Floristic Diversity, Population Structure, Regeneration Status and Socio-Economic Importance of Fach Forest, South Gondar, Northwestern Ethiopia

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Research

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Abstract

Background: The remaining natural forests of Ethiopia are only small patches mostly confined to inaccessible areas and sacred places. Each forest is one of the remnant dry evergreen Afromontane forests (DAFs) in northwestern Ethiopia. There is lack of information on the vegetation ecology of the forest. Thus, the present study was conducted to investigate the floristic composition and diversity, population structure, regeneration status and socio-economic importance of Each forest, and the anthropogenic factors affecting it.

Methods: Vegetation data were collected from a total of 34 plots, measuring 20 m × 20 m (400 m²) each and established along line transects approximately at 100 m intervals. A general survey consisting of field observations, key-informant interviews and Focus Group Discussion (FGD) was used to collect socio-economic data.

Results: A total of 230 vascular plant species belonging to 183 genera and 76 families were recorded from the study area, of which 45 (19.57%) were trees, 62 (26.97%) trees/shrubs, 37 (16.09%) shrubs, 13 (5.65%) woody climbers, 10 (4.35%) herbaceous climbers, and 63 (27.39%) herbs. The family with the highest number of species was Fabaceae (28 species, 12.17% of all species), followed by Asteraceae (18 species, 7.83%), Poaceae (13 species, 5.65%), and Acanthaceae and Euphorbiaceae (9 species each). The Shannon-Wiener diversity and evenness values of woody species were 3.53 and 0.72, and the total density and basal area 4938.24 individuals ha⁻¹ and 19.17 m² ha⁻¹, respectively. The species with the highest Importance Value Index (IVI) value was *Combretum molle* (25.26%), followed by *Olea europaea* subsp. *cuspidata* (21.19%), *Dodonaea angustifolia* (17.80%), and *Calpurnia aurea* (15.05%). The local communities were highly dependent on the forest for fuelwood, construction material, charcoal, timber and farm implements, as well as food (edible fruits), medicines, fodder, and bee forage. Each forest is a protected area and contains sacred places, but at present it is dwindling mainly due to livestock grazing/browsing, tree cutting for various purposes, farmland expansion, rural settlements expansion, urbanization, fire incidences, and exotic species plantations at the expense of the natural forest, as well as soil erosion and climate change.

Conclusions: Each forest possesses high plant diversity and endemism. Woody species having low IVI values and poor regeneration status (as indicated by the Diameter at Breast Height [DBH] class distributions) need high priority for conservation. Each forest has been maintained to the present-day through the combined indigenous (sacred grove) and modern (protected area system) conservation methods, but is now under increasing human pressure. Therefore, effective conservation and management interventions are urgently needed to ensure the long-term maintenance of the forest ecosystem, and benefit the local communities through sustainable utilization of the forest.

Background

It is believed that about 35% of the total land area of Ethiopia was covered with natural forests in the beginning of the 20th century (EFAP 1994). However, the forest cover has been declining from time to time. The forest cover of the country was 16% in the early 1950s, 3.6% in the early 1980s and 2.7% in 1989 (EFAP 1994). The present forest cover of the country is about 4% (Earth Trends 2007). The remaining natural forests of Ethiopia are only small patches mostly confined to inaccessible areas (mountaintops, steep slopes, valleys) and sacred places (churches, monasteries, mosques). Furthermore, these remnant forests are dwindling at an alarming rate due to natural and mainly anthropogenic factors. The major drivers of deforestation and forest degradation are agricultural expansion (farmland expansion, overgrazing by livestock), overexploitation, rural (re)settlements, urbanization, fire incidences and invasive alien species, which are all driven by the rapid human population growth, lack of appropriate policies and strategies, and poverty (Bekele 1993; EFAP 1994; Teketay 2001; Shibru and Balcha 2004; Vivero et al. 2005; Zegeye 2017).

There are three state forests in Libo Kemkem District of the South Gondar Zone, namely Tara Gedam, Abebaye and Fach forests, which were established as protected areas during the Derg regime in 1979, 1980 and 1984, respectively. They are one of the remaining dry evergreen Afromontane forests (DAFs) in the country (Friis et al. 2011). Though it was not possible to get the size of the forests during their establishment, a later report indicated that Tara Gedam, Abebaye and Fach forests had a total land area of 974.50 ha, 133.31 ha and 823.19 ha, respectively (Summary Report on the Tara Gedam Forest Demarcation 2002, unpublished report). The three forests are currently administered by Libo Kemkem District Agricultural Development Office.

Though a few preliminary surveys have been done on Fach forest by other scholars in the past, there has been neither particular nor detailed study on the vegetation ecology and socio-economic aspects of the forest so far. The present study was conducted to generate baseline ecological and socio-economic information, which would be relevant for conservation, management and sustainable utilization of the forest. Therefore, the objectives of the study were to: (a) investigate the floristic composition and diversity, population structure, natural regeneration status and socio-economic importance of the forest; (b) prioritize woody species for conservation based on their Importance Value Index (IVI) values and regeneration status; (c) assess the forest management systems and the role of the churches and monasteries in conserving the forest; (d) identify the anthropogenic factors causing loss and degradation of the forest.

Materials And Methods

Study area

The study was conducted in Fach forest located very close to the small town of Ambo Meda and northeast of Lake Tana, northwestern Ethiopia (Fig. 1). The study area is found in Libo Kemkem District of the South Gondar Zone, within the Amhara National Regional State. Geographically, Libo Kemkem District lies from 11°58'1.5"–12°22'6.7" N and 37°33'25.4"–37°58'16.5" E. The district is bordered by West

Belessa District to the north, Ebenat District to the east, Fogera District to the south (Rib River separates the two districts), Lake Tana to the west, and Gondar Zuria District to the northwest. Libo Kemkem District has a total land area of 1082 km² (CSA 2007a), of which about 42% is rugged terrain, 30% mountainous area, 22% flat land, and 6% undulating terrain (Libo Kemkem District Environmental Protection and Land Administration and Use Office 2012, unpublished report). The altitude of the district ranges from 1800–2850 metres above sea level (m a.s.l.) The capital of the district is Addis Zemen town, which is located about 645 km northwest of the national capital Addis Ababa and 82 km northeast of the regional capital Bahir Dar on the Addis Ababa–Gondar highway. The town is located from 12°06'59"–12°07'25" N and 37°46'14"–37°47'02" E, and has an altitude of 1964 m a.s.l. Ambo Meda town is located about 18 km east of Addis Zemen. Fach forest is located very close to Ambo Meda town. The forest is bordered by Shammo Kebele (*kebele* is the smallest administrative unit in Ethiopia) to the north and northeast, Ambo Meda town to the east, Estifanos Kebele to the southeast and south, and Shehoch Tehara Kebele to the west and northwest. Fach terrain consists of chains of rugged mountains, undulating hills, steep and gentle slopes, valleys, and flat lands. The altitude of Fach forest ranges from 2025 m a.s.l. at the relatively flat lands in the eastern periphery near Ambo Meda to 2390 m a.s.l. at Mt. Silua (the highest peak) in the western part of the forest.

Many areas in Fach forest and around Ambo Meda town are covered by volcanic rocks, mainly basalt. There are extensive rocks and pronounced rock outcrops. Most of the areas have poorly developed soils, quite variable in depth, texture and colour. The soils are mostly shallow and sandy, and are characterized by low organic matter. Soil erosion is severe in the area due to deforestation and overgrazing coupled with slopy terrain.

