous category for calculations) and the rest were exotic species from other/several geographic areas. Seven IUCN[17] red listed species were found; five Least Concerned (LC) and two Vulnerable (VU). With respect to the study sites, SMC contains 22 species belonging to 16 families; QUC contains 24 species from 18 families and maximum 31 species under 19 families from DSC (Fig. 1). The most abundant family was *Fabaceae* containing seven species, followed by *Myricaceae* with three species and families. *Anacardiaceae, Cupressaceae, Moraceae and Rhamnaceae* contains two species each and the rest a single species.

Fig. 1:



Occurrence of woody species recorded from three different church forest ecosystems of Gondar, Ethiopia (Note: SMC = Saint Michael Church; QUC = Queskum Church; DSC = Debrebrhan Selassea Church; O = Overall species; I = Indigenous species; E = Exotic species)

The D_S and BA_S (m^2) of the tree stands were calculated ha^{-1} and shown in table 1. The maximum D_S of 94 ± 10.84 was recorded in *Eucalyptus globulus* trees, followed by the species *Casuarina equistifolia* as 88 ± 4.98 and the minimum was in *Acacia mearnsii* (2 ± 0.00) from SMC. In QUC it peaks in *Juniperus procera* (198 ± 13.00), followed by *Casuarina equistifolia* (72 ± 12.39) and falls in *Acacia abyssinica* as 6 ± 1.41. In DSC, the D_S was highest in *Casuarina equistifolia* (166 ± 9.38), followed by *Eucalyptus globulus* (142 ± 11.54) and lowest in *Carissa spinarum* and *Maytenus arbutifolia* as 2 ± 0.00 in each.

Table 1: Overall Density, basal area and IVI of woody species recorded from different church forest ecosystems in Gondar, Ethiopia during February 2013 to June 2013

S#	Species	Saint Michael Church			Queskum Church			Debrebrhan Selassea Church		
		Dha^{-1}±SD	BAm^2ha^{-1} ± SD	IVI	Dha^{-1}±SD	BAm^2ha^{-1} ± SD	IVI	Dha^{-1}±SD	BAm^2ha^{-1} ± SD	IVI
1	*Acacia abyssinica*	46±3.92	43.43±0.33	17.6293	6±1.41	4.03±0.27	1.7689	14±1.91	3.64±0.19	2.9966
2	*Acacia albida*	44±3.63	46.66±0.74	17.5433	-	-	-	4±0.00	0.66±0.14	0.8221
3	*Acacia bussei*	-	-	-	-	-	-	6±1.41	0.87±0.12	1.2215
4	*Acacia lahai*	22±2.61	15.65±0.53	7.7506	14±2.31	8.05±0.20	3.9504	8±1.51	2.50±0.19	1.7508
5	*Acacia mearnsii*	2±0.00	1.54±0.00	0.7202	12±2.83	7.81±0.26	3.5050	16±1.63	1.77±0.11	3.2084
6	*Albizia gummifera*	24±1.63	13.50±0.29	7.9803	-	-	-	-	-	-
7	*Capparis tomentosa*	-	-	-	54±4.13	20.50±0.26	13.8510	6±2.58	1.56±0.12	1.2845
8	*Carissa spinarum*	-	-	-	36±2.19	12.97±0.32	9.1424	2±0.00	0.90±0.00	0.4624
9	*Casuarina equisetifolia*	88±4.98	45.06±0.41	28.6708	72±12.39	32.79±0.26	19.1851	166±9.38	78.13±0.36	38.7017
10	*Cordia Africana*	20±2.58	16.21±0.59	7.3096	52±4.50	37.71±0.59	15.6994	14±1.91	7.65±0.37	3.3598
11	*Croton macrostachyus*	-	-	-	32±2.61	5.33±0.19	7.3125	20±4.16	4.46±0.13	4.2140
12	*Cupressus lusitanica*	-	-	-	-	-	-	14±1.91	3.08±0.22	2.9459
13	*Dodonaea viscose*	40±3.73	7.02±0.26	11.2431	-	-	-	22±2.52	3.99±0.20	4.5518
14	*Eucalyptus globulus*	94±10.84	284.40±2.67	62.0354	18±4.24	84.22±2.02	14.7866	142±11.54	385.80±2.51	62.0212
15	*Eucalyptus grandis*	80±7.35	76.65±1.34	30.8085	34±4.60	104.00±1.37	20.6917	64±6.32	166.00±2.09	27.2387
16	*Ficus elastica*	6±1.41	29.75±4.71	5.5014	-	-	-	6±1.41	4.43±1.02	1.5442
17	*Ficus sur*	-	-	-	8±1.15	35.92±1.63	6.3732	8±1.15	52.99±5.76	6.3275
18	*Grevillea robusta*	48±3.21	34.68±0.54	16.9816	38±2.99	18.21±0.26	10.2443	36±8.87	19.83±0.32	8.6548
19	*Grewia ferruginea*	24±2.28	13.59±0.32	7.9922	36±7.16	31.47±0.96	11.5736	28±8.72	20.94±0.38	7.2316
20	*Jacaranda mimosifolia*	18±2.52	9.91±0.29	5.9570	16±1.15	6.93±0.23	4.2169	14±1.91	9.50±0.58	3.5275
21	*Juniperus procera*	66±5.62	59.54±0.69	24.9257	198±13.00	180.40±0.71	64.6160	102±10.36	120.90±0.50	30.3884
22	*Maytenus arbutifolia*	34±1.67	12.96±0.36	10.4858	42±3.58	10.26±0.23	10.0260	2±0.00	0.77±0.00	0.4511
23	*Melia azedarach*	48±6.41	15.34±0.18	14.4105	-	-	-	34±5.59	6.93±0.24	7.1040
24	*Millettia ferruginea*	-	-	-	42±8.70	11.29±0.18	10.1613	18±2.61	5.52±0.33	3.9292
25	*Mimusops kumme*	14±1.91	5.24±0.14	4.3051	-	-	-	-	-	-
26	*Myrica salicifolia*	16±1.63	8.19±0.30	5.2129	-	-	-	-	-	-
27	*Olea europaea*	-	-	-	68±5.10	91.59±0.97	26.0857	118±5.01	104.20±0.78	31.9222
28	*Phytolacca dodecandra*	14±1.91	3.74±0.10	4.1060	38±4.28	15.04±0.24	9.8277	62±8.04	22.49±0.26	13.8483
29	*Pinus patula*	-	-	-	-	-	-	8±1.15	36.02±2.26	4.7891
30	*Podocarpus falcatus*	20±2.45	7.15±0.21	6.1053	46±6.80	14.51±0.21	11.4109	28±8.49	12.86±0.18	6.4991
31	*Prunus africanum*	-	-	-	22±4.43	4.33±0.22	5.1143	40±4.13	9.50±0.28	8.4804
32	*Rhamnus prinoides*	-	-	-	14±1.91	4.61±0.18	3.4981	12±1.15	5.19±0.19	2.7563
33	*Rhamnus staddo*	-	-	-	48±3.35	13.24±0.17	11.6573	22±3.06	7.20±0.26	4.8435
34	*Rhus natalensis*	-	-	-	22±1.91	5.76±0.11	5.3017	-	-	-
35	*Schinus molle*	8±1.15	1.98±0.13	2.3253	-	-	-	14±1.91	2.83±0.08	2.9235