Libokemkem District is characterized by moderate climate, locally known as *woina dega* (1500–2300 m a.s.l.). The area has a unimodal rainfall distribution in which the main rainy season is from June–August (locally known as *kiremt*). A small amount of rainfall occurs before the main rainy season from March–May (*belg*) and after the main rainy season from September–November (*meher*). The dry season is from December–February (*bega*). Climatic data obtained from the National Meteorological Services Agency for the study area showed that the mean annual temperature ranges from 18–25 °C, the mean annual maximum and minimum temperatures are 27.9°C and 11.1°C, respectively, and the mean annual rainfall ranges from 900–1200 mm.

Fach forest is one of the remaining DAFs in northwestern Ethiopia. In fact, it is one of the main natural forests in Libo Kemkem District. In its physiognomy, Fach forest is generally characterized by low stature, with some taller forest (in the river banks and relatively flat lands). The forest contains a number of indigenous trees and shrubs interspersed with climbers and herbs (Fig. 2). Within the area of Fach forest are also found mixed/enrichment plantations (scattered plantation stands of exotic and indigenous species among the stands of natural vegetation). The study area is generally poor in wildlife due to pronounced deforestation and other human interferences. The wild animals currently inhabiting the forest include different mammals (apes, monkeys, bushbuck, klipspringer, bush duiker, wild pig, common fox, leopard, spotted hyena, serval, Genet Cat, black leopard, caracal, aardvark, *mitmit*, honey badger, rock

hyrax, rabbit, porcupine, a variety of rodents), a variety of birds (e.g., francolin, guinea fowl), and certain reptiles (e.g., Nile Monitor, snakes, python).

Fach forest forms part of the Lake Tana Sub-Basin, which is the northeastern part of the Blue Nile Basin (Mequanent et al. 2021). It also forms part of the Eastern Afromontane Biodiversity Hotspot (Mittermeier et al. 2004). With a surface area of 3156 km² stretching approximately 84 km north-south and 66 km east-west, Lake Tana is the largest lake in Ethiopia and one of the largest in Africa (zur Heide 2012), containing almost 50% of the country's freshwater resources (de Graaf et al. 2004). Lake Tana is the source of the Blue Nile (locally known as Abay River), the only natural outflowing river (at the southern tip of the lake) and which flows to the Sudan (where it fuses with the White Nile [originating from Lake Victoria] at Khartoum, the country's capital city) and Egypt, flowing for approximately 4750 km and eventually ending up in the Mediterranean Sea. The remnant natural forests including Fach and the wetlands in the Lake Tana Region have a high local and global significance as natural and economic resource, and thus high priority should be given to their conservation and sustainable management (zur Heide 2012).

According to the 2007 Population and Housing Census of Ethiopia, Libo Kemkem District had a total population of 198435, of whom 100987 were males and 97448 females (CSA 2007b). The inhabitants of the study area belong to the Amhara ethnic group, who speak the Amharic language. The majority of the people are Orthodox Christians and few are Muslims. The economy of the local people is predominantly based on subsistence agriculture. The local people are engaged in crop cultivation and livestock rearing – thus a mixed farming system. The major crops grown in the area are tef (*Eragrostis tef*), finger millet (*Eleusine coracana*), maize (*Zea mays*), sorghum (*Sorghum bicolor*), barley (*Hordeum vulgare*), field pea (*Pisum sativum*), faba bean (*Vicia faba*) and nigerseed (*Guizotia abyssinica*). The main livestock reared in the area are cattle, goats, sheep, donkeys, horses, mules and poultry. The people are involved in the collection of forest products (particularly fuelwood, construction material, charcoal and timber, as well as non-wood forest products) for domestic consumption and/or income generation through selling in local markets. The local people have limited access to modern health services, and thus partly depend on traditional medicine to fulfill their healthcare needs. They use medicinal plants, most of which are harvested from the wild including Fach forest, to treat various human and livestock diseases.

There are three churches and monasteries within Fach forest, namely Shammo Medhane-Alem Monastic Church (established in 1270) at the northeastern periphery, Ambo Meda Michael Church at the eastern periphery (close to the town of Ambo Meda), and Estifanos Church at the southern periphery. These churches and monasteries own a certain part of the forest and manage it, still under the umbrella of the protected area system.

Vegetation sampling and data collection

Systematic sampling, in which plots are laid at regular intervals along line transects, was used to collect vegetation data following Mueller-Dombois and Ellenberg (1974) and Sutherland (1996). Three line

transects directed northeast-west were established across the forest. Plots, measuring 20 m × 20 m (400 m²) each, were established along the line transects approximately at 100 m intervals. A total of 34 plots were sampled from the forest. Herbaceous species were sampled using a 1 m × 1 m (1 m²) subplot laid within each main plot where the herbaceous vegetation is assumed to be representative, i.e., nested plot design was used. In each plot, all vascular plant species were listed by their local and/or scientific names, and their identities were recorded. Trees, shrubs and woody climbers were counted. Diameter at Breast Height (DBH) (i.e., 1.3 m above the ground) of trees and shrubs with DBH ≥ 2 cm was measured with a calliper following the methods described by Martin (1995). Individuals of trees and shrubs with DBH < 2 cm were counted by species as seedlings, and included in the regeneration assessment. Altitude and geographic position (latitude, longitude) were measured with a Garmin GPS 72H. Human disturbances were also recorded. Plant species that occur outside the sample plots were also recorded to produce a more complete list of the plant species in the area; but only as present (i.e., they were not included in the subsequent data analysis). Data collection was carried out between November 2016 and March 2017.

Plant specimens were collected, pressed, dried and brought to the Department of Biology, Debre Tabor University. Identification of most plant species was made in the field by recognition and with the help of field assistants (forest guards) as well as local people familiar with the flora, and using available taxonomic literature and databases. Unidentified plant specimens were taken to the National Herbarium (ETH), Addis Ababa University for identification. Plant nomenclature in this paper follows the Flora of Ethiopia and Eritrea (Hedberg and Edwards 1989, 1995; Edwards et al. 1995, 1997, 2000; Hedberg et al. 2003, 2004, 2006, 2009a, 2009b).

Socio-economic survey

A general survey consisting of field observations, key-informant interviews and Focus Group Discussion (FGD) was carried out following Martin (1995). Field observations were made on the biophysical features of the study area, land use types, extent of deforestation and soil erosion, indigenous resource management systems such as traditional agroforestry and soil conservation, and human impacts on the forest. Ten key informants, which have been suggested by the forest guards and representatives of the local communities, were selected and interviewed using the open-ended questionnaire prepared in advance for this purpose. For undertaking the FGD, a group consisting of the representatives of communities around the forests, elderly, youth, clergymen, representatives of governmental institutions (Libo Kemkem District Administrative Office, Libo Kemkem District Agricultural Development Office), forest guards, and coordinator of the Ambo Meda Seedling Nursery was established. At the beginning of the discussion, the aim of the survey was explained to the participants by the investigator so as to ensure openness in the discussion. The actual FGD was carried out using relevant discussion points or questions, mainly the socio-economic importance of the forest, the forest management systems, challenges/problems/constraints in the conservation and management of the forest, and the human activities affecting the forest. The ideas and suggestions forwarded by the group participants were recorded.

Data analysis

The diversity and evenness of woody species were determined using the Shannon-Wiener Diversity Index (H') and Evenness or Equitability Index (E) (Krebs 1989). The density, percentage frequency and dominance / basal area of woody species were calculated. The Importance Value Index (IVI) for each woody species was computed following Cain and Castro (1959) and Lamprecht (1989), as follows:

Relative density = (Density of a species / Total density) $\times$ 100;

Relative frequency = (Frequency of a species / Total frequency) $\times$ 100;

Relative basal area = (Basal area of a species / Total basal area) $\times$ 100;

IVI = Relative density + Relative frequency + Relative basal area.

The DBH data of selected trees and shrubs were categorized into nine classes (1 = < 2 cm; 2 = 2–10 cm; 3 = 10–20 cm; 4 = 20–30 cm; 5 = 30–40 cm; 6 = 40–50 cm; 7 = 50–60 cm; 8 = 60–70 cm; 9 = > 70 cm), and the density of each species in each DBH class was calculated; the DBH class distributions were presented using histograms, i.e., density of individuals (Y-axis) plotted against diameter class (X-axis) (Peters 1996). Based on the profile depicted in the population structures, the regeneration status of the selected woody species was determined.

Results And Discussion

Species richness and composition

A total of 230 vascular plant species belonging to 183 genera and 76 families were identified from the study area. From the total plant families, ferns were represented by 1 family (1.32%), gymnosperms by 1 family (1.32%), and angiosperms by 74 families (97.37%) (dicots by 66 families, 86.84%; monocots by 8 families, 10.53%). The family with the highest number of species was Fabaceae (28 species, 12.17% of all species), followed by Asteraceae (18 species, 7.83%), Poaceae (13 species, 5.65%), Acanthaceae and Euphorbiaceae (9 species each), Celastraceae and Lamiaceae (8 species each), Rutaceae (7 species), Anacardiaceae, Malvaceae, Moraceae and Rubiaceae (6 species each), and Asclepediaceae (5 species). Two families were represented by 4 species each, 6 families by 3 species each, 20 families by 2 species each, and the rest 35 families by only 1 species each. From the total species, 45 (19.57%) were trees, 62 (26.97%) trees/shrubs, 37 (16.09%) shrubs, 13 (5.65%) woody climbers, 10 (4.35%) herbaceous climbers, and 63 (27.39%) herbs. Seventeen species (7.42%) were endemic to the country. Twenty eight trees, shrubs and treelike herbs (12.17%) were cultivated plants (most are exotic and some indigenous).

Taxa (family, genera, species) and endemic richness of Fach forest were higher than or comparable to that of some other DAFs of Ethiopia, for example, Tara Gedam and Abebaye forests (57 families, 114 genera, 143 woody species, 6 endemics) (Zegeye et al. 2011), Ambo (58 woody species) (Melaku 2012),

Zegie (52 families, 113 woody species) (Alealign et al. 2007), Zengena (31 families, 50 woody species) (Tadele et al. 2014), Kuandisha (40 families, 66 woody species) (Berhanu et al. 2017), Kahtassa (47 woody and 34 herbaceous species) (Gebeyehu et al. 2019), Yegof (43 families, 66 genera, 76 woody and herbaceous species) (Woldearegay et al. 2018), Denkoro (66 families, 174 woody and herbaceous species, 12 endemics) (Ayalew et al. 2006), Wof Washa (40 families, 54 genera, 62 woody species) (Fisaha et al. 2013), Menagesha Amba Mariam (76 families, 182 genera, 219 woody and herbaceous species, 16 endemics) (Tilahun et al. 2011), Munessa (41 families, 61 tree species) (Muhammed and Elias 2020), Kimphee (74 families, 136 woody and herbaceous species) (Senbeta and Teketay 2003), Dodola (55 families, 95 genera, 113 woody and herbaceous species, 15 endemics) (Hundera et al. 2007), and Dindin (43 families, 72 genera, 81 woody species) (Shibru and Balcha 2004). Variation in species composition among different forests is attributed to topographic, edaphic and climatic differences, as well as degree of human disturbance.

Diversity and evenness of woody species

The diversity (H') and evenness (E) values of woody species were 3.53 and 0.72, respectively. The high diversity is attributed to habitat diversity and low human disturbances (as slopy terrain limits human exploitation and livestock grazing/browsing). The high evenness showed that there is more or less balanced distribution of individuals among the different species. The diversity value implies the need to conserve the forest from floristic diversity perspective.

The diversity and evenness of woody species in Fach forest were higher than or comparable to that of most other DAFs, for example, Tara Gedam (2.98 and 0.65, respectively) and Abebaye (1.31 and 0.31, respectively) (Zegeye et al. 2011), Ambo (2.73 and 0.67, respectively) (Melaku 2012), Zegie (3.72 and 0.84, respectively) (Alealign et al. 2007), Zengena (2.74 and 0.70, respectively) (Tadele et al. 2014), Kahtassa (2.06 and 0.53, respectively) (Gebeyehu et al. 2019), Yegof (2.26 and 0.57, respectively) (Woldearegay et al. 2018), Wof Washa (3.25 and 0.8, respectively) (Fisaha et al. 2013), Munessa (2.6 and 0.39, respectively) (Muhammed and Elias 2020) and Kimphee (2.92 and 0.66, respectively) (Senbeta and Teketay 2003).

Density and frequency of woody species

The total density (inclusive of seedlings) of woody species was 4938.24 individuals ha^{-1} (Table 1). The species with the highest density was *Dodonaea angustifolia* (605.15 individuals ha^{-1}), followed by *Maytenus serrata* (482.35), *Calpurnia aurea* (481.62), *Euclea racemosa* subsp. *schimperi* (258.82), *Acokanthera schimperi* (232.35), *Carissa spinarum* (180.15), and *Vernonia myriantha* (177.94). These seven most abundant species contributed about 49% of the total density. The high density of the species is attributed to suitable environmental conditions for regeneration, high reproductive capacity of the species, and the relatively better protection of the forest from human exploitation and livestock grazing/browsing as it is a protected area and the presence of sacred places within the forest area. Ten species had the lowest density (0.74 individuals. ha^{-1} each), and thus were poorly represented in the forest.

Table 1

Density (D, number of individuals ha⁻¹), relative density (RD, %), frequency (F, %), relative frequency (RF, %), basal area (BA, m² ha⁻¹), relative basal area (RBA, %) and IVI (%) of woody species (arranged alphabetically by scientific name)