Note: Dha^{-1} = Density/hectare; BAm^2ha^{-1} = Basal Area/hectare; SD = Standard Deviation; IVI = Important Value Index; - = Absence of species

The highest BA_S in m^2 ha^{-1} was found in *Eucalyptus globulus* in SMC and DSC as 284.40 ± 2.67 and 385.80 ± 2.51 followed by *Eucalyptus grandis* (76.65 ± 1.34 and 166.00 ± 2.09) for both sites and it was the lowest in *Acacia mearnsii* and *Acacia albida* as 1.54 ± 0.00 and 0.66 ± 0.14 respectively. In QUC it was maximum in *Juniperus procera* (180.40 ± 0.71) followed by *Eucalyptus grandis* (104.00 ± 1.37) and minimum in *Acacia abyssinica* (4.03 ± 0.27).
The highest IVI was recorded in *Eucalyptus globulus* species from SMC and DSC (62.04 and 62.02), followed by *Eucalyptus grandis* and *Casuarina equistifolia* (30.81 and 38.70) and it was lowest in *Acacia mearnsii* and *Maytenus arbutifolia* as 0.72 and 0.45 respectively. In QUC, it was maximum in *Juniperus procera* (64.62) followed by *Olea europaea* (26.09) and minimum in *Acacia abyssinica* (1.77). An analysis of variance showed that species and its density, and basal area and IVI significantly differ among and within groups ($p < 0.001$). While those between species category (indigenous and exotics) and basal area, a significant difference was found ($p \leq 0.005$) and it was insignificant between species category and density ($p \geq 0.05$).

IVI was calculated separately for indigenous and exotic tree stands apart from the overall calculation. Among indigenous species, the maximum IVI was recorded in *Juniperus procera* as 57.60 and 85.17 from SMC and QUC and the minimum was in *Acacia mearnsii* (1.64) and *Acacia abyssinica* (2.30) respectively. In DSC, it was highest in *Olea europaea* (69.43) and lowest in *Acacia albida* (1.62). Among exotics the maximum IVI was found in *Eucalyptus globulus* from SMC and DSC (105.34 and 111.17) and the minimum was in *Schinus molle* and *Ficus elastica* (4.50 and 3.03 respectively). In QUC, it was higher in *Casuarina equistifolia* (94.22) and lower in *Jacaranda mimosifolia* (20.79). The one way ANOVA results showed that the species' category (indigenous and exotics) and IVI were significant ($p \leq 0.017$).