No.	Scientific name	D	RD	F	RF	BA*	RBA	IVI**
1	<i>Abutilon longicuspe</i>	1.47	0.03	2.94	0.13	0.00	0.01	0.16
2	<i>Acacia abyssinica</i>	5.88	0.12	5.88	0.25	0.63	3.31	3.68
3	<i>Acacia lahai</i>	16.18	0.33	5.88	0.25	0.16	0.82	1.39
4	<i>Acacia pentagona</i>	3.68	0.07	2.94	0.13	-	-	-
5	<i>Acacia pilispina</i>	90.44	1.83	70.59	3.02	0.61	3.17	8.02
6	<i>Acacia polyacantha</i>	1.47	0.03	2.94	0.13	0.01	0.07	0.23
7	<i>Acacia senegal</i>	9.56	0.19	17.65	0.75	0.19	0.99	1.94
8	<i>Acacia seyal</i>	3.68	0.07	5.88	0.25	0.01	0.03	0.36
9	<i>Acanthus eminens</i>	4.41	0.09	5.88	0.25	-	-	-
10	<i>Acanthus polystachius</i>	164.71	3.34	44.12	1.89	-	-	-
11	<i>Acanthus sennii</i>	58.09	1.18	26.47	1.13	-	-	-
12	<i>Acokanthera schimperi</i>	232.35	4.71	70.59	3.02	0.21	1.08	8.81
13	<i>Albizia gummifera</i>	46.32	0.94	17.65	0.75	0.85	4.45	6.14
14	<i>Albizia schimperiana</i>	1.47	0.03	2.94	0.13	0.01	0.04	0.20
15	<i>Allophylus abyssinicus</i>	2.21	0.04	2.94	0.13	0.03	0.14	0.32
16	<i>Apodytes dimidiata</i>	2.21	0.04	2.94	0.13	0.01	0.08	0.25
17	<i>Asparagus africanus</i>	12.50	0.25	29.41	1.26	-	-	-
18	<i>Barleria ventricosa</i>	2.21	0.04	2.94	0.13	-	-	-
19	<i>Bersama abyssinica</i>	44.12	0.89	17.65	0.75	0.08	0.43	2.08
20	<i>Bothriocline schimperi</i>	1.47	0.03	2.94	0.13	-	-	-

* Values are absent (-) since DBH measurement was not taken for the plants; all values indicated as 0 represent values very close to, but above zero

** Had it not been missings in BA (thus RBA), the total IVI would have been 300% than 251.15%

No.	Scientific name	D	RD	F	RF	BA*	RBA	IVI**
21	<i>Bridelia micrantha</i>	1.47	0.03	2.94	0.13	0.02	0.08	0.24
22	<i>Brucea antidysenterica</i>	2.94	0.06	2.94	0.13	-	-	-
23	<i>Buddleja polystachya</i>	7.35	0.15	11.76	0.50	0.05	0.27	0.92
24	<i>Calotropis procera</i>	2.94	0.06	2.94	0.13	-	-	-
25	<i>Calpurnia aurea</i>	481.62	9.75	88.24	3.77	0.29	1.52	15.05
26	<i>Canthium sp.</i>	1.47	0.03	2.94	0.13	-	-	-
27	<i>Capparis tomentosa</i>	39.71	0.80	47.06	2.01	-	-	-
28	<i>Carissa spinarum</i>	180.15	3.65	79.41	3.40	0.19	0.99	8.03
29	<i>Celtis africana</i>	19.12	0.39	29.41	1.26	0.25	1.29	2.93
30	<i>Clausena anisata</i>	5.88	0.12	5.88	0.25	0.01	0.04	0.41
31	<i>Clematis longicauda</i>	52.94	1.07	50.00	2.14	-	-	-
32	<i>Clerodendrum myricoides</i>	11.03	0.22	20.59	0.88	0.01	0.04	1.14
33	<i>Clutia lanceolata</i>	156.62	3.17	52.94	2.26	-	-	-
34	<i>Combretum molle</i>	152.94	3.10	76.47	3.27	3.62	18.89	25.26
35	<i>Cordia africana</i>	1.47	0.03	5.88	0.25	0.14	0.72	1.00
36	<i>Croton macrostachyus</i>	66.18	1.34	58.82	2.52	0.46	2.42	6.28
37	<i>Cussonia ostinii</i>	2.94	0.06	5.88	0.25	0.05	0.24	0.55
38	<i>Cussonia sp.</i>	7.35	0.15	2.94	0.13	0.05	0.24	0.51
39	<i>Dichrostachys cinerea</i>	62.50	1.27	32.35	1.38	0.13	0.67	3.32
40	<i>Dodonaea angustifolia</i>	605.15	12.25	82.35	3.52	0.39	2.03	17.80
41	<i>Dombeya torrida</i>	25.00	0.51	20.59	0.88	0.09	0.49	1.87
42	<i>Dovyalis abyssinica</i>	3.68	0.07	5.88	0.25	0.02	0.10	0.43

* Values are absent (-) since DBH measurement was not taken for the plants; all values indicated as 0 represent values very close to, but above zero

** Had it not been missings in BA (thus RBA), the total IVI would have been 300% than 251.15%

No.	Scientific name	D	RD	F	RF	BA*	RBA	IVI**
43	<i>Ekebergia capensis</i>	5.15	0.10	11.76	0.50	0.14	0.71	1.32
44	<i>Embelia schimperi</i>	2.21	0.04	2.94	0.13	-	-	-
45	<i>Entada abyssinica</i>	3.68	0.07	5.88	0.25	0.04	0.23	0.55
46	<i>Erythrina abyssinica</i>	2.94	0.06	5.88	0.25	0.01	0.03	0.35
47	<i>Euclea racemosa</i> subsp. <i>schimperi</i>	258.82	5.24	70.59	3.02	0.20	1.02	9.28
48	<i>Euphorbia abyssinica</i>	2.94	0.06	2.94	0.13	0.09	0.47	0.66
49	<i>Euphorbia tirucalli</i>	3.68	0.07	2.94	0.13	0.02	0.13	0.33
50	<i>Ficus lutea</i>	1.47	0.03	2.94	0.13	0.06	0.31	0.46
51	<i>Ficus palmata</i>	2.21	0.04	2.94	0.13	-	-	-
52	<i>Ficus sur</i>	1.47	0.03	2.94	0.13	0.54	2.84	2.99
53	<i>Ficus sycomorus</i>	0.74	0.01	2.94	0.13	0.00	0.00	0.15
54	<i>Ficus thonningii</i>	1.47	0.03	2.94	0.13	0.01	0.05	0.20
55	<i>Ficus vasta</i>	2.21	0.04	2.94	0.13	2.11	10.99	11.16
56	<i>Flueggea virosa</i>	1.47	0.03	2.94	0.13	0.00	0.01	0.17
57	<i>Gardenia ternifolia</i>	0.74	0.01	2.94	0.13	0.00	0.01	0.16
58	<i>Gnidia glauca</i>	8.82	0.18	5.88	0.25	0.01	0.08	0.51
59	<i>Grewia ferruginea</i>	100.74	2.04	67.65	2.89	0.21	1.07	6.01
60	<i>Gymnema sylvestre</i>	0.74	0.01	2.94	0.13	-	-	-
61	<i>Helinus mystacinus</i>	39.71	0.80	35.29	1.51	-	-	-
62	<i>Hibiscus macranthus</i>	52.21	1.06	32.35	1.38	-	-	-
63	<i>Hibiscus micranthus</i>	0.74	0.01	2.94	0.13	-	-	-
64	<i>Hippocratea africana</i>	1.47	0.03	2.94	0.13	-	-	-
65	<i>Hypericum quartinianum</i>	5.15	0.10	8.82	0.38	-	-	-

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** Had it not been missings in BA (thus RBA), the total IVI would have been 300% than 251.15%

No.	Scientific name	D	RD	F	RF	BA*	RBA	IVI**
66	<i>Indigofera tinctoria</i>	11.76	0.24	8.82	0.38	-	-	-
67	<i>Jasminum abyssinicum</i>	1.47	0.03	2.94	0.13	-	-	-
68	<i>Jasminum grandiflorum</i> subsp. <i>floribundum</i>	65.44	1.33	64.71	2.77	-	-	-
69	<i>Juniperus procera</i>	1.47	0.03	2.94	0.13	0.19	0.99	1.14
70	<i>Justicia schimperiana</i>	11.03	0.22	2.94	0.13	-	-	-
71	<i>Lannea schimperi</i>	12.50	0.25	20.59	0.88	0.15	0.76	1.90
72	<i>Lippia adoënsis</i>	75.74	1.53	38.24	1.64	0.00	0.01	3.18
73	<i>Maesa lanceolata</i>	2.21	0.04	2.94	0.13	0.00	0.01	0.18
74	<i>Maytenus arbutifolia</i>	27.94	0.57	20.59	0.88	0.02	0.12	1.57
75	<i>Maytenus cortii</i>	0.74	0.01	2.94	0.13	0.03	0.15	0.29
76	<i>Maytenus obscura</i>	2.94	0.06	2.94	0.13	0.03	0.14	0.32
77	<i>Maytenus senegalensis</i>	2.21	0.04	2.94	0.13	0.02	0.09	0.26
78	<i>Maytenus serrata</i>	482.35	9.77	76.47	3.27	0.01	0.05	13.09
79	<i>Maytenus undata</i>	0.74	0.01	2.94	0.13	0.00	0.01	0.16
80	<i>Millettia ferruginea</i>	1.47	0.03	2.94	0.13	0.04	0.19	0.34
81	<i>Mimusops kummel</i>	0.74	0.01	2.94	0.13	0.37	1.93	2.07
82	<i>Myrica salicifolia</i>	2.21	0.04	5.88	0.25	0.01	0.06	0.36
83	<i>Myrsine africana</i>	22.79	0.46	5.88	0.25	0.00	0.01	0.73
84	<i>Nuxia congesta</i>	22.79	0.46	23.53	1.01	0.41	2.14	3.61
85	<i>Ocimum lamiifolium</i>	19.12	0.39	14.71	0.63	-	-	-
86	<i>Olea europaea</i> subsp. <i>cuspidata</i>	92.65	1.88	70.59	3.02	3.12	16.29	21.19
87	<i>Opuntia ficus-indica</i>	1.47	0.03	2.94	0.13	-	-	-

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No.	Scientific name	D	RD	F	RF	BA*	RBA	IVI**
88	<i>Osyris quadripartita</i>	20.59	0.42	20.59	0.88	0.04	0.20	1.50
89	<i>Otostegia integrifolia</i>	23.53	0.48	8.82	0.38	-	-	-
90	<i>Otostegia tomentosa</i>	1.47	0.03	2.94	0.13	-	-	-
91	<i>Pavetta abyssinica</i>	1.47	0.03	2.94	0.13	0.01	0.05	0.20
92	<i>Pavetta oliveriana</i>	1.47	0.03	2.94	0.13	-	-	-
93	<i>Pavonia urens</i>	1.47	0.03	2.94	0.13	-	-	-
94	<i>Periploca linearifolia</i>	2.21	0.04	2.94	0.13	-	-	-
95	<i>Phragmanthera regularis</i>	4.41	0.09	2.94	0.13	-	-	-
96	<i>Phytolacca dodecandra</i>	2.21	0.04	2.94	0.13	-	-	-
97	<i>Piliostigma thonningii</i>	0.74	0.01	2.94	0.13	0.07	0.38	0.52
98	<i>Premna schimperi</i>	101.47	2.05	67.65	2.89	0.19	0.99	5.94
99	<i>Protea gagedi</i>	2.21	0.04	2.94	0.13	0.01	0.07	0.24
100	<i>Prunus africana</i>	2.21	0.04	2.94	0.13	0.07	0.38	0.55
101	<i>Pterolobium stellatum</i>	169.85	3.44	82.35	3.52	-	-	-
102	<i>Rhoicissus tridentata</i>	36.76	0.74	41.18	1.76	-	-	-
103	<i>Rhus glutinosa</i>	80.88	1.64	61.76	2.64	0.33	1.71	5.99
104	<i>Rhus retinorrhea</i>	0.74	0.01	2.94	0.13	0.00	0.00	0.14
105	<i>Rhus vulgaris</i>	149.26	3.02	79.41	3.40	0.79	4.10	10.52
106	<i>Ritchiea albersii</i>	4.41	0.09	5.88	0.25	0.02	0.10	0.44
107	<i>Rosa abyssinica</i>	14.71	0.30	23.53	1.01	0.01	0.07	1.37
108	<i>Rubus steudneri</i>	2.21	0.04	2.94	0.13	-	-	-
109	<i>Rumex nervosus</i>	3.68	0.07	2.94	0.13	-	-	-

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No.	Scientific name	D	RD	F	RF	BA*	RBA	IVI**
110	<i>Ruttya speciosa</i>	2.21	0.04	2.94	0.13	-	-	-
111	<i>Sapium ellipticum</i>	1.47	0.03	2.94	0.13	0.02	0.10	0.26
112	<i>Satureja punctata</i>	2.94	0.06	2.94	0.13	-	-	-
113	<i>Schefflera abyssinica</i>	1.47	0.03	2.94	0.13	0.06	0.31	0.46
114	<i>Schrebera alata</i>	38.97	0.79	41.18	1.76	0.52	2.72	5.27
115	<i>Scolopia theifolia</i>	4.41	0.09	5.88	0.25	0.01	0.04	0.39
116	<i>Senna didymobotrya</i>	2.94	0.06	2.94	0.13	-	-	-
117	<i>Senna singueana</i>	21.32	0.43	26.47	1.13	0.02	0.08	1.64
118	<i>Sida schimperiana</i>	1.47	0.03	2.94	0.13	-	-	-
119	<i>Solanum incanum</i>	39.71	0.80	8.82	0.38	-	-	-
120	<i>Steganotaenia araliacea</i>	4.41	0.09	8.82	0.38	0.02	0.11	0.58
121	<i>Stereospermum kunthianum</i>	12.50	0.25	26.47	1.13	0.33	1.71	3.10
122	<i>Syzygium guineense</i>	3.68	0.07	2.94	0.13	0.14	0.74	0.95
123	<i>Tapinanthus globiferus</i>	1.47	0.03	2.94	0.13	-	-	-
124	<i>Teclea nobilis</i>	13.24	0.27	11.76	0.50	0.03	0.18	0.95
125	<i>Tephrosia elata</i>	1.47	0.03	2.94	0.13	-	-	-
126	<i>Terminalia schimperiana</i>	2.94	0.06	5.88	0.25	0.02	0.11	0.42
127	<i>Triumfetta tomentosa</i>	2.94	0.06	2.94	0.13	-	-	-
128	<i>Urera hypselodendron</i>	2.21	0.04	2.94	0.13	-	-	-
129	<i>Vernonia adoensis</i>	1.47	0.03	2.94	0.13	-	-	-
130	<i>Vernonia amygdalina</i>	0.74	0.01	2.94	0.13	0.02	0.10	0.24

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No.	Scientific name	D	RD	F	RF	BA*	RBA	IVI**
131	<i>Vernonia myriantha</i>	177.94	3.60	26.47	1.13	0.03	0.13	4.87
132	<i>Vernonia rueppellii</i>	1.47	0.03	2.94	0.13	-	-	-
133	<i>Woodfordia uniflora</i>	7.35	0.15	2.94	0.13	0.00	0.02	0.30
134	<i>Ximenia americana</i>	2.21	0.04	5.88	0.25	0.01	0.03	0.33
Total		4938.24	100.00	2338.24	100.00	19.17	100.00	251.15
* Values are absent (-) since DBH measurement was not taken for the plants; all values indicated as 0 represent values very close to, but above zero								
** Had it not been missings in BA (thus RBA), the total IVI would have been 300% than 251.15%								