Variations in density, basal area, richness, diversity and evenness followed different patterns (Table 2). The highest overall stand density was recorded from DSC as 1050 ± 42.21and the lowest from SMC (776 ± 26.63). It was maximum in QUC (790 ± 41.64) and minimum in SMC (386 ± 16.66) for indigenous tree stands. In exotics' category, stand density peaks in DSC (498 ± 57.85) and falls in QUC (178 ± 22.51).

Among the categories, the overall basal area was maximum in DSC (1103.12 ± 76.34) and minimum in SMC (752 ± 59.51). In indigenous category, it was highest in QUC (514.81 ± 42.40) and lowest in SMC (254.43 ± 18.06) and in exotics, the highest basal area was recorded from DSC (712.54 ± 121.84) and the lowest in QUC (246.15 ± 42.56).

Table 2: Tree stand characteristics of the church forest ecosystems in Gondar, Ethiopia

Site	Category	Stand density (ha^{-1})	Basal Area (m^2ha^{-1})	Richness (S)	Diversity (H')	Evenness (H'E)
SMC	Overall	776 ± 26.63	752.21 ± 59.51	22	2.8277	0.9148
	Indigenous	386 ± 16.66	254.43 ± 18.06	14	2.4672	0.9349
	Exotics	390 ± 35.86	497.78 ± 92.77	8	1.8054	0.8682
QUC	Overall	968 ± 38.10	760.96 ± 42.50	24	2.8799	0.9062
	Indigenous	790 ± 41.64	514.81 ± 42.40	19	2.6150	0.8881
	Exotics	178 ± 22.51	246.15 ± 42.56	5	1.4603	0.9073
DSC	Overall	1050 ± 42.21	1103.12 ± 76.34	31	2.8713	0.8361
	Indigenous	552 ± 31.26	390.58 ± 33.50	21	2.5385	0.8338
	Exotics	498 ± 57.85	712.54 ± 121.84	10	1.7817	0.7738

Note: SMC = Saint Michael Church; QUC = Queskum Church; DSC = Debrebrhan Selassea Church.

The highest species richness (S) was recorded in DSC for all the three categories. The results of diversity calculation shows variations among the three churches, the maximum overall and indigenous species' diversity (H') was recorded from QUC as 2.8799 and 2.6150 respectively and it was maximum for exotics' category in SMC (1.8054). The species evenness (H'E) calculation showed highest evenness in overall and indigenous categories in SMC as 0.9148 and 0.9349 and for exotics category in QUC as 0.9073.

The SJ calculation showed maximum species similarity among overall and indigenous categories between QUC and DSC as 71.86 % and 80.95 % respectively and it was highest for exotics between SMC and DSC (80.00 %) as given in table 3.

Table 3: Jaccard's species similarity index values in percentage between three sites of church forest ecosystems of Gondar, Ethiopia

Category	SMC & QUC	SMC & DSC	QUC & DSC
Overall	43.75	55.88	71.86
Indigenous	36.36	45.46	80.95
Exotics	62.50	80.00	50.00

Note: SMC = Saint Michael Church; QUC = Queskum Church; DSC = Debrebrhan Selassea Church.

The result of this study revealed that density, IVI and diversity values of a tree stand in different church forests significantly differed. In general, the higher density of exotic species lowers overall diversity. For instance, in SMC and DSC exotics had higher density where diversities were low. However, indigenous tree stands had higher diversity than exotic species at all the sites. This coincides with[11, 18 & 19]. Maintaining species' diversity is an important means to obtain high growth rate in forest management. In contrast, the present findings show negative association in diversity with the net basal area. In SMC and DSC, the overall and exotics net basal area of stands are comparatively higher than QUC. Similarly, size of the stand was also larger in SMC and DSC than in QUC. The size and net basal area of tree stands negatively influences stand diversity. This pattern was reported by Liang[20]. The distribution of species richness along altitude gradients is governed by a series of interacting biological, climatic and historical factors[21]. Further, altitude represents a complex gradient along which many environmental variables change simultaneously[22]. It is impossible to say whether most of the relationships between species' richness and altitude are the result of an underlying monotonic trend with the environment. Several studies have found a decreasing trend in species' diversity and richness with altitude[23 & 24]. However, the species' diversity and richness increase up to 2500 m.a.s.l. and decreas above this altitude[25 & 26].

CONCLUSION

This study concludes that there are not any anthropogenic pressures except exotic species invasion. Most of the indigenous tree species inhabited church forests and their diversity values were also higher than the exotic species. These forests provide an excellent opportunity to conserve natural forests and to restore degraded areas into productive and diverse natural forests, in unique mountainous landscape of northern Ethiopia.

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