The total density of woody species in Fach forest was higher than that of most other DAFs, for example, Tara Gedam (3001 individuals ha⁻¹) and Abebaye (2850 individuals ha⁻¹) (Zegeye et al. 2011), Zegie (3318 individuals ha⁻¹) (Alelign et al. 2007), Zengena (2202 individuals ha⁻¹) (Tadele et al. 2014), Yegof (1768 individuals ha⁻¹) (Woldearegay et al. 2018), Hugumburda (1218 individuals ha⁻¹) (Aynekulu 2011), Wof Washa (699 individuals ha⁻¹) (Fisaha et al. 2013), Gedo (782 individuals ha⁻¹) (Kebede et al. 2014), Munessa (481 individuals ha⁻¹) (Muhammed and Elias 2020), Kimphee (3059 individuals ha⁻¹) (Senbeta and Teketay 2003), Adelle (898 individuals ha⁻¹) and Boditi (498 individuals ha⁻¹) (Yineger et al. 2008), Dodola (761 individuals ha⁻¹) (Hundera et al. 2007) and Dindin (1750 individuals ha⁻¹) (Shibru and Balcha 2004), but lower than Debre Libanos (18508 individuals·ha⁻¹) (Hordofa 2013).

The species with the highest frequency was *Calpurnia aurea* (88.24%), followed by *Dodonaea angustifolia* and *Pterolobium stellatum* (82.35% each), *Carissa spinarum* and *Rhus vulgaris* (79.41% each), and *Combretum molle* and *Maytenus serrata* (76.47% each) (Table 1). The high frequency indicates regular horizontal distribution of the species in the forest. On the other hand, 66 species had the lowest frequency (2.94% each), and thus were infrequent in the forest.

Density and frequency of the woody species varied considerably among the species. The variation in density and frequency between species is attributed to habitat differences, habitat preferences among the species, species characteristics for adaptation, conditions for regeneration, and degree of human disturbance (Tesfaye and Teketay 2005; Zegeye et al. 2006, 2011).

Dominance / basal area of woody species

The total basal area of woody species was 19.17 m² ha⁻¹ (Table 1). The species with the highest basal area was *Combretum molle* (3.62 m² ha⁻¹), followed by *Olea europaea* subsp. *cuspidata* (3.12), *Ficus vasta* (2.11), *Albizia gummifera* (0.85), *Rhus vulgaris* (0.79), *Acacia abyssinica* (0.63), and *Acacia pilispina* (0.61). These seven most dominant woody species accounted for about 61% of the total basal area. *Ficus vasta* and *Acacia abyssinica* had high basal areas because of their larger diameters, though they had low densities. The basal areas of all other woody species were negligible. *Dodonaea*

angustifolia, *Maytenus serrata*, *Calpurnia aurea*, *Euclea racemosa* subsp. *schimperi*, *Acokanthera schimperi*, *Carissa spinarum* and *Vernonia myriantha* had high densities but their basal areas were less than that of the aforementioned species due to their smaller diameters. It indicated that the total basal area of woody species was low since most species having high densities were shrubs and small-sized trees, and big-sized trees were absent or represented by very few numbers of individuals (this is due to slopy terrain, rocky land and shallow soil, as well as human exploitation). The presence of high numbers of small-sized trees and inadequate numbers of big-sized trees indicates that Fach forest is at the stage of secondary development. Similar results were reported by Kebede et al. (2014), Teketay et al. (2016) and Woldearegay et al. (2018).

The relative ecological importance and/or dominance of tree species in a forest ecosystem can better be depicted from measurements of basal area than stem counts (Cain and Castro 1959). Woody species with the largest contribution in basal area can be considered as the most important species in a forest. Accordingly, *Combretum molle*, *Olea europaea* subsp. *cuspidata* and *Ficus vasta* were the most dominant tree species in Fach forest.

The total basal area of woody species in Fach forest was lower than that of most other DAFs, for example, Tara Gedam ($115.36 \text{ m}^2 \text{ ha}^{-1}$) and Abebaye ($49.45 \text{ m}^2 \text{ ha}^{-1}$) (Zegeye et al. 2011); Zengena ($23.3 \text{ m}^2 \text{ ha}^{-1}$) (Tadele et al. 2014); Denkoro ($45 \text{ m}^2 \text{ ha}^{-1}$) (Ayalew et al. 2006); Wof Washa ($101.8 \text{ m}^2 \text{ ha}^{-1}$), Menagesha ($36.1 \text{ m}^2 \text{ ha}^{-1}$) and Chilimo ($30.1 \text{ m}^2 \text{ ha}^{-1}$) (Bekele 1993); Wof Washa ($64.32 \text{ m}^2 \text{ ha}^{-1}$) (Fisaha et al. 2013); Gedo ($35.45 \text{ m}^2 \text{ ha}^{-1}$) (Kebede et al. 2014); Munessa ($91.75 \text{ m}^2 \text{ ha}^{-1}$) (Muhammed and Elias 2020); Adelle ($26.39 \text{ m}^2 \text{ ha}^{-1}$) and Boditi ($23.34 \text{ m}^2 \text{ ha}^{-1}$) (Yineger et al. 2008); Dodola ($129 \text{ m}^2 \text{ ha}^{-1}$) (Hundera et al. 2007); and Dindin ($49 \text{ m}^2 \text{ ha}^{-1}$) (Shibru and Balcha 2004); but higher than Kuandisha ($15.3 \text{ m}^2 \text{ ha}^{-1}$) (Berhanu et al. 2017), Yegof ($15.85 \text{ m}^2 \text{ ha}^{-1}$) (Woldearegay et al. 2018), and Hugumburda ($9.23 \text{ m}^2 \text{ ha}^{-1}$) (Aynekulu 2011).

Importance Value Index (IVI) of woody species

The species with the highest IVI value was *Combretum molle* (25.26%), followed by *Olea europaea* subsp. *cuspidata* (21.19%), *Dodonaea angustifolia* (17.80%), *Calpurnia aurea* (15.05%), *Maytenus serrata* (13.09%), *Ficus vasta* (11.16%), *Rhus vulgaris* (10.52%), *Euclea racemosa* subsp. *schimperi* (9.28%), *Acokanthera schimperi* (8.81%), *Carissa spinarum* (8.03%), and *Acacia pilispina* (8.02%) (Table 1). These 11 most important woody species contributed about 59% of the total IVI value. The high IVI value of *F. vasta* was because of its high relative basal area, though it had low relative density and relative frequency. *Rhus retinorrhea* had the least IVI value (0.14%). Thirty four species (including *R. retinorrhea*) had low IVI values ($\leq 0.5\%$ each), and thus were ecologically less important in the forest.

The IVI is an important parameter that reveals the ecological importance and/or dominance of species in a given ecosystem (Cain and Castro 1959; Lamprecht 1989). Species with high IVI values are considered more important than those with low IVI values. According to Curtis and McIntosh (1951), a given species is said to be dominant if it had the highest IVI value compared to other plant species within an area. In a

very general sense, the higher the IVI value of a species, the more successful it is in that particular habitat (Peters 1996). Accordingly, *Combretum molle*, *Olea europaea* subsp. *cuspidata*, *Dodonaea angustifolia*, *Calpurnia aurea*, *Maytenus serrata*, *Ficus vasta*, *Rhus vulgaris*, *Euclea racemosa* subsp. *schimperi*, *Acokanthera schimperi*, *Carissa spinarum* and *Acacia pilispina* were ecologically the most important species in Fach forest. In other words, these species were more abundant, frequent and dominant in the forest.

The IVI values can also be used to prioritize species for conservation: species with high IVI values need less conservation efforts whereas those with low IVI values need high conservation efforts (Shibru and Balcha 2004). The results suggest that species with low IVI values such as *Rhus retinorrhea*, *Ficus sycomorus*, *Maytenus undata*, *Gardenia ternifolia*, *Abutilon longicuspe*, *Flueggea virosa*, *Maesa lanceolata*, *Albizia schimperiana*, *Pavetta abyssinica* and *Ficus thonningii* should be given high priority for conservation.

Population structure and regeneration status of woody species

The DBH class distributions of woody species exhibited different patterns (Fig. 3), and showed that there are species with high number of individuals in the lower classes and some species in the middle classes. The patterns of DBH class distributions indicated the general trends of population dynamics and recruitment processes of the species. From the DBH class distributions of the species, two broad types of regeneration status were determined: good and poor regeneration. Some species possessed high number of individuals in the lower DBH classes, particularly the first class (DBH $\leq$ 2 cm, i.e., seedlings), and this suggests that they have good regeneration potential. This implies that dying adult individuals will be replaced by the growth of individuals from the smaller size classes and seems to be a self-sustaining plant population. The species with good regeneration potential were *Olea europaea* subsp. *cuspidata*, *Combretum molle*, *Calpurnia aurea*, *Euclea racemosa* subsp. *schimperi*, *Acokanthera schimperi*, and *Acacia pilispina*. Here it is important to note that *Acacia pilispina* had high number of individuals in the first DBH class (though less than the second class), indicating that the species has a relatively good regeneration potential. Most of the species, however, possessed low number of individuals in the lower DBH classes, particularly the first class, and this suggests that the species are in poor regeneration status (demonstrated hampered natural regeneration). The species with poor regeneration status were *Rhus glutinosa*, *Premna schimperi*, *Albizia gummifera*, and *Shrebera alata*. Hampered or poor regeneration is due to human disturbances, particularly livestock grazing/browsing and tree cutting for various purposes, as well as unfavourable environmental conditions such as soil erosion and climate change. The aforementioned factors have been reported as the major reasons for hampered or poor regeneration (Wassie and Teketay 2006; Zegeye et al. 2006, 2011; Teketay et al. 2016).

The DBH class distributions of *Olea europaea* subsp. *cuspidata*, *Calpurnia aurea*, *Combretum molle*, *Euclea racemosa* subsp. *schimperi* and *Acokanthera schimperi* showed a reverse “J” distribution. The DBH class distributions of all woody species showed a reverse “J” distribution, in which there is high

number of individuals in the first class with decrease towards the middle and higher classes. It is interesting to see that *Olea europaea* subsp. *cuspidata* has shown good regeneration potential, unlike the poor regeneration status of the species in many other forests, for instance, Tara Gedam (Zegeye et al. 2011).

A reverse “J” distribution is considered as an indication of stable population structure or good regeneration status (Silvertown and Doust 1993; Bekele 1993; Teketay 1997; Zegeye et al. 2006, 2011; Teketay et al. 2016). The natural regeneration potential of Fach forest was promising, provided that appropriate conservation and management interventions could be employed. But here it is important to note that some of the species (*Rhus glutinosa*, *Premna schimperi*, *Albizia gummifera*, *Shrebera alata*) are in poor regeneration status and thus require due attention from conservation point of view.

Socio-economic importance of the forest to the local communities

The responses from the key informants indicated that Fach forest is the major source of fuelwood (most of the woody species), construction material (several woody and some herbaceous species, e.g., *Juniperus procera*, *Olea europaea* subsp. *cuspidata*, *Cordia africana*, *Scolopia theifolia*, *Justicia schimperiana*, *Clematis longicauda*, *Hyparrhenia hirta*), charcoal (e.g., *Combretum molle*, *Acacia lahai*, *A. pilispina*, *Dichrostachys cinerea*, *Rhus glutinosa*), timber (e.g., *Juniperus procera*, *Cordia africana*, *Apodytes dimidiata*, *Schefflera abyssinica*, *Ekebergia capensis*, *Albizia gummifera*, *Bridelia micrantha*), and farm implements (e.g., *Olea europaea* subsp. *cuspidata*, *Acacia* spp., *Rhus glutinosa*, *Albizia gummifera*, *Croton macrostachyus*, *Ficus sur*). It is also the source of food (edible fruits) (e.g., *Syzygium guineense*, *Mimusops kummel*, *Cordia africana*, *Ximenia americana*, *Carissa spinarum*, *Rosa abyssinica*, *Rhus vulgaris*), medicines (e.g., *Vernonia amygdalina*, *Phytolacca dodecandra*, *Justicia schimperiana*, *Brucea antidysenterica*, *Ocimum lamiifolium*, *Gymnema sylvestre*, *Stephania abyssinica*, *Verbascum sinaiticum*, *Datura stramonium*, *Cucumis ficifolius*), fodder, and bee forage (a total of 27 woody and herbaceous species were identified, e.g., *Acacia* spp., *Cordia africana*, *Croton macrostachyus*, *Carissa spinarum*, *Dombeya torrida*, *Pterolobium stellatum*, *Guizotia scabra*, *Andropogon abyssinicus*). From the 230 plant species identified from the study area, 122 (53%) had already been identified by Fichtl and Adi (1994) for their great values as bee forage. Some farmers living around the forest practice beekeeping to get honey for domestic consumption (food and medicine) and mainly income generation through selling. Forest management has created employment opportunities for the forest guards (currently a total of 9) and workers of the seedling nursery. Moreover, the forest has a potential value for tourism/ecotourism.

Conservation and management of the forest

The conservation and management of Fach forest is a tripartite venture: the conservation efforts of local communities, religious institutions (churches and monasteries), and governmental institutions. Moreover, indigenous (sacred grove) and modern (protected area system) conservation methods have been merged

to conserve and manage the forest – a vital synergy. The integration of the conservation methods and the integration of the relevant stakeholders are crucial for conserving the biodiversity.

Role of local communities

The local people have environmentally friendly resource management systems and practices. Terracing and traditional agroforestry are widely practiced in the area. The major reason for constructing terraces is to control soil erosion and improve soil fertility and thereby increase crop production. In addition, the farmers construct terraces on farm boundaries to serve as demarcation lines between adjacent farmlands of different farmers. The local people retain and/or plant indigenous trees (e.g., *Acacia abyssinica*, *Cordia africana*, *Combretum molle*, *Croton macrostachyus*, *Sapium ellipticum*, *Ficus thonningii*, *F. sur*, *F. vasta*) in and around the farmlands, and plant *Euphorbia tirucalli* as a hedge along the edges of crop fields, yards, and roads. They also plant exotic species (e.g., *Eucalyptus globulus*, *Jacaranda mimosifolia*, *Melia azedarach*, *Spathodea campanulata* subsp. *nilotica*) in the homesteads, farm woodlots, and roadsides. Besides control of soil erosion and improvement of soil fertility, trees retained and/or planted in the agroforestry systems provide various forest products (fuelwood, construction material, timber, farm implements, food, medicines, fodder, bee forage), and serve as shade and live fence. Thus, the agroforestry systems reduce the pressure on the natural forest, showing the indirect contribution of local communities in conserving the forest.

The maintenance of the sacred groves in the study area is attributed to the strong religious belief and respect of the followers to the church, which is considered the house of God. Cutting trees from the sacred groves is taboo. If a person cuts trees from the sacred sites, the followers of the church inform the case to the religious fathers, and the doer is condemned. The followers of the church actively participate in the religious, conservation (e.g., tree planting in church/monastery yards) and development activities of the churches and monasteries. The majority of the Ethiopian people have respect and trust for the Ethiopian Orthodox Tewahedo Church (EOTC) and it is this spirit that supported the church to maintain forest resources till this generation (Wassie 2002).

The communities in the study area were involved in the conservation activities of the government like construction of terraces and tree plantation programs. The local communities were also instrumental in controlling the forest fire incidences that have occurred in Fach forest at different times.

Role of religious institutions (churches and monasteries)

Although the main role of the churches and monasteries is to give religious service to the followers of the church, they are also involved in protecting the sacred groves, planting trees in church/monastery yards, and giving advice to the followers about the importance of conserving the sacred groves. The EOTC has a long history of conserving sacred groves, i.e. patches of natural vegetation conserved on sacred sites. The EOTC has over 30 million followers, 400,000 clergies and 35,000 churches in Ethiopia (Wassie 2002). Churches and monasteries have played a great role in the conservation of sacred groves in particular and forest resources of the country in general (Wassie et al. 2005; Zegeye et al. 2006).

Role of governmental institutions

As Fach forest is a protected area, it is managed by governmental institutions, particularly Libo Kemkem District Agricultural Development Office. Governmental institutions enforce legal protection of the forest. As such, a total of 9 forest guards have been employed on contractual basis to protect the forest from human and livestock interferences. The forest guards are trying their best to control tree felling and livestock grazing/browsing and enforce the existing forest law. Indeed, the existence of the forest is largely attributed to the remarkable efforts of the forest guards. Though it is very limited, enrichment tree planting has been carried out in the forest (exotic as well as indigenous tree species). Four firebreaks (fire control gaps) have been established in the forest by removing woody vegetation so as to control the spread of fire incidence and thus reduce its impacts. Moreover, there is a minor seedling nursery near Ambo Meda. The nursery produces seedlings of exotic and indigenous trees and distributes to users (model farmers, schools, youth associations, churches and monasteries, institutions). Governmental institutions are promoting tree planting (reforestation, afforestation, agroforestry) in the study area, and this reduces the pressure on the natural forest. In fact, a rigorous tree planting is needed in the study area and beyond.

Threats to the forest

Fach forest is a protected state forest and contains sacred places, but it has been dwindling from time to time due to livestock grazing/browsing, tree cutting for various purposes (fuelwood, construction material, charcoal, timber, farm tools), farmland expansion to the peripheral areas of the forest, rural settlements expansion, urbanization (expansion of Ambo Meda town), fire incidences (seven major fire incidences have occurred since the establishment of the protected forest; also a minor fire incidence has occurred during the data collection of this study), exotic species plantations (mainly *Cupressus lusitanica* and *Eucalyptus globulus*) at the expense of the natural forest, and road construction across the forest (Addis Zemen–Ebenat main road; minor gravel roads built during the Derg regime for transport of wood harvested from the forest), as well as soil erosion and climate change. The forest will diminish in the near future unless appropriate and immediate measures are taken. The loss of the forest will lead to loss of biodiversity, particularly the endemic plant species. This calls for strengthening the conservation and management of the forest, as it harbours high number of plant species including endemics, and is a refuge for different plants and animals that have disappeared from most parts of northwestern Ethiopia. A proper forest management plan should be developed and implemented to reverse or at least stabilize the present trend in the forest.

Conclusions And Recommendations

Fach forest possesses high plant diversity and endemism, which is attributed to habitat heterogeneity as well as conservation efforts. As revealed by their IVI values, *Combretum molle*, *Olea europaea* subsp. *cuspidata*, *Dodonaea angustifolia*, *Calpurnia aurea*, *Maytenus serrata*, *Ficus vasta* and *Rhus vulgaris* were ecologically the most important species in the forest. The DBH class distributions indicated that

most woody species have good regeneration potential, but some are in poor regeneration status. Woody species having low IVI values (such as *Rhus retinorrhea* and *Ficus sycomorus*) and poor regeneration status (such as *Rhus glutinosa* and *Premna schimperi*) need high priority for conservation.

The local communities were highly dependent on the forest for fuelwood, construction material, charcoal, timber and farm implements, as well as food (edible fruits), medicines, fodder, and bee forage. The forest has been maintained to the present-day through the combined indigenous (sacred grove) and modern (protected area system) conservation methods. At present, however, the forest is dwindling due to livestock grazing/browsing, tree cutting for various purposes, farmland expansion, rural settlements expansion, urbanization, fire incidences, and exotic species plantations at the expense of the natural forest, as well as soil erosion and climate change. Therefore, effective conservation and management interventions are urgently needed to ensure the long-term maintenance of the forest ecosystem, and benefit the local communities through sustainable utilization of the forest.

Therefore, in order to ensure the long-term maintenance of the forest, the following recommendations are forwarded:

- Employ *in situ* and *ex situ* conservation methods for the conservation of woody species having low IVI values and poor regeneration status;
- Develop appropriate forest management plan to enhance the conservation, development and sustainable utilization of the forest;
- Promote tree planting (reforestation, afforestation, agroforestry) in the area with emphasis on multipurpose indigenous and suitable exotic tree species to reduce the pressure on the natural forest;
- Establish fire prevention and control system with the necessary facilities;
- Provide the local communities with alternative sources of energy (hydroelectric, solar, biogas) and locally-made energy-saving stoves (*mirt*, *gonzie*, *tikikil*, *lakech*) to reduce the dependency on the forest for fuelwood and charcoal;
- Promote agricultural and forestry extension services in the area;
- Carry out further research on the forest, particularly ethnobotany, reproductive biology of the endemic plant species, soil seed banks, forest pathology, and carbon stock potentials, as well as wildlife.

Abbreviations

DAFs: Dry evergreen Afromontane forests; FGD: Focus Group Discussion; IVI: Importance Value Index; DBH: Diameter at Breast Height; D: Density; RD: Relative density; F: Frequency; RF: Relative frequency; BA: Basal area; RBA: Relative basal area

Declarations

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Authors' contributions

The author made all the contributions to this manuscript.

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Availability of data and materials

The list of plant species identified from Fach forest can be provided by the author upon request.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Competing interests

The author declares that there is no conflict of interest.

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Figures

Figure 1

Map of (right) Ethiopia showing the location of Lake Tana and its basin and (left) Lake Tana Sub-Basin showing the location of the study area

Figure 2

Partial views of Fach forest (photos by Haileab Zegeye)

Density (individuals ha⁻¹)

Figure 3

DBH class distributions of some selected trees and shrubs and all woody species in Fach forest (DBH classes: 1 = < 2 cm; 2 = 2–10 cm; 3 = 10–20 cm; 4 = 20–30 cm; 5 = 30–40 cm; 6 = 40–50 cm; 7 = 50–60 cm; 8 = 60–70 cm; 9 = > 70 cm)